# Introduction

## The National Science Foundation

The National Science Foundation (NSF) was created in 1950 as an independent agency of the Federal government. Its functions include the support of research and education in engineering and the sciences. NSF continues to explore the frontier primarily by sponsoring basic research, stimulating technology, and strengthening engineering and scientific education in engineering and the sciences. NSF makes awards to academic institutions, private research firms, industrial labs, and major research facilities and centers. About 55,000 experienced researchers and educators from across the country, representing a wide variety of disciplines, volunteer their time to help Foundation staff assess the merits of more than 30,000 proposals a year.

## Directorate for Engineering

Through its Directorate for Engineering (ENG), NSF promotes the progress of engineering and technology, helping the Nation stay in the forefront of technology by giving engineering education and research broad, long-range support.

## Vision Statement

Engineering integrates new knowledge across ever changing disciplines and applies it to the creation of new and improved products, systems, and services. Done well, the creation of shared wealth with a respect for the quality of life and the environment is the result. As we enter the 21st century, we envision an integrated engineering community, forged out of the many engineering and related science disciplines. Added attention to disciplinary interfaces, where new knowledge is increasingly created, will generate fresh ideas and directions for engineering and boost the synergy between education and research. Innovative couplings between universities, industry, and government will develop to exploit new discoveries, applying engineering solutions to the Nation's most pressing problems. The engineering process will facilitate social and economic progress.

Because of improvements in the quality of education, engineers in the 21st century will have a broader command of science and technology, as well as a better understanding of the world and its peoples. Increasingly, they will reflect the rich fabric of American life, with all its diversity. They will be able to assume stronger leadership roles in government, industry, and academe. Likewise, the education of all citizens will include an early exposure to the engineering process and its impact on society, which is needed to understand and deal with our rapidly changing technological world.

### Mission Statement and Goals

In the context of its vision, NSF fosters excellence, quality, and innovation in the development and application of engineering knowledge and human resources to enhance the Nation's economic well-being, security, and quality of life. The Directorate for Engineering is clearly in the "capacity building" business and does not support research only for the resulting new knowledge. Rather, it also seeks to increase the potential of the engineering community, to create and apply technology and to educate the next generation of engineers. In pursuit of this mission, the Directorate has established the following goals:

- Improve the quality of engineering education and the retention of students to yield well-educated, professionally oriented engineers who are able to assume broad leadership roles in society.
- Foster intellectual growth and technological advances by supporting leading-edge research in the engineering disciplines and at disciplinary interfaces where new knowledge is increasingly created.
- Increase the scholarly synergy between education and research and emphasize design, synthesis, and experimentation in these activities.

- Increase significantly the number of women, under-represented minorities, and persons with disabilities who participate fully in engineering education, research, and practice.
- Foster increased cooperation among the diverse engineering constituencies, including building stronger bridges between academe and industry, and encourage cooperation with other countries to promote mutually beneficial sharing of knowledge and resources.

## Divisions of the Directorate for Engineering

Engineering's mission is carried out through the creative interaction of the following seven divisions:

### Biological and Critical Systems (BCS)

The division is composed of *Bioengineering, Environmental and Ocean Systems*, and *Hazard Mitigation Research.*

*Bioengineering* applies engineering methods to problems in the life and health sciences and develops new engineering technologies through knowledge of the living system. *Environmental and Ocean Systems* focuses on the contaminant interactions that threaten the quality of land, water, and air and research into the use of coastal ocean space, advanced sensing and measurement techniques, structures, and vehicles.

*Hazard Mitigation Research* targets Earthquake Hazard Mitigation and Natural and Man-Made Hazard Mitigation. In addition to research into engineering, planning, and societal aspects of earthquake hazard reduction, support is provided for engineering research to reduce the social impacts of such phenomena as strong winds, landslides, expansive soils, floods, and drought.

### Chemical and Thermal Systems (CTS)

Chemical manufacturing and thermal processes are fundamental to technological progress in a range of areas, including energy, the environment, pharmaceuticals, new materials, and food. The division supports research that helps maintain American preeminence in the chemical and pharmaceutical industries, which consistently have produced a positive balance of international trade. Examples of research include membrane and electrically assisted bioseparations, the synthesis of diamond films for use in electronic devices, and advances in catalysis.

### Design and Manufacturing Systems (DDM)

The division supports research to develop and expand the scientific and engineering foundations of manufacturing and materials processing across a spectrum of U.S. industries. Key research areas include advanced materials-processing methods; concurrent design of materials; processing and manufacturing; and developing machines, sensors, and technologies for computer control of manufacturing processes and operations. A vital part of this effort includes developing operations research and production systems methods that underlie the range of engineering systems.

### Electrical and Communications Systems (ECS)

The division seeks to enhance the knowledge base for electrical, electronic and photonic, electromechanical, and optical technologies and to facilitate their integration with engineering education. ECS also develops the analytical tools and techniques for computational simulation and control of complex engineering systems and aims to accelerate the emergence of potentially high-impact technologies of national importance.

### Engineering Education and Centers (EEC)

The mission of the division is to create new paradigms and improve the quality of engineering education and research by emphasizing engineering practice through a cross-disciplinary team approach and systems integration and industrial linkages. EEC seeks to increase the number of engineering professionals by more effectively developing and retaining the Nation's human engineering resources. EEC's *Engineering Education* programs seek to improve the quality of engineering education and retain students to yield well-educated, professionally oriented engineers who are internationally competitive and able to assume broad leadership roles in society. These programs address curriculum development, graduate student support, and research experiences for undergraduates.

The *Engineering Centers* programs support university-based research centers across a spectrum of technologies essential to U.S. economic competitiveness. The centers also address fundamental research issues crucial to next-generation technological advances and involve university/industry/government planning, research, and education.

### Industrial Innovation Interface (III)

The division is responsible for a range of research and analysis programs that affect U.S. industrial productivity. These programs, which aim to improve the speed and efficiency of transferring the results of NSF research and technology to the marketplace, are the *Small Business Innovation Research (SBIR) Program*, the *Management of Technology Program*, and the *Special Studies and Analysis Program*.

### Mechanical and Structural Systems (MSS)

The division supports research that enhances engineering knowledge in structures, geomechanics, mechanics, materials engineering, tribology and surface engineering, and mechanical systems. A major national problem is the decaying infrastructure--buildings, bridges, and highways. MSS-supported research is helping assess the condition of such facilities and provide new construction materials and processes to enhance the infrastructure.

*Note: Because the Foundation is making a determined effort to increase the award duration, proposers are encouraged to submit research proposals having a 3-year research plan and budget.*

## General Information

The Foundation provides awards for research in engineering and the sciences. The awardee is wholly responsible for the conduct of such research and preparation of the results for publication. The Foundation, therefore, does not assume responsibility for such findings or their interpretation.

The Foundation welcomes proposals on behalf of all qualified engineers and scientists, and strongly encourages women, minorities, and persons with disabilities to compete fully in any of the research and research related programs described in this document.In accordance with Federal statutes and regulations and NSF policies, no person on grounds of race, color, age, sex, national origin, or disability shall be excluded from participation in, denied the benefits of, or be subject to discrimination under any program or activity receiving financial assistance from the National Science Foundation.

Catalog of Federal Domestic Assistance, Number 47.041, Engineering.

*Facilitation Awards for Handicapped Scientists and Engineers* (FAH) provides funding for special assistance or equipment to enable persons with disabilities (investigators and other staff, including student research assistants) to work on an NSF project. See the FAH program announcement, or contact the FAH Coordinator in the Directorate for Education and Human Resources.

The National Science Foundation has TDD (Telephonic Device for the Deaf) capability that enables people with a hearing impairment to communicate with the Division of Personnel and Management regarding NSF programs, employment or general information. This number is (202) 357-7492.
For more information see:

STIS flyer 91-10 included with this publication, (how to get online information about NSF programs)
Guide to Programs (program details and deadlines)
*Grants for Research and Education in Science and Engineering* (how to apply, includes required forms.)

To order these publications:
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Washington, DC 20550

## NSF Electronic Proposal Submission Project General Information

The Directorate for Engineering strongly encourages the submission of electronic proposals to increase the speed, accuraccy, and effectiveness in reviewing proposals and making grants.The Electronic Proposal Submission (EPS) project is the initial phase of NSF's transition from paper-based to electronic processing of proposals. The primary goal of this phase is understanding the current and potential problems and barriers at NSF and at the universities. The EPS software, accompanying data entry utilities, and procedures provide the capability for principal investigators (PI's) and university administrative staff to enter the NSF proposal forms data, combine them with PI-created documents (including graphics), print the proposal, and send the proposal over university electronic networks as well as over the Internet for submission to NSF. The actual submission is via FTP (File Transfer Protocol) followed by the faxing of the signed cover sheet.

### Characteristics/Requirements of EPS

The institution created documents must be in PostScript, a trademark of Adobe Systems Inc. PostScript was chosen as the file format for the documents because it is widely supported and handles text and graphics easily. The institution, therefore, must have PostScript printers to print copies of the proposal.

The institution's authorized representative's (AIR) office must have access to an Internet host computer to submit the electronic file to NSF. The entire submission must be electronic. Paper sections, e.g., paper appendices, are not acceptable.

Proposals are deemed received when the electronic file and the faxed signed cover sheet are both received at NSF. The submission via FTP takes only a few minutes. The EPS office produces all required proposal copies and submits the copies to the NSF proposal login unit where they are processed in the normal manner.

The EPS forms are consistent with the current version of the NSF Grants for Research and Education in Science and Engineering (GRESE).

### The Role of the Authorized Institutional Representative

The AIR's signature is required on the cover sheet of the proposal. To accommodate the variety of university proposal processing and submission procedures, the EPS office at NSF assigns to the university AIR an account and password on the EPS host computer. The AIR is free to give the password to other university offices and individuals and therefore permit them to submit proposals to NSF. Any proposal appearing in the university's passworded account is assumed to have been authorized by the university's AIR. In any case no proposal is processed until the fax of the signed cover sheet is received. The details on obtaining the account as well as the submission procedure are in the NSF Science & Technology Information System (STIS) document, epsinfo(.ps).

### For More Information

*To Obtain EPS Documentation and Programs* - EPS software and documentation are both available on STIS. You may obtain EPS information from STIS via download, anonymous ftp, or e- mail. To obtain info via e-mail, send to stisserv@nsf.gov (Internet) or stisserv@NSF (BITNET). The text of the message should be as follows (the Subject line is ignored):

get <*document name*>
The names of the available EPS documents and their contents are:
*epsflyer(.ps)* Short summary of the EPS project (PostScript Version).
*epsinfo(.ps)* General information about the EPS project (PostScript version).
*epsprog4* Instructions to obtain the software and documentation for version 4 (PC-DOS only).
*epsprog3* Instructions to obtain the software and documentation for version 3.0 (available for the Unix, Mac, and PC environments).
*epslist* Instructions to join the EPS e-mail list.
*epssrc* Instructions to obtain the EPS version 4 source code.

For general information about STIS, send an e-mail message to stisinfo@nsf.gov (Internet) or stisinfo@NSF (BITNET) or call 202-357- 7861 and ask for publication NSF 91-10, the "STIS Flyer."

To Connect to the Internet - Call the National Network Service Center, the support center for the NSFNet, at 617-873-3400 for information and procedures to connect your university to the Internet.

For Additional Assistance

e-mail: eps@nsf.gov (Internet) or eps@NSF (BITNET)

Phone: 202-357-7439; FAX: 202-357-7663; TDD: 202-357-7492

# Division of Biological and Critical Systems

**(202) 357-9545**

This Division comprises two sections: Bioengineering and Environmental Systems, and Hazard Mitigation. The Bioengineering and Environmental Systems Section is concerned with applying engineering principles to solving biomedical problems and improving our ability to apply engineering principles to correct problems that impair the usefulness of land, air, and water; and exploring basic engineering problems in the development, conservation, and uses of ocean resources and systems. The relatively new disciplinary field of bioengineering supports research that leads to the development of new and improved devices and products for human health care and for aiding persons with disabilities; the understanding of living systems; and the development and production of new products derived from advances in biology. Bioengineering supports the goal to provide a fundamental engineering base for the economic commercialization of biotechnology.

The Hazard Mitigation Section seeks to develop a basic engineering understanding of potentially destructive natural phenomena such as earthquakes, floods, droughts, sea level rise, greenhouse effects, expanding and collapsing soils, extreme winds, landslides, tsunamis and storm surges. Research support provides new engineering capabilities to understand, prepare for and recover from natural disaster.

Effective natural hazard mitigation requires the joint research efforts of many disciplines. These joint efforts are encouraged through individual projects and through research funding of the National Center for Earthquake Engineering Research and the Cooperative Research Program in Wind Engineering, which coordinate projects addressing a common goal.

## Bioengineering and Environmental Systems Section

### Bioengineering and Aiding the Disabled Program

Engineering research activities in this program involve four categories: Biochemical Engineering, Biotechnology, Biomedical Engineering, and Aiding the Disabled.

Topic areas of common interest to all four program categories include the following:

*Tissue Engineering*. This is the application of the principles and methods of engineering and life sciences to the fundamental understanding of structure-function relationships in normal and pathological mammalian tissues, and the development of biological substitutes to restore tissues. The engineering of living tissues requires a broad interdisciplinary bioengineering approach.

Recent advances in the study of growth, both at the macroscopic tissue level and at the microscopic cellular level, have set the stage for the development of practical applications of tissue engineering. New information is being derived from biochemistry and cellular phenomena on the one hand, and whole living tissue of animals on the other. Controlled synthesis of living tissue appears, therefore, to be a promising endeavor where engineering approaches promise short and long term applications involving a wide spectrum of tissues.

*Biosensors*. Biosensors are devices that utilize a biological component. There is a clear need to focus research more intensely on new types of biosensors for industrial, medical and environmental monitoring and control. In order to address this need, efforts to foster close cooperation between otherwise distant areas of expertise are encouraged. Collaborative efforts among specialists in, for example, biochemistry, immunology, molecular biology, microelectronics, physical chemistry, thin-film technology, optics, lithography, and engineering are desired.

## Biochemical Engineering

Biochemical Engineering research supports the design and development of traditional and recombinant DNA processes for bioproduct manufacturing. Biomass projects utilizing biological microorganisms for the transformation of organic raw materials (biomass) into useful products are emphasized. Projects in food process engineering involving fermentation technology are of special interest. Downstream processing is becoming increasingly important as new advances in the separation and purification sciences accelerate. Support emphasis is on engineering research with up to three investigators, with group grants being emphasized in the biotechnology specialty area.

*Molecular and Cellular Engineering.* This expanding area of engineering research encompasses pure and mixed culture processes, modeling and optimization of cell and metabolite production, development of new biochemical reactors, protein engineering, and the conversion of synthetic gas and other chemical feed stocks to value added products via biological means. New techniques in the monitoring and control of molecular and cellular engineering are also of interest.

*Biomass Processing.* Emphasis is on establishing the necessary engineering knowledge base for transforming organic raw materials (biomass) into useful products. Specific objectives are to develop biological conversion processes for transforming renewable materials into useful end products, examine biological means to separate biomass components (cellulose, hemicellulose, lignin, and other natural polymers), devise methods for producing selected high-value chemical constituents from algae and microbes, and exploit genetically engineered organisms for biomass utilization.

*Food Processing.* Research focuses on fermentation processes and other uses of biologicals for the conversion and/or manufacture of important food products. Consideration is given to more conventional food processing strategies and projects involving marine aquaculture.

*Downstream Processing*. The capability to purify bioproducts in a cost-effective manner on a commercial scale is a critical technical gate in the bioprocessing of high value-added products such as therapeutics for human health care. New processes and a major enhancement of existing processes are needed to accomplish essential purification.

There are several factors that make the downstream processing (i.e., separation and purification) of a wide spectrum of potential therapeutic products more difficult than conventional processing. Very dilute concentrations of complicated mixtures with high purity specifications, including a sterile, pyrogen-free product, present problems that require novel solutions. Another very significant problem is the synthesis and recovery of proteins with the appropriate structure to insure the required biological activity. An additional complicating factor is that the bioprocessing facilities often must be designed and operated in accordance with strict regulations issued by the Food and Drug Administration.

Downstream processing includes at least four sequential steps: removal of insolubles, isolation of products, purification, and polishing. Many techniques need exploring to carry out these steps. Examples of important technologies include: immuno affinity chromatography, electrophoresis, aqueous two-phase systems, selective precipitation, ultrafiltration, membrane technology, ion exchange techniques, reversed micellular recovery processes, high pressure liquid chromatography, upstream enhancements, and process monitoring and control.

Transforming these technologies from laboratory scale to production scale is a bioprocess engineering challenge of immense magnitude. Not only are the problems cited earlier of concern, but the heat and shear sensitivity of proteins make the task even more difficult.

### Biotechnology (Engineering Research Related to the Life Sciences)

Research linking the expertise of engineering with the life sciences is crucial to providing a fundamental engineering basis for the economical manufacturing of substances of biological origin. This is becoming more important as an increasing number of products from genetic engineering and cell fusion technology reaches the market place. Novel bioprocess engineering, both upstream and downstream, needs to meet

this challenge. This type of research requires engineers and life scientists who are broadly competent in each of their fields, and who are also willing to collaborate on research projects involving these fields.

One intention of this category is to address the problems associated with the production and processing of substances obtained through the application of principles and techniques of modern molecular biology. New and creative ideas as well as cross-disciplinary efforts to do this are encouraged.

Another intention is to build up the academic infrastructure needed to educate and train personnel capable of carrying out commercial-scale biological processes. As part of this effort, NSF provides support for NSF Young Investigator and Research Initiation Awards.

Educating and training of personnel capable of carrying out commercial-scale biological processes are further facets of this program. This is carried out by having undergraduate and graduate students, and postdoctoral associates participate in carrying out the research projects.

Specific program topics include, but are not limited to, fundamental studies of:

*Cell Culturing Systems.* Research efforts are directed toward increasing our fundamental engineering knowledge of cellular processes needed for making substances of biological origin. This includes systems capable of culturing normal and genetically altered cells.

*Bioreactors.* Research efforts are directed toward the fundamental understanding of the use of proteins, cells or other biological materials in the design and scale-up of novel biological reactors.

*Separation and Purification Processes.* Research efforts are directed toward expanding our fundamental engineering knowledge of commercial-scale separation and purification processes of complex and often unstable substances obtained from cell culturing systems and/or novel bioreactors.

*Monitoring and Control Methods.* Research efforts are directed toward the fundamental understanding of techniques capable of monitoring the metabolic state of cells in a culture as well as the status of conditions within a cell culturing system, a bioreactor, or separation and purification processes for products obtained from cell culturing systems and/or bioreactors. The design and implementation of sensing devices based on these studies are encouraged. Process control algorithms enabling the use of these monitoring techniques for controlling and optimizing biological processes are also needed.

## Biomedical Engineering

The Biomedical Engineering research supports fundamental engineering research that: (1) enhances the understanding of biological phenomena through the use of engineering principles; or (2) has the potential to contribute to the generation of new engineering knowledge through the study of biological systems. The program encourages interdisciplinary investigations into engineering and biological systems, devices and applications, health technologies, and systems integration. Supported projects include the areas of signal and image processing, imaging devices, biomaterials, controls, orthopedics, and modeling.

## Aiding Persons with Disabilities

The focus of this activity is on research to advance technology to aid persons with disabilities. The restoration of, or the substitution for, a sensory deficit and the alleviation of an orthopedic problem are but some of the areas of interest. Projects to improve or develop new orthoses and artificial joints, process, and/or transcribe sensory information, enable alternative forms of communication, and develop control systems to restore limb movements, are of interest.

The program also supports student design projects to develop devices for individuals with disabilities. These multi-year projects include the identification, design, development, testing, and documentation process. Completed projects included environmental switches, computer interfaces, sports equipment, toy adaptation, educational laboratory modifications, and workstation modifications.

## Environmental and Ocean Systems Program

Engineering research activities in this program are conducted in two categories: Environmental Systems and Ocean Systems.

### Environmental Systems

Environmental Systems supports research to discover and learn how to apply engineering principles to correct adverse effects on land, water, and air resources, which would otherwise impair the usefulness of those resources. Progress toward this goal is accomplished by support of research on the diffusion, dispersion, and the physical, chemical, and biological interactions of pollutants in the environment that adversely affects its quality; innovative water and wastewater treatment processes and systems; and engineering approaches to manage or eliminate pollutants that adversely affect environmental quality. Research to improve the science base for regulation of pollutants and to improve monitoring for compliance with existing regulations, enforcement of regulations, or policy issues is not supported by this program.

*Water and Wastewater Treatment.* Research is directed toward new techniques to disinfect and decontaminate water; physical, chemical, and biological treatment of industrial wastes; control strategies for wastewater treatment processes to improve reliability, performance, and operation; and the management of products and byproducts from water and wastewater treatment, concentrating on their potential resource values.

*Environmental Biotechnology.* Research includes concepts to develop and utilize microorganisms for detoxification of hazardous organic substances that threaten the quality of surface and groundwater. Genetic modification of microorganisms may prove an effective approach by which potential contaminants are detoxified. Use of these organisms may require engineering approaches that are different from those used to deal with contaminants by conventional biological, chemical, or physical methods and processes.

*Groundwater Issues.* Research focuses on surface and underground pollutant transport, including pollutant interactions with surrounding soils and biological transformations; improved modeling, simulation, and real-time response to unexpected environmental intrusions; and validation of models.

### Ocean Engineering Systems

The Ocean Engineering Systems research area supports the continuation of a thrust to develop fundamental knowledge in ocean engineering and to develop information to characterize the ocean environment. This activity is carried out in cooperation with the Directorate for Geosciences' Ocean Sciences Division. An important objective is to encourage interdisciplinary proposals and joint activity between ocean engineering researchers and ocean science researchers.

Improvements in our ability to design and synthesize solutions to engineering problems in the ocean environment are needed in order to develop low-cost, safe, and effective capabilities to provide ocean production and harvesting of food, energy production and distribution, non-traditional transportation, and the utilization of ocean space. Research projects focus on fundamental or applied engineering questions or feasibility studies designed to advance engineering and scientific knowledge. Commercial product development is not supported.

Research projects are supported in any area of ocean engineering (e.g., electrical, chemical, mechanical, civil, bioengineering, and engineering aspects of mariculture). They can be directed toward knowledge to stimulate the development of ocean resources, such as energy, minerals, and fisheries, or of technologies associated with ocean activities, such as transportation, power generation, communication, or waste management.

Specific research topic areas include, but are not limited to:

• Fundamental research topics that may enable the eventual realization of autonomous ocean-based work systems for the development of ocean resources.

• Materials in the ocean environment, e.g., effects of fatigue on strength; combined effects of stress and corrosion; effects of biofouling; stress corrosion of submerged elements; and effects of high pressure at moderately low temperatures on the mechanical properties of materials.

• Sensing, processing, and communication of ocean and sea floor data.

• Synthesis and design of large-scale ocean structures.

The Foundation encourages the development of research programs in conjunction with Federal research laboratories, other universities or private-sector laboratories when additional and expanded equipment, facilities, or instrumentation capability enhance the research program.

# Hazard Mitigation Section

## Earthquake Hazard Mitigation Program

Engineering research activities in this program are conducted under four categories: Siting and Geotechnical Systems; Structural Systems; Architectural and Mechanical Systems; and Earthquake Systems Integration. Basic scientific research in earthquake seismology is supported by the Earth Sciences Division in the Geosciences Directorate of NSF.

### Siting and Geotechnical Systems

Research in this area addresses the fundamental engineering issues related to earthquake ground shaking, and estimates earthquake interactions on geologic structures including surface and subsurface soil and rock systems. The primary areas of support include strong ground motion research, emphasizing the measurement, analysis, and verification of the engineering behavior of near-field ground motion and the development of an adequate data base to develop engineering design decisions; geotechnical systems stability research including analytical and experimental studies to upgrade the engineering understanding and modeling of earthquake ground failures, such as liquefaction, subsidence, and failure of foundations, slopes, and embankment structures; tsunami systems engineering research including studies to understand the generation and propagation of tsunamis and resulting damage to coastal structures; and lifeline engineering research related to geotechnical systems such as buried pipeline systems.

### Structural Systems

Research in this area supports efforts to develop capabilities to predict the dynamic behavior of structures during earthquakes, establish practical guidelines and methods for engineering design against seismic loads, and develop economically feasible methods to strengthen existing hazardous structures. Examples of areas supported include: general risk and hazard analysis; dynamic nonlinear behavior of structures, their components, and subsystems as related to material property interaction effects and structural geometry; safety of dam-reservoir systems and offshore structures; new design methods, guidelines, and systems for seismic analysis and design; knowledge-based computer systems; system identification, reliability and optimization for safety design; and generic approaches for the analysis and design of lifeline systems and other major facilities.

### Architectural and Mechanical Systems

These systems generally constitute that portion of a structure not taken directly into account when evaluating the structures strength or resistance to applied forces, as well as other items such as computers and building contents, mechanical equipment, and electrical distribution equipment. Research objectives include the development of methods and techniques to predict seismic loading, economically feasible methods and techniques for seismic-resistant design, and architectural approaches to controlling seismic behavior. Areas of interest include, but are not limited to: in-structure response determination; secondary

systems effects; dynamic response of mechanical,electrical and other equipment; generic fragility determination; connections and anchorages, particularly of structural to non-structural elements; base isolation; energy absorption; cladding response; system reliability; and seismic-resistant methods for upgrading or retrofitting structures for changes in primary use.

### Earthquake Systems Integration

This subelement supports research and related activities, such as information dissemination, that are intended to improve the basis for actions taken by practitioners and policymakers to mitigate, prepare for, and recover from earthquakes. In the mitigation area, topics considered include analyses of the costs and benefits of alternative earthquake hazard reduction measures and studies of the barriers to the adoption and implementation of seismic safety measures. Research on preparedness strategies in connection with communications, transportation, fire protection, health care, and other critical systems is also supported. In addition, research which assesses the impacts of earthquakes on urban and regional systems is supported in order to provide a firmer basis for mitigation and preparedness decisions. Relevant topics include analyses of casualties; studies of emergency response systems including those that provide search and rescue in collapsed buildings, and delivery of emergency services and relief; and analyses of recovery problems and reconstruction to reduce future vulnerability.

## Natural and Man-Made Hazard Mitigation Program

This program supports research activities that strengthen the knowledge base on: (1) the physical phenomena underlying natural hazards such as hurricanes and tornadoes, floods and droughts, landslides, subsidence, and other ground failures; (2) the understanding of their interactions with and the impacts on populations, the natural environment, and structures; (3) the necessary techniques for better assessing the nature, magnitude, risk, and cost of the impacts of these hazards; (4) the prediction of natural hazard occurrences; and (5) the creation and dissemination of the engineering and scientific information needed for mitigating and preventing the consequences of these kinds of disasters.

Advances are expected to be realized in areas such as: the ability to understand and measure the influence of human actions on the atmospheric, hydrologic, and geomorphic extreme events already mentioned, and on the trends and consequences of these changes; real-time predictive capabilities; methods for identifying, assessing, managing, and communicating risks; estimating the probability of extremely rare events; the application of expert systems and artificial intelligence in natural hazard mitigation and the use of advanced information storage/retrieval systems; the physical and mathematical simulation of these natural hazards and benchmark field experiments; the understanding of the consequences of multiple natural hazards; new designs, materials, codes, and building techniques to withstand extreme natural events; the knowledge of the consequences of natural and technological disasters when combined; and the development of advanced, economic, and quality instrumentation and of network systems.

# Division of Chemical and Thermal Systems

**(202) 357-9606**

The objective of the Chemical and Thermal Systems Division is to contribute to the knowledge base for a large number of industrial processes involving the transformation and transport of matter and energy. The transformation processes may be chemical, biological, physical, or a combination of these. The industrial processes involve a wide range of technological pursuits found in such industries as aerospace, electronics, resources, environment, petroleum, biochemical, materials, food, and allied activities.

Research is supported for the development of fundamental engineering principles, process control and optimization strategies, mathematical models, and experimental techniques, with emphasis on those projects having the potential for innovation and broad application. In order to increase the likelihood of such applications, cooperative projects between university and industry groups, especially those advocating a systems approach, are encouraged. Programs supported by this Division are described below.

## Chemical Reaction Processes Program

This program supports fundamental and applied research on: rates and mechanisms of important classes of catalyzed and uncatalyzed chemical reactions as they relate to the design and application of catalysts, chemical processes, and specialized materials; chemical phenomena occurring at or near solid surfaces and interfaces; electrochemical and photochemical processes of engineering significance or with commercial potential; design and optimization of complex chemical processes; dynamic modeling and control of process systems and individual process units; reactive processing of polymer and thin films; and interactions between chemical reactions and transport processes in reactive systems, and the use of this information in the design of complex chemical reactors. Specific areas include but are not limited to the following:

### Kinetics

Both theoretical and experimental aspects of chemical kinetics are supported. Interest centers on generic problems, including sol-gel reactions, solid-solid reactions, gas-solid reactions, and reactions in unusual media such as supercritical fluids.

### Catalysis

Fundamental studies of catalyst-reactant interactions, adsorption and desorption phenomena, surface morphology, and mechanisms of surface reactions are supported. Emphasis is on heterogeneous catalysis, although studies of industrially significant homogeneous processes are also considered. Support is provided for the development of new measurement techniques for studying catalyst behavior under conditions of use. Studies of catalyst structure; framework catalysts; catalyst surfaces and active sites; interactions of catalysts with supports, reactants, or modifiers; structure sensitivity; and bulk-surface relations continue to be of interest. Surface characterization studies must have a direct relationship to reactive systems for support in this program.

### Reaction Engineering

Reaction Engineering quantifies the interplay of kinetics and transport phenomena in relating reactor performance to operating conditions and input variables. Traditional research on scaleup of reactors used in the chemical industry will continue to be supported, as well as chemical vapor deposition of semiconductor materials; high-temperature and high-pressure processing of new advanced ceramics and inorganic fibers used to reinforce composites; new catalyst preparation interrelated to studies of configurational diffusion; reaction engineering of composite materials; batch and semibatch processing; plasma reaction engineering; reaction engineering aspects of manufacturing superconducting materials; hybrid chemical and biochemical reactors; complex heterogeneous polymerization systems; fluid flow and

reaction rates in molding and extrusion processes; and novel copolymerization and graft polymerization methodology to create high-impact, temperature-insensitive, composite materials.

### Electrochemical and Photochemical Processes

This area supports the design of processes driven, initiated, or controlled by electrochemical or photochemical (including solar or laser) means, and studies of underlying phenomena such as mechanisms of chemical transformation, electron transfer, and energy transfer.

### Active Surfaces

Chemically specific surface phenomena related to problems of technological interest are appropriate in this program. Examples include electrocatalysts, sensors, reactive masks, and electronically or optically active surfaces.

### Process Design and Control

The overall focus of research in these areas is automation of the design and control of chemical manufacturing facilities. Research in nonlinear control, multivariable control, practical adaptive and self-learning control, robust control, routine methods of fault diagnosis, design of separation sequences, and reactor networks continue to be an integral part of the program. Special emphasis is placed on the use of artificial intelligence and expert systems to deal with large-scale systems as well as the adaptation of new technologies such as neuroengineering and parallel processing to process design and control problems.

## Interfacial Transport and Separation Processes Program

This program supports fundamental research in areas related to interfacial phenomena, mass transport phenomena, separation science, and phase equilibrium thermodynamics. Engineering science research in these areas supports various aspects of engineering technology with major impact on chemical and material processing, as well as bioprocess engineering. Research in this program also contributes to the division emphasis on basic knowledge impacting on physico-chemical hazardous waste treatment and avoidance.

The program provides support for new theories and approaches for determining the thermodynamic properties of fluids and fluid mixtures in biological and other fluids with complex molecules. These studies include aspects of the behavior of gases and fluids at interfaces, such as adsorption. Also supported are promising new approaches to understanding concentration-driven transport phenomena in mixing systems, in mass flow in porous media, in polymer systems, in advanced electrical and optical materials processing, and in bioengineering. Support is also given for research related to the engineering science of self-organizing fluid microstructures such as are formed by surfactants. This includes studies of micelles, microemulsions, lipid tubules, and Langmuir-Blodgett and other types of microfilms.

Research in the area of separation science includes novel approaches to traditional separation processes as well as studies of promising new processes. Support is provided for all fundamental aspects of membrane separations, including new membrane materials and membrane-based processes. Novel and promising separation processes which deal with dilute solutions such as are encountered in toxic chemical wastewater treatment are encouraged. The program also emphasizes research to improve the understanding and materials for large-scale chromatography, affinity chromatography, field-induced separations such as electrophoresis, and other bioseparations. Also supported are surfactant-based separations, aqueous two- phase separations, facilitated transport in membranes, and novel separations with significant potential for engineering applications.

## Fluid, Particulate, and Hydraulic Systems Program

This program supports fundamental and applied research on mechanisms and phenomena governing single- and multiphase fluid flow, particle formation and transport, and fluid-solid system interaction. No

bias exists with respect to methods, whether analytical, numerical, experimental, or a combination of these. Research is sought which contributes to improving the predictability, precision, and control of existing systems that involve the dynamics of fluids and particulates, as well as the innovative uses of fluids and particulates in materials development, manufacturing, and the environment. Since fluid and particulate behavior controls many processing and manufacturing technologies, the hoped-for impact is improvement in the predictability, precision, and control of existing systems, as well as new uses of fluids in materials and processing. Existing and suggested support areas include:

*Large Reynolds Number Flow.* This includes turbulent shear layers, boundary layers, plumes, and mixing phenomena in single- and multiphase systems. Some topics of interest are flow instability and transition to turbulence, as well as the characterization of turbulence. Of further interest are transient organized flow structures, flow separation and reattachment at solid surfaces, particle entrainment, transport and deposition, and the interactive influence of particles on flow behavior.

*Density Stratified Flows.* This topic includes mixing and dispersion, surface and internal waves, the interaction of waves and structures, and various free-surface phenomena that play a role in hydraulics. The program supports research on the influence of sediment transport on flow mechanisms, and on erosion problems including bed and bank stability, meandering, and coastal sediment transport.

*Flow of Complex Fluids.* This includes non-Newtonian polymer solutions, composite materials in the fluid state, slurries, bubbly fluids, and flows with phase changes. Some topics of interest are relating the macroscopicrheological behavior to microscopic structures and colloidal forces, relating microscopic structure both in the interior and at boundaries to shear or other imposed body forces, and uses for fluids with unique rheological properties. Included are single- and multiphase flow through porous media especially when medium geometry changes due to particle deposition, compaction or dissolution, flow in extremely thin films or small diameter tubes, flow with a moving contact line, and flow with regions in which the continuum approximation may break down. Special attention is given to quantitative visualization of particulate and multiphase flows, and to direct numerical simulation using parallel computing.

*Deliberate Production and/or Modification of Small Particles with Controlled Properties.* This includes kinetics of particle nucleation, diffusional growth, coagulation, and breakage. Fundamental research is supported on production processes which yield particles of high purity, unique composition, or unique surface properties.

*Particle Attachment to or Removal from Surfaces.* Examples include surface cleaning, micromachining, etching, printing, and production of textured surfaces with unique optical, adsorptive, or reactive properties. Research that elucidates particle-particle or particle-substrate forces and relates these to the aforementioned processes is supported.

*Efficient Removal of Particles from Processing Streams or Plant Effluents and Efficient Separation of Particles Based on Size, Bulk Composition, or Surface Composition.* Examples include the influence of fluid and colloidal forces on filtration, cycloning, electrostatic precipitation, magnetic separation, and scrubbing, among others.

The research areas outlined above encompass phenomena dominated by viscous or surface forces, as well as those dominated by fluid inertia usually manifested through turbulence. Particularly challenging is research to advance the ability to predict and control flows with microstructure resulting from the simultaneous interplay of turbulence, thermal and composition structures, and the development of improved or novel diagnostic tools for such flows.

## Thermal Systems Program

This program supports research in areas where thermal phenomena play a major role, with special emphasis placed on problems involving interaction with other physical processes in a manner consistent with significant engineering applications. The models that form the basis of the research, whether experimental, numerical, or analytical, should possess sufficient fidelity with respect to the avowed

application to enable useful results by practitioners. Within these guidelines, topics spanning the entire gamut of thermal phenomena are eligible for support. Higher priority is given to the cutting edge of technology problems.

## Thermal Transport and Thermal Processing

A major element of the program deals with transport processes induced by thermal gradients and thermal history, and their manipulation to achieve engineering goals. This engineering science forms an important part of the intellectual infrastructure of a number of modern technologies. Topics of interest include not only the prediction, enhancement, and reduction of heat transfer rates, but also the thermal aspect of thermally induced stresses, flows, oscillations, composition distributions, and their influence on material microstructure and physical properties. Some areas of interest overlap with other programs at NSF. In those cases, a definition of the principal knowledge gap may help in determining the most appropriate forum. Priority is given to innovative, insightful investigations of fundamental problems with broad applications and to novel use of heat transfer principles to meet the engineering needs of the nation. Without implying exclusivity, research is sought in the following classes of problems:

*Critical New Fundamental Areas*: Focus is on the physics of thermal transport whose importance was brought to light by new technological developments or by the advancement of improved understanding. For example, meso-scale thermal conduction, covering phenomena with scales spanning the molecular or phonon scales and the continuum scales, is a subject of increasing importance to microelectronics and micromechanical technology. The physics of the three-phase line in the presence of thermal gradients and motion (also known as the dynamic contact angle problem) is vitally important to the understanding of boiling and condensation, and of solidification of solutions and alloys with free surfaces.

*New and Novel Approaches to Long-standing Basic Problems*: New and evolving applications place a premium on thorough understanding of basic thermal transport processes and rational prediction capabilities. Examples of long-standing challenges include radiative transfer with complex geometries and spectral distributions, turbulent heat transfer, and multiphase and phase-change heat transfer. However, research intended to add to the existing design data base rather than to provide insight, including the testing of known computational and modelling methodologies, may receive a lower priority.

*Thermal Transport Problems in Modern Technologies:* Examples include cooling and thermal stress of electronics components and assemblies, thermal processing of metallic and polymeric materials (e.g., casting, spraying and molding), thermal effects in manufacturing technology (laser machining), and thermal processes in the manufacturing of electronic materials (e.g. crystal growth from melt) and electronic devices (e.g. laser-modulated chemical vapor deposition, laser writing, and repairing of electronic circuits).

## Combustion and Plasma Systems

A second major element of the Thermal Systems Program is concerned with high-temperature, chemically reacting systems. Support provides for fundamental investigations that can lead to clean and efficient combustion of gaseous, liquid, and solid fuels, with a concurrent reduction of pollutants. Also of interest are the combustion processes in low-grade fuels and toxic materials, with a view towards an improvement in current combustor/incinerator technologies. Specific topics of concern are the interaction of turbulence and chemical kinetics; the application of non-intrusive diagnostics to practical systems; the development, improvement, and validation of combustion models; gas phase kinetics; spray combustion; soot formation mechanisms; the structure, propagation, and extinction of flames; and kinetics of the solid phase.

The use of combustion reactions to synthesize a specific product, as opposed to simply liberate heat, is an area of growing interest. The fundamental phenomena controlling the production of high-temperature materials through solid-solid and solid-gas combustion reactions are subjects in need of study. Three major sub-areas under this topic of combustion synthesis are: self-propagating high-temperature synthesis (SHS); use of combustion processes for production of ultrafine ceramic materials; and deposition of films of desired materials (e.g., diamond) from combustion product streams.

# Division of Design and Manufacturing Systems

**(202) 357-7508**

The goal of the Division is to support research that will deepen our understanding of the processes, machinery, and systems that comprise modern manufacturing, and to make the country's manufacturing base more competitive by increasing its innovation and responsiveness to changing needs. This is accomplished through research to create, develop, and expand the engineering foundations of processing methods for current and future engineering materials, and of design and manufacturing methods and systems for making useful products from these materials. The emphasis is on research employing a blend of experimental, analytical, and computational efforts directed towards developing economically competitive and environmentally compatible technologies. Included are methodologies for concurrent design and production of products with engineered microstructures and properties, innovative fabrication and assembly techniques, and integrated production systems. Research leading to the development of manufacturing machines, and sensors and control technologies for computer control of manufacturing processes and operations are encouraged. The development of operations research and production systems methodologies that underlie the full range of engineering systems is a vital part of this effort.

Given the inherent complexity and interdisciplinary nature of research in design and manufacturing, a portion of the grants from the Division are made to small groups of investigators with complementary skills who collaborate on substantial problems. To ensure relevance and importance, to promote knowledge transfer, and to leverage resources, we encourage university-based researchers to seek active collaboration from industry and national laboratories on proposed projects. To encourage appropriate teaming, the Division conducts special initiatives (e.g., the Strategic Manufacturing Initiative, the Research Thrust on Engineering and Technology Management, the Engineering Faculty Internships Initiative, and the Intelligent Material Handling Systems Initiative) and workshops in special interest areas such as Pharmaceutical Manufacturing and Electronics Manufacturing. It also sponsors an annual conference, usually in January, at which all of the Division's grantees are expected to be present. At these conferences, the grantees interact with others from academia, industry and government. Participation in this conference should be taken into account in submitting proposals. The target dates for receiving unsolicited proposals to the various programs of the Division are ***April 1*** and ***October 1***, annually.

## Design and Computer-Integrated Engineering Program

### Engineering Design

The goal of this program is the development of a theoretical foundation of principles and procedures for engineering design. The program supports research in: theories of design; methodologies and models of design; and organization and management of engineering design systems. Examples include computational models for the design process, languages, and representations for design considerations; advanced modeling, analysis, simulation, and/or optimization of design processes; and technology management issues related to the design of engineering systems.

### Integration Engineering

Research focuses on understanding the informational framework, techniques, and systems that integrate design and manufacturing. Current areas of interest include process planning, design for manufacturability, assembly, service, and concurrent design. While the main objective of the program is to form a bridge between design and manufacturing, research efforts aimed at integrating all aspects of the manufacturing life cycle are encouraged.

## Manufacturing Processes and Equipment Program

### Manufacturing Processes

The program supports the innovation of manufacturing processes for making useful products from new and traditional materials through the understanding and control of the behavior of materials during processing. Fundamental research on the modeling, simulation, and control of existing manufacturing processes, carried out in the context of a demonstrated understanding of current practice and preferably, with active industrial cooperation and support in the testing of new methodologies on industrially relevant processing equipment, is also encouraged. Proposals in the processing of metals, ceramics, polymers, composite, and electronic materials that improve the capability, productivity, and/or efficiency of manufacturing processes or decrease their environmental impact are sought.

### Manufacturing Machines and Equipment

The program encourages experimental and theoretical research that leads to the building of models and physical prototypes of future generations of machines and equipment required for manufacturing. This research often requires multidisciplinary activity to find innovative approaches using emerging technologies in unusual combinations, thus encouraging new and more appropriate interdisciplinary teaming in academia with opportunities for industrial collaboration and support. Examples of supportable research include self-adapting machines, real-time data acquisition and processing for manufacturing automation, strategies for the use of data from a variety of sensors for the control of machines, ultra-precision manufacturing equipment, and other automated systems for the factories of the future. Also included is the research leading to future generations of equipment and machines for the processing of advanced materials.

## Operations Research and Production Systems Program

### Operations Research

This program supports basic research in analytic and computational methods for the modeling, analysis, design, and optimization of production and service systems. While research funded by this program is oriented toward basic methodologies, it should also be strongly motivated by engineering problems. Research topics range from new mathematical techniques to application-oriented algorithmic research. These topics focus on large-scale problems with a variety of interconnected components generally involving people, information, and machines. Examples of topics include basic research in optimization, scheduling, routing, location, simulation, queuing theory, and stochastic processes.

### Production Systems

The objective of this program is to encourage basic and applied research in all aspects of production at a systems level. Topics include operational issues such as cost and performance analysis, inventory management, production planning and scheduling, reliability, quality, material handling, logistics, distribution, and human-machine integration within the production environment. While the main focus of the program is on manufacturing systems, research with application to the full range of production systems including communication, transportation, and distribution systems is also encouraged.

# Division of Electrical and Communications Systems

**(202) 357-9618**

The Division of Electrical and Communications Systems, supports fundamental engineering research on the conceptualization, analysis, design and fabrication of materials, devices, systems, and phenomena that involve electrical, electronic, electromechanical, or optical technologies. Research funding is also provided for the development of analytical methods and computational algorithms for technology utilization that supports the full range of engineering disciplines. Through the Emerging Technology Initiation Program, the Division also supports selected, innovative engineering technologies that cut across traditional disciplinary boundaries.

The goal of the Division is to enhance the knowledge base and academic infrastructure in relevant research areas, which contribute to the development, manufacture, and deployment of engineering products and systems that benefit the Nation's economy, national security and overall societal welfare. The Division accomplishes these goals through the following programs:

*Solid State and Microstructures* - Supports research in the design, fabrication, and modeling of solid-state electronic devices and fabrication processes, and processing and characterization equipment, with an emphasis on non-standard materials, such as gallium-arsenide, diamond film, and Langmuir-Blodgett films. Growth and characterization of electronic materials with emphasis on techniques with a future impact for electronic and optoelectronic devices and integrated circuits are supported. Examples in materials research include III-V heterostructures, II-IV materials, high temperature superconductor films, ferroelectric and magnetic materials, interfaces between materials particularly semiconductor and dielectric, materials and structures for nanoelectronics, and research in quantum devices. Research efforts seek reduced device size, with device features in the submicron range. The program also supports research in microelectromechanical systems.

*Emerging Technologies Initiation* - This program supports small, multi-disciplinary group research in selected high-risk areas, with a goal of developing an institutional infrastructure for academic research in new areas of high commercial potential. Proposals are accepted only in response to announcements, and only in selected areas. To date, research is supported in the areas of tissue engineering, biosensors, microelectromechanical systems, and ultrafine particle engineering.

*Quantum Electronics, Waves, and Beams* - Fundamental engineering and scientific research principally in areas of quantum electronics, including lightwave technology, plasmas, and electromagnetics. Theoretical and experimental research related to the generation, propagation, interaction, manipulation, and analysis of electromagnetic radiation and charged particles and their technology implementation are appropriated to this program. Also included in the program are optoelectronic and photonic devices and systems, and optical computing and storage.

*Engineering Systems* - This program supports research on analytical and computational methods for the modeling, analysis, estimation, identification, optimization, and control of engineering systems. The emphasis is on generic methods motivated by a wide variety of engineering systems such as robots, power systems, manufacturing and production systems, and electronic systems. The application of these tools to the issues of largeness, nonlinearities, and other complexities of systems like the power generation-transmission-distribution system is of particular interest. In addition, the neuro-engineering component develops, tests, and evaluates new algorithms that can be implemented as artificial networks.

*Communications and Computational Systems*--The interactive characteristics of communications engineering and computational engineering provide the framework of the Communications and Computational Systems Program. Computational engineering forms the bridge between engineering and applied mathematics and integrates computational power with advanced analysis and experiments for engineering applications. Communications engineering supports research necessary for the design and development of ultra high speed, ultra high capacity optical communications and optical computing systems.

## Solid State and Microstructures Program

This program encompasses research to describe the design, fabrication, and operation of devices and small integrated systems with dimensions from 1nm to 10nm. The program addresses electronic and micro-electromechanical devices and is sufficiently broad to include device technologies such as silicon microsensors, high-temperature superconductor devices, and magneto-optical storage media. The program deals with new device concepts, physics, modeling, and simulation, with particular emphasis on devices with sub-micrometer critical dimensions and device operation in the quantum regime. The program also addresses new electronic materials of potential device interest. The scope of this program includes the study of new processing, lithographic, measurement, instrumentation, and manufacturing technologies used to fabricate electronic devices.

### Electronic Materials Growth and Characterization

This program area includes the growth and characterization of electronic materials, with emphasis on those techniques with future impact on electronic and optoelectronic devices and integrated circuits. Techniques that provide more accurate characterization of materials are also a part of this program.

### Device Processing Techniques

This program addresses advanced processing techniques that permit fabrication of improved and novel solid state electronic devices. Special emphasis is placed on fundamental studies of processes that provide the capability to fabricate and manufacture sub-micrometer dimension devices. New resists, transient processing techniques using lasers, advanced plasma-based processing, and X-ray lithography are some examples of areas of research in this program.

### Device Physics Research

This program includes the study of compound semiconductor, silicon, novel superconducting, and magnetic devices. Emphasis is placed on experimentally based research into fundamental phenomenon underlying device operation. Novel device concepts based on small feature size, quantum effects, or innovative processing techniques are also emphasized.

### Device and Processing Modeling and Simulation

This area includes the development of quantitative information relating device structure and processing input parameters to device output parameters. The emphasis of this work is to develop models that characterize processes and device parameters and describe electron transport mechanisms in devices. The study of the physics and statistics of process sensitivity and device instability is also a part of this program.

### Processing and Characterization Equipment Development

Research in this program area addresses experiments directed to the development of equipment for processing or characterization of devices and materials. Examples of such equipment are sources suitable for x-ray lithography and scanning electron tunneling microscopes for the characterization of semiconductor devices.

### Microelectromechanical Devices and Systems (MEMS)

This activity includes research on design, fabrication, operation, and theoretical modeling of microelectromechanical devices. The program addresses the new knowledge of physical phenomena at small dimensions required to understand these devices. This program places emphasis on fundamental research leading to new MEMS technologies.

Research is often jointly supported with other NSF programs. Some principal investigators are co-funded from the Low Temperature Physics, Solid State Physics, and Ceramics and Electronic Materials

Programs in the Division of Materials Research; the Division of Astronomical Sciences; and the Quantum Electronics, Waves, and Beams Program.

## Emerging Technologies Initiation Program

The Emerging Technologies Initiation (ETI) program was created to establish an academic infrastructure to develop new multidisciplinary engineering research areas. The objectives of the program are to (1) provide for the identification of new concepts and technologies with potential for near-term breakthroughs, (2) encourage collaborative academic research projects by funding investigators from two or more different academic disciplines, and (3) provide support for those concepts that could be transformed into important, new, internationally competitive technologies. A goal of the program is to enhance U.S. economic competitiveness by accelerating emergence of new technologies through the crucial basic research stage of innovative and embryonic technologies, leading to new industries that produce high-value-added products, processes, and services. The ETI program, unlike other NSF programs, does not accept proposals except under announcements that identify specific research areas. The research areas selected for funding in any year are the only areas for which proposals are received. All other proposals are returned without review.

Each year, ETI activities are reviewed considering the technical progress and program budget to determine whether continued funding is warranted. The ETI program typically supports a particular area of research for three to six years. Pending the outcome of this review, new areas for funding also may be selected, and a program announcement prepared for the solicitation of new and renewal proposals. New ETI research areas are chosen based on three criteria: (1) the potential for the area to yield results to a multidisciplinary research approach, (2) the potential for contribution to basic knowledge through academic research, and (3) the potential for the research to result in a new class of products, processes, or services for civilian application. ETI grants are typically three-year grants to small groups of researchers, and they are often cofunded with other NSF research programs.

The ETI program has active research in two areas, microelectromechanical systems (MEMS) and ultrafine particle engineering. MEMS includes mechanical, electromechanical, and other systems ranging in size typically below a cubic millimeter, and with critical feature sizes ranging to less than a micron. Research in ultrafine particle engineering focuses on the synthesis and processing of nanometer-sized particles with controlled properties for applications to advanced materials such as ceramics, metals, optical structures, and semiconductors.

## Quantum Electronics, Waves, And Beams Program

The Quantum Electronics, Waves, and Beams Program supports fundamental scientific and engineering research principally in areas of quantum electronics, including lightwave technology or photonics, plasmas, and electromagnetics. Theoretical and experimental research related to the generation, propagation, interaction, manipulation, and analysis of electromagnetic radiation and charged particles and to their technology implementation is appropriate to this program. Photonic applications, such as optical wave guides, switching of logic circuits, and optical computing and communication are also part of this program. Research areas supported by this program include:

### Quantum Electronics

Modern optical and laser-related research, including new laser sources and concepts, associated devices and techniques, is supported. Also included are novel laser applications, ultrashort-pulse phenomena, coherent phenomena, and nonlinear optics research with emphasis on new materials approaches.

### Lightwave Technology

Applications of photonics to optical information technology, optical communications, and optical computing, storage, and signal processing are included. Emphasis is on devices, phenomena and related materials technology and includes exploitation of nonlinear properties of matter, waveguide technology,

optical sources, receivers and amplifiers, optoelectronic devices, integrated optics, optical switching devices, ultrafast optical processes, and optical interconnections. Collaboration of materials specialists, chemists, etc., and involvement with other NSF and government-supported programs (e.g., Engineering Research Centers) is encouraged.

### Plasmas

Basic plasma studies and innovative engineering applications in areas other than fusion or space-related research are included. Emphasis is on development of basic concepts and techniques in the generation and control of plasmas and plasma phenomena. Research areas include wave interactions in plasmas, nonlinear phenomena, laser-plasma interactions, and applications of plasmas in technologically important areas such as in semiconductor materials processing. Electron or ion beam generation and utilization are also included.

### Electromagnetics

Novel applications of electromagnetic theory or advanced electromagnetic device work is included. Emphasis is on creativity in approach as well as advancement of the field. Topics include fundamental new research approaches to microelectronics and millimeter wave fields; propagation on a chip in two- and three-dimensional space; radiation and scattering effects; high-speed interconnections; as well as theoretical and experimental research related to new types of computer-based design rules. Engineering advances in remote sensing, including sensor technologies and propagation and scattering in random media are also included.

## Engineering Systems Program

The Engineering Systems Program supports basic research in analytical and computational methods for the analysis, modeling, optimization, and control of dynamic systems. Topics range from introduction of new mathematical methods to implementation-oriented algorithmic research. The modeling, estimation, analysis, optimization, and control of systems require more sophisticated tools to address the complexities of future engineering systems. The multidisciplinary nature of Systems Engineering encourages cofunded research with other programs in the Directorate for Engineering, the Division of Mathematical Sciences, and the Directorate of Computer and Information Science and Engineering.

The research areas supported by the Engineering Systems Program are given below. The first two research areas emphasize the development of basic methodology. The other three areas emphasize largeness, complexity, and nonlinearity issues associated principally with the large electric power generation, transmission, and distribution systems.

### Modeling and System Identification

Areas of research include methods to combine the first principle models with experimental data, characterization of uncertainties in the model parameters; and high frequency dynamics, estimation, filtering, and decision theory for fault detection and intelligent control. Theoretical and experimental research includes numerically reliable computations and mapping algorithms to parallel architectures for real-time estimation and control.

### Controller Design and Implementation

Supported by this sub element is multivariable control of dynamic systems with modeling uncertainties and/or stochastic inputs and analysis, design, and optimization of nonlinear dynamic systems. The methodology ranges from geometric-algebraic theory to computer-oriented control algorithms, including computer-aided control system design. Emphasis is on optimal gain scheduling algorithms, auto-tuning, adaptive and nonlinear control, fuzzy control, and discrete-event dynamic systems.

### Power System Operation

Theoretical and computational issues associated with state estimation, unit commitment, optimal power flow, automatic generation control, forecasting, power quality, interchange transaction, energy storage, and distribution automation. Emphasis is on the basic challenges introduced by the complexity and expanded use of the interconnected system. This includes research into the impact of advanced technologies such as superconductivity, power electronics, and electric vehicles.

### Security Analysis

Fundamental issues of power system loadability, fault analysis, stability, contingency analysis, and reliability are supported. Emphasis is on developing a firm understanding of the basic theory and algorithms needed to ensure the integrity of the Nation's electrical infrastructure. In addition, this program supports research into the use of high performance computing and neuroengineering concepts to provide rapid diagnosis of system problems and evaluation of alternative control actions.

### Neuroengineering

This subelement stresses the problems associated with the design of artificial neural networks to control actions over time or to identify dynamic systems. Work on improved supervised learning through associative memory or improved real-time convergence also is supported. The research must use or develop learning algorithms of general scope and of relevance to large-scale nonlinear problems. Priority goes to designs such as adaptive critics and recurrent nets for system identification, motivated by intelligent control challenges resistant to more conventional designs.

## Communications And Computational Systems Program

The Communications and Computational Systems Program has two major components: communications engineering and computational engineering. The interactive characteristics of the program components encourage and allow for a range of research activity support. Computational engineering provides the interface between engineering and applied mathematics and integrates computational power with advanced analysis and experiments for engineering applications. Communications engineering supports research necessary for the design and development of ultra high speed, ultra high capacity optical communications and optical computing systems.

The two components of this program intersect. They are designed to serve as points of continued interaction. Communications engineering serves as the focus for communications research within the Engineering Directorate. The multidisciplinary features of computational engineering serve as a bridge to other programs both in Engineering as well as with other parts of the Foundation. Interactions with Engineering Research Centers are strengthened and developed with new engineering centers as common areas of interests are identified. Areas of program emphasis are the following:

### Communications Engineering

Systems aspects for the sensing, transmission, processing, and detection of optoelectronic and optical signals are investigated. Optical fibers represent the dominant media for transmission. Optical communication systems supports research in: source generation, detection, modulation, analog and digital processing, coding, and other systems considerations. Optical computing supports research in logic and computing functions using ultra-high-speed switching, architectures, and systems. Collaboration with neuroengineering is strong in the area of associative memories for optical parallel processing. Materials and device research conducted through the Lightwave Technology element of the Quantum Electronics, Waves, and Beams program, and the Solid State and Microstructures Programs are tightly coupled to communications engineering.

### Computational Engineering

Supported activities are dedicated to the discovery, development, and application of computer-oriented algorithms including numerical, symbolic, and other methods of solution for engineering applications.

The major areas of support are development of data interpretation techniques, pre - and post - processing of data, multidimensional solution representation, interactive graphics, and development of algorithms (adaptive method, error analysis, concurrent techniques, semi-analytical solutions). Collaborative and multi-disciplinary projects as well as joint support of research with other programs both within ECS and with other NSF programs will continue to be emphasized.

# Division of Engineering Education and Centers

**(202) 257-9707**

The Engineering Education and Centers Division enhances U.S. economic well-being and industrial competitiveness through new paradigms to improve the quality of the Nation's engineering research and education. This is accomplished by emphasizing engineering practice through a cross-disciplinary team approach, systems integration, and industrial linkages. The Division improves the quality of engineering education to yield well-educated, professionally oriented engineers who are internationally competitive and able to assume broad leadership roles in industry, academe, and society in general.

Program areas supported by this Division are:

- Engineering Education Coalitions
- Engineering Research Centers
- Industry/University Cooperative Research Centers
- State/Industry University Cooperative Research Centers
- Human Resource Development

A brief description of each activity supported follows. Program announcements are available for each.

## Engineering Education Coalitions Program

These multi-university awards draw from a diverse spectrum of engineering programs and are intended to increase dramatically the quality of undergraduate engineering education by developing and disseminating new structures and approaches; creating strong linkages and intellectual exchanges between U.S. engineering schools; and increasing the number of degrees awarded (especially to women, minorities, and persons with disabilities). Awards average $3 million per year and are funded for a maximum of five years. Four Coalitions are currently being funded. For information on proposal submission deadlines and to obtain copies of the program announcement, use STIS or call (202) 786-9532.

## Engineering Research Centers Program (ERC)

The goal of this program is to develop knowledge and technological advances in areas important to the international competitiveness of U.S. industry by supporting major cross-disciplinary research and education centers at universities. While the Engineering Research Centers will differ from one another, they all share three defining characteristics. First, their programs emphasize the synthesis, integration, and management of engineering systems; and seek to integrate different disciplines in order to provide the requisite knowledge, methodologies, and tools underlying engineering practice. Secondly, the programs include a significant educational component, involving undergraduate and graduate students in the research and experimenting with new course material to emphasize the systems aspects of many engineering fields. Thirdly, each ERC provides a research environment that promotes working relations between students and faculty on one hand and practicing engineers and scientists on the other and has a strong commitment for support from industry (money, equipment, and people in any combination). NSF support averages $2.2 million per year, within a range of $1.7-$3.3 million. On average, centers receive nearly twice that amount from industry, states, their universities, and other sources. Centers have the potential for 11 years of support from the ERC Program, with periodic reviews.

ERCs are located at academic research institutions where they are expected to promote strong links between research and education. Cooperation between one or more schools in a region is encouraged where the combined activity will enhance the ERC and the engineering education and research activities of the region.

Proposals are submitted in response to a competitive program solicitation and must be prepared following the guidelines contained in the solicitation. There are currently 18 centers. For information on proposal submission, use STIS or call (202) 357-9707.

## Industry/University Cooperative Research Centers Program (I/UCRC)

This program encourages highly leveraged industry/university cooperation by focusing a center's research on issues relevant to the needs of the members of the center's Industrial Advisory Board. The NSF role is catalytic and usually starts by support a planning grant. Each center conducts research that is of interest to both industry and the university, with a provision that industry takes over support within five years of operation. The program develops centers based on strong university research programs responsive to research needs of the industry.

The joint support by NSF and industry provides for a broad-based research program that is large enough to be of interest to industry but is normally too large for any one company to undertake alone. Research programs of the centers correspond to the university's engineering and scientific expertise. NSF base support for fully operating centers is between $50,000-100,000 per year, with the potential for additional funds to support human resource development activities and projects that tie together the complementary research of centers. NSF also funds an independent evaluator to assess the progress and outcome of each center. Industry funds must be at a minimum of $300,000 per year from six or more firms.

At the end of FY 1991, there were 50 operational centers of which 23 were over five years old. Industrial and state support will approach $100 million, compared to NSF's $4.0 million annual support.

Thus the centers augment the engineering and scientific research support thrust of other NSF programs. For a copy of the non-competitive program announcement and additional center planning and organizational information, use STIS or call (202) 357-7307.

## State/Industry University Cooperative Research Centers Program (S/IUCRC)

This is a joint initiative between the National Governors' Association and NSF to support research and other activities that contribute significantly to local economic development and the competitiveness of U.S. industry. These centers actively focus on small business, technology transfer, and local economic development at the state level with industrial support. This new model extends the I/UCRC model to focus on more active means of technology transfer including experimentation with test beds, hands-on teaching of new concepts to upgrade small business, etc. These centers also may extend their work to include proprietary projects designed to speed development, with the support of industry and the state.

At the end of FY 1992 there were 10 operational centers. The centers build on "core" research activities funded jointly by NSF, the States, and industry. NSF's share holds at $150,000, $225,000 or $300,000 for three levels of centers, depending on the matching funds received from the State and industry. Companies and/or the State may provide additional funds for any component of the center. Centers compete for NSF support in an announced competition. For information on proposal submission and a copy of the program announcement, use STIS or call (202) 357-7307.

## Human Resource Development Program

### Graduate Research Traineeships (GRT)

This program encourages more U.S. citizens and Permanent Residents to complete doctorates in engineering, especially women, minorities, and persons with disabilities. Graduate Research Traineeship awards are packages of student support.

The colleges and universities that receive the awards are responsible for the selection and retention of trainees and the administration of traineeships. Awards are funded for a maximum of five years. Within each award, traineeships provide a $14,000 per year stipend and a $7,500 per year cost-of-education allowance instead of tuition and fees normally charged to students of similar academic standing (unless such charges are optional or refundable). A one-time $3,500 per trainee project enhancement allowance to be directly matched by the institution is provided in the initial year of an award. Proposals must request a minimum of five traineeships. There is no limit on the maximum number of traineeship requests in an individual proposal or by all proposals submitted by an institution. Only one proposal may be submitted by

a department or comparable organizational unit within an institution. There is no limit, however, on the number of departmental units within an eligible institution submitting proposals. Successful proposers are encouraged to design flexible periods of support for their trainees, thereby enhancing the impact of the program on engineering graduate education. For information on the deadline for proposal submission and to obtain copies of the program announcement, use STIS or call (202) 786-9631.

### Combined Research-Curriculum Development in Technological Areas of National Importance

Support is provided for projects which stimulate classroom involvement of research-oriented faculty in order to enhance the transfer of new research results into the curriculum. These grants are co-funded by the research divisions and this Division. Awards average $400,000 for three years of support. For inquiries about the program, use STIS or call (202) 786-9634.

### Engineering Research Equipment Grants (REG)

Grants are made for the acquisition or upgrading of research equipment that will provide new research capabilities or improve the quality and broaden the scope of engineering research at academic institutions. Reasonable costs for assembly and/or fabrication of equipment will be considered in cases where it is not possible to purchase "off the shelf" items that are needed for research. Substantial cost sharing is required. While there are no specific minimum/maximum award amounts, awards typically average $20,000 to $200,000. Approximately 100 awards are made each year. Technical inquiries should be directed to the appropriate engineering division. For administrative inquiries and to obtain copies of the REG program announcement, use STIS or call (202) 786-9530.

### Research Initiation Awards (RIA)

This program provides an opportunity for full-time faculty members without any current or prior federal research support to initiate academic engineering research. Proposers compete for funding with one another and not with more experienced researchers. Goals are to encourage faculty to begin their research careers and to make academic careers in the engineering fields more attractive to prospective and existing faculty members. Grants are for initiation of theoretical and/or experimental research projects in any area normally supported by the Directorate for Engineering. Funds provided are $90,000 for three years duration ($30,000 per year) with an additional amount up to $10,000 available for equipment if the university matches the request. Approximately 150 awards are made each year. Technical inquiries should be directed to the appropriate engineering division. For information on the proposal submission deadline and to obtain copies of the program announcement, use STIS or call (202) 786-9530.

### Research Experiences for Undergraduates (REU) Awards

Support is provided for proposals that seek to attract talented students into academic research careers in engineering. Proposals are in two major categories: (1) *REU Sites* and (2) *REU Supplements*. *Site* grants are institutional awards designed to initiate and conduct undergraduate research participation projects for a number of students appropriate to the discipline and setting. *Supplements* are made to ongoing NSF research grants to provide research experiences on these grants for a small number of undergraduates. REU Sites are funded for up to three years and average $50,000 per year in support. REU supplements are funded for up to $5,000. For information on proposal submission deadlines and to obtain copies of the REU program announcement, use STIS or call (202) 786-9634.

### Minority Research Initiation (MRI), Planning, and Career Advancement Awards (CAA)

Support is provided to provide opportunities for a minority engineer to: (1) become actively engaged in research as an independent investigator; (2) to plan and prepare a research proposal; and (3) expand activities that can advance the applicant's research career. MRI's range from $25,000 to $90,000/year for up to three years. Planning grants average $12,000 for one year. Minority CAA's are a maximum of $50,000 for one year with an additional $10,000 available for equipment. For information on proposal

submission deadlines and to obtain copies of the program announcement, NSF 90-143, use STIS or call (202) 357-9634.

## Research Planning Grants (RPG) and Career Advancement Awards (CAA) for Women Engineers

RPG awards are made to (1) help increase the number of new women engineers participating in NSF's research programs; and (2) to facilitate preliminary studies and other activities related to the development of competitive research projects and proposals by women who have not previously received independent Federal research funding. RPG's are one-time awards that may be used for preliminary work to determine the feasibility of a proposed line of inquiry, and/or for other activities that will facilitate proposal development. A grantee is expected to submit a full research proposal to NSF subsequent to the completion of her RPG. RPG's are limited to $18,000 for up to 18 months. Institutional cost-sharing is encouraged, including provision of some released time and waiver of administrative expenses.

The goal of a CAA is to support activities that can expand a promising applicant's research career potential by helping them acquire expertise in new areas, assist those who have had a significant research career interruption to acquire "updating" for re-entry into their respective fields, etc. CAA's are not substitutes for regular research grants nor are they intended to provide "start-up" funds to establish a laboratory. Awards are limited to a maximum of $50,000 with a possible addition of up to $10,000 for equipment, if required, and are usually for 12 months. CAA's are not renewable.

The NSF-wide target date for submission of CAA and RPG proposals is January 15th. The program announcement number is NSF 90-121 and is available through STIS. For administrative inquiries call (202) 786-9634.

## Funding for Support of Women, Minority, and Disabled High School and Undergraduate Students as Engineering Research Assistants

Support is provided for supplemental funding for investigators who wish to include women, minority, and disabled undergraduate or high school students as research assistants on their projects. Supplemental funding of up to $5,000, including indirect costs, may be requested for each student added to the project. Students must be U.S. citizens or permanent residents at the time of proposal submission. Funds provided by this program are limited to two students per grant. Up to 10 percent of this amount may be used for supplies and services. The support may be used for a summer, a quarter, or an academic year. Additional funds in excess of $5,000 may be requested, if necessary, to provide special equipment, modify equipment, or provide other services required specifically for participation of persons with disabilities. The equipment must be specifically related to the research work (e.g., prosthetic devices to manipulate a specific piece of equipment) and not for general assistance (e.g., wheelchairs or ramps). New proposals should follow the disciplinary program's deadline or target for submission of proposals. Supplementary proposals have no submission deadlines. The program announcement number is NSF 91-122 and is available through STIS. Investigators should contact the cognizant engineering program director for information on submission of proposals and for types of research supported. Administrative inquiries may be directed to (202) 786-9634.

# Division of Industrial Innovation Interface

**(202) 653-5202**

The Industrial Innovation Interface Division carries out research and analysis programs that affect US industrial productivity. These programs aim to improve the speed and efficiency by which the results of NSF research and technology are introduced into the marketplace. The specific programs are: the Small Business Innovation Research (SBIR) Program, the Management of Technology (MOT) Program, and the Special Studies and Assessments Program.

The SBIR Program supports cutting edge research in technology intensive firms leading to the creation of new products and services and rapid commercialization of NSF research. This research program is implemented under P.L. 99-443. The MOT Program focuses upon the interface between engineering and business and seeks to develop the knowledge base for improving the means of deriving economic benefits from engineering and technological progress. The research conducted by interdisciplinary research teams combine expertise in engineering, management, and business practice. The Special Studies and Assessment Program is a cross disciplinary effort that will advance U.S. engineering by supporting studies and technology assessments that deal with academic and professional issues and opportunities for engineering.

## Small Business Innovation Research Program (SBIR)

The Small Business Innovation Research Program was designed and implemented by the Foundation in 1977. It served as the model for the Small Business Innovation Development Act of 1982 and eventually became the national SBIR program. Then, as now, it served to stimulate innovation and to couple small high technology companies to the basic research community. In the decade since its inception, SBIR has complemented the NSF basic research programs by providing a linking mechanism with the market place. While many studies may be cited, a Rand Corporation study showed clearly that the results of basic research do not readily find their way to the marketplace without the use of intermediate mechanisms. SBIR provides such a mechanism.

The four purposes of the SBIR program at the Foundation, are:

- stimulation of technological innovation
- use of small business to meet Federal research and development needs,
- foster minority and disadvantaged persons to participate in innovation, and
- increase private sector commercialization of innovations from Federal research and development.

The SBIR Program is a three phased research effort. Phase I is a six month effort at a funding level of $50,000 for experimental or analytic work designed to bolster the justification for a major research effort...a "feasibility" effort. Phase II is the major portion of the work and is designed to cover a two year period, at a funding level of $250,000 to $300,000. Phase III is the development phase designed to rely on private sector funding or support. The proposal evaluation decisions for the Phase II awards emphasize a critical need for private sector commitment for Phase III before an award is made.

## Management of Technology Program

The Management of Technology Program focuses upon the interface between engineering and business. The research effort is in the management of engineering and technology that creates the knowledge base, methods and tools to: (a) improve the ability of engineering design and manufacturing practice to determine and meet market needs; and (b) improve corporate ability to integrate technology strategy with business strategy.

Examples of considered research includes: Accurate cost analysis in product and production design; effective modeling of customer requirements integrated upstream into engineering design systems; effective modeling of investment requirements in the make/buy designs in factory design and in analysis

of return-on-investment in factory simulation; effective focusing of product application from basic research advances; imaginative experimentation in product completeness for new technology applications, etc.

Research is interdisciplinary with research teams combining expertise in engineering, management, and business practice. Teams of researchers are expected to include representatives from an academic engineering school, an academic management school or social science department, and a commercial firm.

## Special Studies and Assessments Program

The Special Studies and Assessments Program is a cross-disciplinary activity that: advances U.S. engineering through international cooperation; and supports policy studies and technology assessments that deal with academic and professional issues and opportunities for engineering. Examples of current studies supported include the Japanese Technology Evaluation Center (JTEC) in collaboration with other federal agencies. These assessments have evaluated Japanese R&D in space robotics, advanced computing, and construction technologies. Workshops to evaluate and disseminate engineering program results are also supported.

# Division of Mechanical and Structural Systems

**(202) 357-9542**

The objective of this Division is to support research that will advance the engineering knowledge base in the broad areas of structures, geomechanics, solid mechanics, materials engineering, tribology, surface engineering, and mechanical systems. Specific research directions are driven by intrinsic interest in phenomena arising in mechanical and structural systems and by the need to solve increasingly complex problems requiring consideration of systems synthesis and integration. Research methods include a blend of techniques involving mathematical and computer simulation and physical experimentation.

The Division encourages research that will lead to the creation of new and more cost-effective structures; the understanding of mechanisms of deterioration of constructed structures; the control of mechanical systems; active and passive noise control; and the dynamics and development of diagnostic methods and techniques for repair and retrofit. Support includes interdisciplinary studies on advanced materials processing, engineering, and tribology. Funding exists for the use of the principles of mechanics to enhance performance and availability of engineering materials and systems. The development of new geomaterials and systems is also important in the Division's areas of support.

Cooperative efforts are encouraged between engineering schools, industry, and national and government laboratories, as is the advancement of U.S. engineering through international cooperative research and other activities. Particular emphasis is placed on improving opportunities for young investigators, the disabled, women, and minorities. The Division places a strong emphasis on improving the dissemination of research results to potential users in both the universities and industry. Research proposals involving several disciplines are welcome and these are considered jointly with programs in other divisions.

Given the inherent complexity and interdisciplinary nature of research, a portion of the grants from this Division is made to small groups of investigators with complementary skills who propose to collaborate on substantial problems. To ensure relevance and importance, to promote knowledge transfer, and to leverage resources, university-based researchers are encouraged to seek active collaboration from industry and national laboratories on proposed projects. The target dates for achieving unsolicited proposals to the various programs of the Division are April 1 and November 1, annually. Because the Foundation is making a determined effort to increase the award duration, proposers are encouraged to submit research proposals having a 3-year research plan and budget.

## Dynamic Systems and Control Program

This program supports research on the dynamic behavior, design, and control of mechanisms, machines, processes, structures, and other engineered physical systems. The primary emphasis is on the physical modeling of dynamic systems of all types, and on improving the knowledge base for analyzing their performance and aspects of their control. Research topics include dynamics theory, control of mechanical systems, acoustics and noise control, design methology, and machine dynamics. The major program support addresses significant gaps in or extends the knowledge base of these disciplines. Current interests focus on intelligent control of mechanical systems. A second category of research is high-risk research that may lead to revolutionary advancement in the field. A third category involves codification of research results, placing them in a form useful in professional practice. The program includes, but is not limited to, research in the following areas: theoretical foundations and analytical methods for dynamic systems; analytical and experimental techniques for machine dynamics; noise and vibration analysis and control; engineering systems control; and design of mechanical systems.

## Surface Engineering and Tribology Program

Funding is provided for basic engineering research on the unique characteristics of surfaces, interfaces, and near-surface materials, as these characteristics affect the performance of mechanical components and structures subject to tribological conditions, mechanical and thermal stresses, and corrosion or environmental degradation. Innovative research is encouraged leading to new ways of generating or

characterizing surfaces that are engineered for optimal mechanical properties, topography and microstructure, leading to improved tribological materials, lubricants or coatings for operation under severe conditions. Also supported are modeling of tribosystems and the use of signals from tribological events for tribosensing and process control. Collaborative work between investigators with complementary skills is encouraged. Current thrust areas are:

*Friction.* The fundamental nature of friction and its dependence on basic materials properties, surface characteristics, and operating conditions and models of materials; determination or calculation of minimum friction; and friction in deformation processing.

*Surface Modification.* The development of low-friction surfaces and new coatings or surface modification techniques for protection against wear and thermal or corrosive degradation.

*Tribology of Engineered Surfaces.* The effects of processing, topography, microstructure, composition, interface thickness, etc., on the tribological behavior of engineered surfaces and combined surface mechanics/tribo- testing/modeling/materials engineering approaches are encouraged.

## Mechanics and Materials Program

This program supports research to develop engineering and scientific foundations of the design, mechanical response, and failure of all classes of solids. Theoretical, experimental, and computational investigations of deformation, fatigue, and fracture behavior, accounting for the underlying phase, defect, and microstructural state and its origin, transformation, and evolution are emphasized.

Research that bridges the traditional boundaries between the disciplinary areas of solid mechanics and materials science and engineering is encouraged.

Besides the awards to single investigators, awards are made to small groups of investigators (two to four) with complementary skills who collaborate on substantial problems in well-defined areas. Such group research should employ a blend of analytical, experimental, and computational efforts. Research thrusts change over time. For the immediate future they are:

- Design and realization of new materials for mechanical performance
- Physical experiments on micro and macroscales, and constitutive modeling for inelastic deformation and failure under multi-axial static and dynamic loadings
- Modeling and computer simulation of thermo-mechanical aspects of materials processing and manufacturing, spanning the range of new understanding of the older, well-established processes to new processes, including those involving optical and electronic materials and devices.
- Special emphasis on micromechanics and experimental techniques for high temperature materials, failure of composites, and surfaces and interfaces in computer technology.

## Structures, Geomechanics, and Building Systems Program

This program supports research on progressive design, construction, maintenance, and operation of safe, long-lived, efficient, and economical civil engineering systems and facilities. It supports research to better understand the science and technology of deteriorating infrastructure; actions to diagnose, repair, remediate, retrofit, and enhance the performance of existing constructed facilities; and incorporating the knowledge gained to improve the performance of new constructed facilities.

Innovative research is needed to preserve the Nation's large constructed facilities (i.e., buildings, bridges, highways, airports, tunnels, waste repositories, dams, ports, and harbors) which have been deteriorating because of the natural and man-made hazards, pollution, use beyond the original design, aging of the materials, and obsolescence. Major research areas of interest are included in the following three program elements.

### Structural Systems and Construction Process

*Structural Systems.* Research in structural systems includes analysis and design methods using computers. Emphasis is placed upon prediction of structural behavior from load sources; methods of analysis of buildings and structural systems and their components (e.g., connections) under fixed, steady-state, and transient loads; active and passive control of structural responses to extreme loading conditions; intelligent structures/materials and total systems; structural reliability and optimization; and knowledge-based expert systems (KBES) for structural design and materials. A focus includes better analysis, design, and methods which lead to improved codes, standards, and design criteria for use in practice.

*Construction Processes.* Research in construction processes includes construction engineering analysis, design, and management. Emphasis is placed on basic research on innovative construction materials, construction engineering, risk and uncertainty, organization and management of human and materials resources in the construction process, intelligent material handling systems, disaster recovery, knowledge-based expert systems, and robotics in construction. A focus includes research on construction processes which integrate advanced technology using test-bed simulations and integrated computer-aided design, construction control, and construction automation.

## Geomechanical, Geotechnical, and Geo-Environmental Systems Program

This program emphasizes fundamental and innovative research to improve analytical, computational, and experimental geo-systems. The transfer of knowledge, data, and information from the research stage to use by designers and industry are encouraged. Research aimed at increasing the basic understanding of the behavior of geomaterials in ambient, subterranean, offshore, hazardous, and extra-terrestrial environments is encouraged. The results should contribute in the long term to improving; basic concepts in geomechanics and in the behavior of geocomposite materials; assessment and remediation of hazards involved in geo-environmental waste management; manufacture and stability of geo-structures (including underground space); soil-structure interaction; computer-aided geo-technology; and knowledge-based data management. Emphasis is placed on: physics of multiphase groundwater flow, contaminant transport in ego-materials; constitutive relationships and experimental verification in geomechanics; groundwater modeling; transferability of laboratory scale measurements and concepts to field scale; "intelligent" geocomposites with advanced bio- and synthetic-polymeric materials; manufacture and intelligent material handling of new generation geo-materials; large scale data base management; knowledge-based expert systems for optimal design strategies; nondestructive and in situ evaluation and calibration systems; quality and performance testing and control of geo-systems; and computer-aided construction to increase optimization and reliability of geo-structures.

## Large Structural and Building Systems Program

*Diagnostic Techniques for Large-Scale Systems.* Basic research addresses accurate nondestructive evaluation of the condition, residual strength, and remaining life of existing large civil engineering systems. Research is directed toward the integration of innovations in sensor, microelectronic systems technology, and signature analysis to develop "intelligent" structures and materials that provide advanced diagnostic data. These can be used to advance diagnostic procedures such as tomographic reconstruction.

The data obtained by these methods will serve to determine the performance of the structure, condition assessment, prediction of life expectancy, and safety of components and the total system. Data will also serve to determine the degree and type of repair, retrofit, and/or replacement.

*Building Systems.* This program element is concerned with research on systems analysis and innovative design of buildings including "intelligent buildings" and work environments, and integration and optimization of building systems--structural materials, building services, communication, and equipment. Emphasis is placed on: building evaluation and diagnostics; total building performance including environmental engineering and user response; physical environment and integrated systems engineering to optimize efficiency in use; building economics and life cycle costing; security and safety including

accidents, fire and building failures; conservation of resources and building reuse; knowledge-based expert systems; and computer-aided design of integrated building systems and other structures.

*Repair, Retrofit, Remediation, and Rehabilitation.* Basic research addresses developing new materials, techniques, and strategies for these purposes as an ultimate use. New materials include synthetics, composites, polymers, epoxies, fiberglass composites, and ceramics in new concepts of application. Techniques for achieving safety of structures by analysis, and experiments in laboratory and the field can also be addressed.

*Bridges.* Basic research is conducted to determine performance of bridges, safety, nondestructive evaluation, new concepts, replacement of decks, and strengthening the total system, including soil-structure interaction, as well as innovative materials and techniques for repair, retrofit, and replacement. Research on self monitoring systems for intelligent behavior of the total system required for safety determinations is also supported.

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