Directorate for Engineering (ENG)

The Directorate for Engineering (ENG) supports engineering research and education in a competitive environment that emphasizes innovation, creativity, and excellence. This support benefits the Nation by creating the human resources and knowledge that spur technological innovation and economic growth in an increasingly swift, complex, and interconnected world. A significant portion of ENG's funds is invested in investigator-initiated research. Although the research supported by ENG is fundamental in nature, much of it is focused on societal needs. Over the long term, ENG investments contribute to innovation that enables the creation of valuable new products and services and new and more productive enterprises that enhance the Nation's future economic strength, security, and quality of life.

ENG's investment and partnerships with academe, federal agencies, and private industry as well as collaboration with other National Science Foundation (NSF) directorates in the emerging technologies of microsystems and nanotechnology, information technology, and biotechnology enable significant advances in health care, manufacturing, education, and the service industry. For example, awards made by the Grant Opportunities for Academic Liaison with Industry (GOALI) Program, which receives strong ENG support, bring university and industry collaborators together at the conceptual phase of a research and education endeavor. Strengthening these intellectual connections increases the value of engineering education and fundamental research to the private sector and opens exciting new areas of research.

Overall, NSF provides about 36 percent of the total Federal support for fundamental engineering research at universities and colleges in the United States.

The Directorate for Engineering supports programs and activities through the following:

- Crosscutting Programs and Activities
- Division of Bioengineering and Environmental Systems (BES)
- Division of Chemical and Transport Systems (CTS)
- Division of Civil and Mechanical Systems (CMS)
- Division of Design, Manufacture, and Industrial Innovation (DMII)
- Division of Electrical and Communications Systems (ECS)
- Division of Engineering Education and Centers (EEC)

For More Information
Visit the ENG Directorate home page, http://www.eng.nsf.gov/.

DIRECTORATE FOR ENGINEERING

Crosscutting Programs and Activities

NSF-Wide Activities

In addition to the programs and activities mentioned in this section, the Directorate for Engineering (ENG) takes an active role in the following NSF-wide programs and activities: Nanoscale Science and Engineering, Biocomplexity in the Environment, Information Technology Research, Mathematical Sciences, and Human and Social Dynamics priority areas. Faculty Early Career Development (CAREER) Program, Research Experiences for Undergraduates (REU), Integrative Graduate Education and Research Training (IGERT), Graduate Fellowships (e.g., Graduate Research Fellowships, GK-12 Teaching Fellowships), Grant Opportunities for Academic Liaison with Industry (GOALI), Major Research Instrumentation (MRI), undergraduate activities, the ADVANCE program to increase the participation of women in the scientific and engineering workforce, minority programs, Small Business Innovation Research (SBIR), Small Business Technology Transfer Research (STTR), and programs for persons with disabilities.

For More Information
Visit the NSF Crosscutting Programs home page, http://www.nsf.gov/home/crssprgm/.

Engineering-Wide Activities

The ENG Directorate also has programs that are available across all of its divisions. The Materials Use: Science, Engineering, and Society (MUSES) component of Biocomplexity in the Environment is an important ENG-wide activity. Another emphasis is in Sensing and Sensor Technology. For information about ENG's education programs, see the Division of Engineering Education and Centers (EEC) section of this Guide; or visit the EEC home page, http://www.eng.nsf.gov/eec.

DIRECTORATE FOR ENGINEERING

Division of Bioengineering and Environmental Systems

The Division of Bioengineering and Environmental Systems (BES) supports research that

- expands the knowledge base of bioengineering at scales ranging from proteins and cells to organ systems, large bioreactors, and biomanufacturing systems, including mathematical models, devices, and instrumentation systems. BES is particularly interested in postgenomic engineering, metabolic engineering, and tissue engineering. BES continues its strong interest in upstream and downstream processing of proteins and other biochemicals (see the Biochemical Engineering and Biotechnology Program for more information).
- applies engineering principles to the models and tools used in understanding living systems, and to products for human health care. BES supports the development of prototypes for new and improved devices and software for persons with disabilities. Emphasis is placed on basic engineering research that will contribute to better and more efficient health care delivery and that will aid people with disabilities. Current areas of interest include biomedical photonics and sensing (see the Biomedical Engineering Program for more information).
- improves our ability to apply engineering principles to avoid and correct problems that impair the usefulness of land, air, and water. Current interest areas include environmental remediation, especially with respect to understanding the fate and transport of surface and groundwater pollutants; novel processes for waste treatment; industrial ecology; and technologies for avoiding pollution (see the Environmental Engineering and Technology Program for more information).

The BES Division supports the following programs and activities:

1. Biochemical Engineering and Biotechnology
2. Biomedical Engineering and Research to Aid Persons with Disabilities
3. Environmental Engineering and Technology

For More Information
Write to the Division of Bioengineering and Environmental Systems, National Science Foundation, 4201 Wilson Boulevard, Room 565, Arlington, VA 22230; or contact the division by telephone, 703-292-8320; or by fax, 703-292-9098; or visit the BES home page, http://www.eng.nsf.gov/bes.

1. Biochemical Engineering and Biotechnology

Supports research that links the expertise of engineering with that of the life sciences to provide a fundamental basis for economical manufacturing of substances of biological origin. Engineers and small groups of engineers and scientists are encouraged to apply for support. Synergy among the various disciplines in these types of projects is a very important evaluation criterion. Current areas of interest include the following:

- **Postgenomic Engineering**—Quantitative methods for predicting the phenotypic behavior of proteins, pathways, and cells from genomic data.
- **Metabolic Engineering**—Methods for understanding and beneficially altering the chemical pathways of living systems.
- **Tissue Engineering**—Development of polymeric scaffolding, imbedding of cells, cell-to-cell communications, tissue biomechanics, and so forth.
- **Bioprocessing**—Novel bioreactors and processing systems and controls; major changes in downstream isolation and purification.

2. Biomedical Engineering and Research to Aid Persons with Disabilities

Supports fundamental engineering research that has the potential to contribute to improved health care and

reduced of health care costs. Other areas of interest include models and tools for understanding biological systems; fundamental improvements in deriving information from cells, tissues, organs, and organ systems; extraction of useful information from complex biomedical signals; new approaches to the design of structures and materials for eventual medical use; and new methods of controlling living systems. The program is also directed toward the characterization, restoration, and substitution of normal functions in humans. The research could lead to the development of new technologies or to the novel application of existing technologies rather than to product development. Also supported are undergraduate engineering design projects, especially those that provide prototype "custom-designed" devices or software for persons with mental or physical disabilities. New areas of research interest include biomedical photonics and sensors.

3. Environmental Engineering and Technology

Supports sustainable developmental research, the goal of which is to reduce the adverse effects on land, fresh and salt water, and air that are brought on by the solid, liquid, and gaseous discharges that result from human activity, causing deterioration of those resources. The program also supports innovative research in the areas of biological, chemical, and physical processes that are used alone or as components of engineered systems to restore the usefulness of polluted land, water, and air resources. Emphasis is on engineering principles that underlie pollution avoidance, and pollution treatment and repair. Improved sensors, innovative production processes, waste reduction and recycling, and industrial ecology are important to this program. Research may be directed toward improving the cost-effectiveness of pollution avoidance as well as developing new principles for pollution avoidance technologies. The program places particular emphasis on engineering principles that underlie pollution avoidance.

DIRECTORATE FOR ENGINEERING

Division of Chemical and Transport Systems

Technologies and processes for transforming materials and energy are critical to improve living standards, prolong life, and protect the natural environment. The Division of Chemical and Transport Systems (CTS) supports research that contributes to the knowledge base important for the design and control of a large number of industrial processes. Relevant areas of application include production of chemicals, pharmaceuticals, petroleum and petrochemicals; synthetic and natural materials such as polymers and electronic materials; energy; and waste treatment. CTS support is directed to fundamental engineering principles involving mathematical models of macro and molecular systems and experimental techniques. Emphasis is on projects that have the potential for innovation and broad application in areas related to environmental preservation, materials development, and chemical and thermal processing. Increased emphasis is being placed on formation of nanostructured functional materials, environmentally benign chemical and materials processing, the development of sustainable and more efficient energy systems, and effective integration of research and education.

The CTS Division supports four general thematic areas through the following programs:

1. Chemical Reaction Processes
2. Interfacial, Transport, and Separation Processes
3. Fluid and Particle Processes
4. Thermal Systems

For More Information
Write to the Division of Chemical and Transport Systems, National Science Foundation, 4201 Wilson Boulevard, Room 525, Arlington, VA 22230; or contact the division by telephone, 703-292-8371; or by fax, 703-292-9054; or visit the CTS home page, http://www.eng.nsf.gov/cts.

1. Chemical Reaction Processes

This program consists of two components: (1) Kinetics, Catalysis, and Molecular Processes (KCMP) and (2) Process and Reaction Engineering (PRE). Activities supported through the components include research on the rates and mechanisms of important classes of chemical reactions and on the quantitative description of chemical reactors and processes.

- **Kinetics, Catalysis, and Molecular Processes (KCMP)**—Supports the study of reactions at the molecular scale. Topics of interest include fundamental theories, novel modeling, and simulation approaches to reactive molecular processes; molecular modeling to relate atomistic-level phenomena to plant-scale design; single-molecule mechanisms and characterization; combinatorial catalysis and combinatorial chemistry; automated parallel synthesis and high-throughput screening; catalytic and materials process informatics; catalysis in medicine and life processes; reactions in nanoenvironments; large-scale kinetics databases and intelligent data management; distributed and collaborative reactive process characterization; bioinspired reactive process design; nanofabricated reactive processes; nanophase control in reactive processes; electrochemical and photochemical processes; environmentally sustainable and abundant feedstocks; wasteless pathways and pollution prevention; low-temperature chemical processes; and single-step processing.
- **Process and Reaction Engineering (PRE)**—Generally deals with reactors, macroscopic reaction systems, and chemical-processing plants. Topics of interest include design and optimization of complex chemical processes including scheduling and supply-chain modeling; dynamic modeling and control of processes; combined reaction and separation; sensors for process and quality control; reactive processing of polymers, ceramics, and thin films; global integration of chemical processes within the service economy; interactions between chemical reactions and transport processes in reactive systems; and the use of information technology in the design of complex chemical reactors.

2. Interfacial, Transport, and Separation Processes

Activities supported through the components in this program support research in areas related to interfacial phenomena and mass transport, separation science, and phase-equilibrium thermodynamics. The two components of the program are (1) Interfacial, Transport, and Thermodynamics (ITT) and (2) Separation and Purification Processes (SPP).

- **Interfacial, Transport, and Thermodynamics (ITT)**—Major focus areas include advanced materials processing and environmentally benign processing. ITT provides support for fundamental approaches and theories that deal with the thermodynamics of complex fluids and transport phenomena at interfaces of synthetic and biological systems, and the processing of nanoscale materials and thin films. The ITT Program also supports research aimed at minimizing hazardous products in chemical and materials manufacturing, with a focus on environmentally friendly coatings, alternate reactions, and processing media.
- **Separation and Purification Processes (SPP)**—Major focus areas include the development of functional materials as effective mass-separation agents, high-performance computing and modeling applied to separation processes, and novel strategies that combine several phenomena to accomplish effective separations. The SPP Program supports basic research that involves novel membranes and adsorbents; modeling and computations applied over a range of scales, from a molecular level to macroscale analysis of separation processes; and separations utilizing combined effects of controlled hydrodynamics, adsorption phenomena, electrical or magnetic fields, and chemical reactions.

3. Fluid and Particle Processes

Consists of two components (1) Fluid Dynamics and Hydraulics (FDH) and (2) Particulate and Multiphase Processes (PMP). Activities supported through these components include fundamental research on mechanisms and phenomena that govern single- and multiphase fluid flow; particle formation and transport, various multiphase processes; synthesis and processing of nanostructured materials, and fluid and solid system interactions.

- **Fluid Dynamics and Hydraulics (FDH)**—Supports basic research on fluid dynamics, both computational and experimental. Major areas of interest include turbulence, flow in complex geometries, stability and transition in polymer processing, and flow in nanostructures, with applications to design and control machines and processes. The program also strives to increase the understanding and predictive capabilities of flows in rivers and coastal areas for environmental and commercial applications.
- **Particulate and Multiphase Processes (PMP)**—Funds research on topics related to multiphase and dispersed systems. Areas of interest include not only multiphase flows but also the synthesis and processing of nanoparticles. In addition to experimental studies, the program supports work on molecular and mesoscale modeling of particle formation and materials synthesis. Hierarchical simulation techniques that will lead to insights of engineering relevance and nonintrusive measurement techniques are supported, as is research on innovative uses of particles in new processes and technologies.

4. Thermal Systems

This program consists of two components (1) Thermal Transport and Thermal Processes (TTP) and (2) Combustion and Plasma Systems (CPS). Priorities in both programs include projects related to environmental quality and energy efficiency as well as new manufacturing techniques.

- **Thermal Transport and Thermal Processes (TTP)**—Supports projects that seek a basic understanding of heat transfer, particularly at the micro- and nanoscale levels, and that apply heat and mass transfer principles to technologically-related fields. Areas in need of basic heat-transfer research include photon and phonon transport in thin films, laser/radiation interactions with liquid and solid phases, macroscopic transport with microstructure formation during solidification, flow and heat transport in porous media, microjet cooling for electronic equipment; phase-change materials, non-isothermal rheology, and crystal growth. Examples of technologically related fields are manufacturing, laser processing and machining, welding, gas turbines, heating and ventilation systems, biotechnology, and cryogenics.
- **Combustion and Plasma Systems (CPS)**—Supports research on the fundamental, physical, and chemical processes involved in combustion. A primary objective is to address major problems such as the formation of pollutants in combustion, energy-conversion inefficiencies, and fire hazards. The program supports fundamental science and engineering studies that underlie the application of plasma technology in situations such as chemical conversions, materials refining, and energy recovery. Projects supported by CPS apply combustion or plasma processing to such areas as production of fine powders or thin films, waste

destruction, sterilization, and surface modification. Major topics covered include flame chemistry, incineration, internal combustion engines, pollutant formation from combustion, models of combustion or plasma systems, diagnostics for combustion and plasmas, plasma chemistry and physics, and combustion synthesis. CPS also supports computational efforts in both theory and simulation, and experimental studies on real engineering systems or laboratory models, diagnostic techniques, and real-time monitoring of processes.

DIRECTORATE FOR ENGINEERING

Division of Civil and Mechanical Systems

The Division of Civil and Mechanical Systems (CMS) supports research that contributes to the knowledge base and intellectual growth in the areas of infrastructure construction and management, geotechnology, structures, dynamics and control, mechanics and materials, sensing for civil and mechanical systems, and the reduction of risks induced by earthquakes and other natural and technological hazards.

The CMS Division encourages cross-disciplinary partnerships at the intersections of traditional disciplines. These partnerships promote discoveries using technologies such as autoadaptive systems, nanotechnology, and information technology to enable revolutionary advances in the Nation's civil and mechanical systems.

The CMS Division supports the following research programs:

1. Dynamic System Modeling, Sensing, and Control (DSMSC)
2. Geotechnical and Geohazards Systems (GGS)
3. Infrastructure and Information Systems (IIS)
4. Solid Mechanics and Materials Engineering (SMME)
5. Structural Systems and Engineering (SSE)
6. George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES)

For More Information
Write to the Division of Civil and Mechanical Systems, National Science Foundation, 4201 Wilson Boulevard, Room 545, Arlington, VA 22230; or contact the division by telephone, 703-292-8360; or by fax, 703-292-9053; or visit the CMS home page, http://www.eng.nsf.gov/cms.

1. Dynamic System Modeling, Sensing, and Control (DSMSC)

Supports research on the fundamental engineering concepts and mathematical theories for modeling, analysis, simulation, and control of complex nonlinear dynamic systems, including the study of new control methods, acoustics, vibrations, and kinematics relationships. DSMSC invests in research on information technology as related to smart and autoadaptive civil and mechanical systems, including the study of new technologies for sensing and acquiring information; multiple and intelligent system functionality; integration of sensors, actuators, controllers, and power sources; and modeling, synthesis, simulation, and prototyping of intelligent systems and their components.

2. Geotechnical and Geohazards Systems (GGS)

Seeks to advance the fundamental engineering and related knowledge for geostructures—foundations, slopes, excavations, soil and rock improvement technologies, and reinforcement systems; geohazards mitigation; constitutive modeling and verification; remediation and containment of geo-environmental contamination; transferability of laboratory results to field scale; and nondestructive and in situ evaluation. GHS support is given for research that will increase the geotechnical and geohazards knowledge necessary to mitigate the impacts of natural and technological hazards in both constructed and natural environments. A broad spectrum of research is supported, including the use of data from laboratory and field experiments to develop and validate innovative designs and methodologies; the application of new sensing and information technologies to the simulation of complex phenomena; and the collection of data from catastrophic events including deployment of rapid-response reconnaissance.

3. Infrastructure and Information Systems (IIS)

Supports research to develop new science bases necessary for developing and deploying advanced information systems and technologies required to sustain the Nation's infrastructure. IIS research affects infrastructure system design, construction, maintenance, and operation and control. It includes networking technology, Internet-based

data systems, voice and data communications technologies, and geographical information systems-based multimedia global infrastructure information systems. The IIS Program is also interested in systems and network approaches to infrastructure management and life-cycle engineering, integrated systems behavior and network simulation, hazard preparedness and response, societal and economic impacts, decision theory, intelligent systems and engineering (life-cycle design), and conceptual and theoretical bases of scalable enterprise for civil systems construction and management.

4. Solid Mechanics and Materials Engineering (SMME)

Links the expertise of analytical, computational, and experimental solid mechanics and biomechanics with materials and surface engineering to understand, characterize, analyze, design, and control the mechanical properties and performance of materials and devices. SMME supports research on the deformation, fracture, fatigue, friction, wear, and corrosion of all types of materials, including composites, nanostructured materials, construction materials, and coatings and surface modification for service under extreme conditions. The program also supports experimental and analytical investigations and simulation modeling of material microstructures and their connections to nano-, meso-, and macroscale structural behavior.

5. Structural Systems and Engineering (SSE)

Emphasizes new discoveries in the design, construction, repair, rehabilitation, upgrade, and maintenance of structural materials and systems. SSE supports research that will advance the knowledge base on the application of advanced polymer materials and high-performance steel and concrete materials, durability of construction materials, soil structure interaction, safety and reliability of bridges and other structures including applications of condition assessment to structural systems, and integrated building systems. Also of interest is research that will lead to improved understanding of the impact of extreme events on the performance of the constructed environment and on interactions between natural and constructed environments.

6. NSF George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES)

Funded under the NSF Major Research Equipment and Facilities Construction Account, NEES is authorized for a construction period of 5 years through September 30, 2004, for a total NSF contribution of $81.8 million. The goal of NEES is to provide a national networked collaboratory of geographically distributed shared-use, next-generation experimental research equipment sites. The sites will be equipped with teleobservation and teleoperation capabilities that will transform the environment for earthquake engineering research and education through collaborative and integrated experimentation, computation, theory, database, and model-based simulation. The goal is to improve the seismic design and performance of U.S. civil and mechanical infrastructure systems. When the construction is completed, the NEES consortium will operate the NEES collaboratory through the year 2014.

The NEES collaboratory will include 15 to 20 equipment sites (shake tables, centrifuges, tsunami wave basin, large-scale laboratory experimentation systems, and field experimentation and monitoring installations) networked together through a high performance Internet. In addition to providing access for telepresence at the NEES equipment sites, the network will use cutting-edge tools to link high performance computational and data storage facilities, including a curated repository for experimental and analytical earthquake engineering and related data. The network will also provide distributed physical and numerical simulation capabilities and resources for visualization of experimental and computed data. For further information, visit the program's Web site, http://www.eng.nsf.gov/nees.

DIRECTORATE FOR ENGINEERING

Division of Design, Manufacture, and Industrial Innovation

The Division of Design, Manufacture, and Industrial Innovation (DMII) supports fundamental academic research in design, manufacturing, and industrial engineering. DMII also manages crosscutting industrial innovation programs that encompass major components of NSF.

Technological advances, increasing global competition, and the Internet have combined to make today's manufacturing activities increasingly integrative, such that the distinction between "manufacturing" and "service" has become blurred. The mission of the Engineering Design and Manufacture research programs is to address this rapidly changing environment; the challenge it poses to the Nation's economic well-being; the expanding opportunities of the emerging service sector; and the need for an educated technical workforce for the manufacturing and service enterprises of the future.

To address this mission, DMII identifies and supports fundamental research on issues that span the areas supported within the Engineering Directorate—from design to manufacturing to service. These areas include size scales from the "nano" environment that will drive tomorrow's manufacturing processes to the "macro" or global enterprise scale that defines the production systems of the traditional manufacturing sector and extends into the growing service sector of the future. DMII-funded research includes an emphasis on environmentally benign manufacturing and a sustainable industrial economy, and seeks to address those fundamental issues that will deepen our understanding of the processes and systems that comprise modern design, manufacturing, and service enterprises and benefit society. The Division maintains a commitment to the integration of research and education and the education of a diverse engineering workforce that will be responsive to the needs of industrial and service enterprises.

The DMII Division's academic research programs are grouped into the following two clusters:

- Engineering Decision Systems
- Manufacturing Process and Equipment Systems

The former focuses on the mathematical aspects of design, service, and enterprise systems; the latter addresses the physical aspects of materials and manufacturing processes.

- Industrial Innovation Programs

DMII's Industrial Innovation Programs support small business and organizational innovation research as well as programs that seek collaboration with industry. These programs are crosscutting and span all areas supported by the Engineering Directorate and many other parts of NSF.

For More Information
Write to the Division of Design, Manufacture, and Industrial Innovation, National Science Foundation, 4201 Wilson Boulevard, Room 550, Arlington, VA 22230; or visit the DMII home page, http://www.eng.nsf.gov/dmii; or contact by telephone, 703-292-8330; or by fax, 703-292-9056. Personal visits are also welcome.

• Engineering Decision Systems Cluster

The Engineering Decision Systems Cluster provides funding for fundamental research on theory and methods that guide and support decisions about the design and operation of products and enterprise systems. The programs are distinguished by their focus on methods that:

- are founded in mathematics, statistics, decision sciences, economics, and information technology, as opposed to the natural and social sciences; and

- address the prescriptive derivation of preferred choice, as opposed to descriptive characterization of scientific and engineering phenomena.

Much of the research is computational and/or exploits capabilities of the Internet but development of commercial software or networks is not supported. Similarly, incorporation of the research into educational programs is encouraged, but supported projects must have significant research content.

The cluster consists of the following programs:

1. Engineering Design
2. Operations Research
3. Manufacturing Enterprise Systems
4. Service Enterprise Engineering

For More Information
Visit the Engineering Decision Systems Cluster Web site, http://www.eng.nsf.gov/dmii/Message/EDS/eds.htm.

1. Engineering Design (ED)

Focuses on fundamental theory and general-purpose tools for conceptualization and description of engineered products and systems, including analysis of alternatives and selection of preferred choices. The program embraces a holistic view of design that recognizes that choices are best made in a total-system, life-cycle context. ED does not support the design of specific products or systems, but instead seeks novel advances in generic design theory and methodology.

2. Operations Research (OR)

Is concerned with generic tools for modeling and optimization of engineering design, manufacturing, and service enterprise operations. Emphasis is on improving basic analytical and computational techniques, especially where their potential for impact on relevant engineering and operations management problems is apparent.

3. Manufacturing Enterprise Systems (MES)

Addresses research that is focused on design, planning, and control of operations in manufacturing enterprises, including the associated procurement and distribution supply chains. Contributions should extend the range of analytical and computational techniques applicable to these enterprise operations and advance novel models that offer policy insight or the prospect of implementable solutions. Research in MES is typically performed with the guidance or collaboration of appropriate industrial partners.

4. Service Enterprise Engineering (SEE)

Addresses engineering issues particular to the service sector. Contributions should extend the range of analytical and computational techniques addressed to service enterprise operations and advance novel models offering policy insight or the prospect of implementable solutions. However, the measurement and conceptualization of service processes as engineered systems may themselves represent a contribution in some applications. Research in SEE is typically performed with the guidance or collaboration of appropriate industrial partners.

• Manufacturing Processes And Equipment Systems Cluster

The manufacturing enterprise requires the integration of appropriate scientific, engineering, and mathematics disciplines with design objectives within a systems framework where the desired outcome is a viable product or service. Product realization, integrated product and process development (IPPD), and concurrent engineering are all aspects of the manufacturing enterprise. The drivers for the manufacturing enterprise are the economic, energy, and environmental issues that define viability in terms of cost, delivery, and performance. The major developments in manufacturing during the past 30 years include computer-integrated manufacturing; automation in robotics and

flexible manufacturing systems for lean and agile manufacturing; artificial intelligence and Internet-based systems for distributed manufacturing; quality assurance; net shape processes; additive, layered, and beam processing, including solid freeform fabrication and surface modification; and open-architecture manufacturing systems. However, research is needed in order to make macro-, meso-, micro-, and nanomanufacturing more productive, predictable, efficient, economical, environmentally benign, and globally competitive.

The goals of the Manufacturing Processes and Equipment Systems Cluster are:

- to support research that will advance our understanding of the manufacturing processes, machine tools, and systems within the broad scope of unit manufacturing processes; and
- to bring about manufacturing innovations that have an impact on the economy and society.

The cluster emphasizes research that employs a blend of analytical, computational, and experimental efforts to address three key research issues: predictability, producibility, and productivity. These issues are key to enhancing performance, efficiency, quality, and the reduction/elimination of adverse environmental effects in manufacturing to make U.S. industries globally competitive.

There are three program elements under this cluster:
1. Manufacturing Machines and Equipment (MME)
2. Materials Processing and Manufacturing (MPM)
3. Nanomanufacturing (NM)

For More Information
Visit the Manufacturing Processes and Equipment Systems Cluster Web site, http://www.eng.nsf.gov/dmii/Message/MPES/mpes.htm.

1. Manufacturing Machines and Equipment (MME)

Focuses on generating the fundamental knowledge for building next-generation machines and equipment and their applications for materials processing, parts manufacture, assembly, inspection, and other operations. It supports theoretical and experimental research in mechanism, surface integrity, monitoring and control, metrology, part fixturing, environmental effects, performance, and productivity improvements related to micro-, meso-, and macromachining processes and manufacturing equipment.

2. Materials Processing and Manufacturing (MPM)

Supports the innovation of novel manufacturing processes and methodologies for making useful products from new and recycled materials through the understanding and control of the behavior of materials during processing. Typical research activities include the net shape processing of metals, ceramics, polymers, and composite materials. The program does not support research in the processing of semiconductor materials such as Si and GaAs.

3. Nanomanufacturing (NM)

Supports innovative, fundamental research in the science and technology of nanostructured materials, components, and systems leading to potential breakthroughs in the manufacturability of new industrial products or enabling useful services and new applications. Emphasis is on theoretical and experimental research that addresses the underlying necessities for predictability, producibility, and productivity in manufacturing at the nanoscale.

• Industrial Innovation Programs

The Industrial Innovation Programs address innovation opportunities for small businesses, as well as academic research on the innovation process itself. These programs provide opportunities for academic research to link with the industrial sector and include:
1. Small Business Innovation Research (SBIR)

2. Small Business Technology Transfer (STTR)
3. Grant Opportunities for Academic Liaison with Industry (GOALI)
4. Innovation and Organizational Change (IOC)

For More Information
Visit the DMII home page, http://www.eng.nsf.gov/dmii.

1. Small Business Innovation Research (SBIR)

Offers opportunities and incentives for creative small businesses that are involved in science, engineering, education, or technology to conduct innovative, high-risk research on important scientific and technical problems. Research supported by the SBIR Program should have significant potential for commercialization and public benefit. This three-phase program offers incentives for converting federally supported research carried out in Phases I and II into commercial application in Phase III, which is funded by private capital.

2. Small Business Technology Transfer (STTR)

Links entrepreneurs with the academic research community and encourages commercialization of government-funded research by the private sector. Proposals submitted to the STTR Program must have small-business principal investigators, but up to 60 percent of STTR funding may be used to support university subcontracts necessary to assist in the commercialization of research products by the small business firm. STTR is a three-phase program that offers incentives for converting research done in Phases I and II to commercial application in Phase III, which is funded by private capital. The difference between SBIR and STTR is in the requirements for partnership of the small business sector with the academic community.

3. Grant Opportunities for Academic Liaison with Industry (GOALI)

This initiative aims to encourage industry/university partnerships by making funds available for the support of an eclectic mix of industry/university linkages. Specifically, GOALI provides support (1) to conduct research and gain experience with production processes in an industrial setting; (2) for industry scientists and engineers to bring industry's perspective and integrative skills to academe; and (3) for interdisciplinary industry/university teams to conduct long-term projects. GOALI supports faculty, postdoctoral fellows, and students in developing creative modes of collaborative interaction with industry through individual or small-group projects, and supports industry-based fellowships for graduate students and postdoctoral fellows. GOALI targets high-risk, high-gain research that focuses on fundamental topics that would not have been undertaken by industry, and supports the development of innovative, collaborative, industry/university educational programs and the direct transfer of new knowledge between academe and industry.

4. Innovation and Organizational Change (IOC)

Seeks to create and apply fundamental new knowledge with the aim of improving the effectiveness of the design, administration, and management of organizations, including industrial, educational, service, government, and nonprofit and voluntary organizations. The program encourages dissemination of knowledge gained from research to organizations and institutions that can design and implement improvements based on what has been learned. The Directorates for Engineering; Social, Behavioral, and Economic Sciences; and Education and Human Resources jointly support IOC. The program places a priority on investigator-initiated research that advances our understanding of the fundamental processes and structures of organizations in a variety of institutional contexts. Prospective IOC research might draw on or include organizational behavior and theory, industrial engineering, industrial/organizational psychology, organizational sociology, and public administration and management science. Proposers should work with partner organizations in business, nonprofits, governmental agencies, and educational institutions.

DIRECTORATE FOR ENGINEERING

Division of Electrical and Communications Systems

The Division of Electrical and Communications Systems (ECS) addresses the fundamental research issues underlying device technologies and the engineering systems principles of complex systems and applications. ECS also seeks to ensure the education of a diverse workforce prepared to support the continued rapid development of these technologies as drivers of the global economy. The research and education supported by ECS are fundamental to developing synergy between macro-, micro- and nanotechnology, biotechnology, and information technology in support of homeland security and the emerging new industries and economy of the 21st century.

The study of microelectronic, spin electronic, organoelectronic, nanoelectronic, micromagnetic, photonic, optoelectric, and microelectromechanical devices and their integration into circuits and microsystems is rapidly expanding in technical scope and application. New generations of integrated microsystems incorporate microchip technology with mechanical, biological, chemical, and optical sensors, actuators, and signal processing devices to achieve new functionality. Trends toward smaller devices raise new research challenges to fabricate molecular-based nanoscale structures and understand quantum principles, which dominate their behavior. Modern computing and communications systems are based on these devices. Wireless methods of telemetry to extract data from these new devices are equally important in order to realize local and global networks of sensors and other devices for analysis, interpretation, and extrapolation.

Research on the design and analysis of systems and the convergence of control, communications, and computation forms the basis for new research on data-rich complex dynamical systems. These systems, which learn new functions and adapt to changing environments, are especially important for advanced applications. The integration of device research and systems principles has broad applications in telecommunications, wireless networks, security, and efficiency of power system grids, thus enabling technologies for alternate energy sources such as space solar power, environment, transportation, biomedicine, nanomanufacturing, and other areas.

ECS supports integrative research through opportunities that encourage innovative and collaborative systems-oriented research. ECS also provides support for specialized resources and infrastructure—such as the National Nanofabrication User Networks—that facilitate research and education activities as well as the development of a strong and diverse engineering workforce.

The ECS Division supports the following programs and activities:

1. Electronics, Photonics, and Device Technologies (EPDT)
2. Control, Networks, and Computational Intelligence (CNCI)
3. Integrative Systems (IS)
4. Resources and Infrastructure

For More Information
Write to the Division of Electrical and Communications Systems, National Science Foundation, 4201 Wilson Boulevard, Room 675, Arlington, VA 22230; or contact the division by telephone, 703-292-8339; or by fax, 703-292-9147; or visit the ECS home page, http://www.eng.nsf.gov/ecs.

1. Electronics, Photonics, and Device Technologies (EPDT)

Seeks to improve the fundamental understanding of devices and components based on the principles of electronics, photonics, electromagnetics, electro-optics, electromechanics, and related physical phenomena. Additionally, seeks to enable the design of integrated microsystems that define new capabilities and applications; experimental and theoretical studies of nanoscale electronic, spintronic, and photonic devices and principles; use of nanotechnology for device fabrication; and related topics in quantum and molecular engineering and quantum computing are of particular current interest. Answers and alternative strategies to the challenges identified for conventional silicon electrodes at the nanoscale are needed for both fabrication and metrology. Adaptive and reconfigurable devices and low-power/low-noise electronics are used in novel network architectures and advanced communications systems. Microsensors and microactuators, MEMS, RF MEMS, and bioMEMS are used in diverse areas ranging from industry and defense applications to biology and medicine. New answers are needed for wireless applications involving RF ICs, smart antennas, reconfigurable antennas, wireless sensors and devices,

and wireless systems on a chip. Also needed are new methods for the modeling, design, and characterization of electromagnetic materials and devices. The program invites proposals for research that can lead to high performance of macro-, micro- and nanoscale devices, components, and materials; advanced methods of design, modeling, and simulation of devices and components; and improved techniques for processing, fabrication, and manufacturing.

2. Control, Networks, and Computational Intelligence (CNCI)

Supports creative research underlying the analysis and design of intelligent engineering systems and networks for control, communications, and computation. The program invites proposals for research that can lead to improved methods for analysis, design, optimization, reliability, robustness, and evaluation of complex systems. Distributed systems and networks occur in telecommunications; power, energy, and transportation systems; and agile and adaptive sensor networks that will be needed to monitor and protect our critical infrastructure, as well as the emerging cyberinfrastructure. Hybrid systems incorporate both continuous and symbolic knowledge representation and are of increasing interest in the study of networks, manufacturing, and transportation systems. Adaptive, learning, and self-organizing principles offer potential for improved performance of systems with unknown models and changing characteristics, especially in biomedical and environmental applications. Biologically inspired methods and algorithms, including neural networks, evolutionary computation, behavioral architectures, and intelligent agents for engineering applications are also of interest. High-performance and domain-specific computation as well as quantum computing are applied to the development of simulation, design, and decision tools for engineering applications.

3. Integrative Systems (IS)

Stimulates innovative research in areas that integrate device concepts and systems principles to aid in the development of new technologies and new research directions. Proposals are sought that address fundamental research issues associated with the analysis and design of such integrative systems. Areas of opportunity are announced on the ECS Division home page. In addition, researchers are welcome to propose potential topics of interest and are encouraged to discuss them with a program director. An example of an integrated microsystem is a miniature implantable device that combines sensors, actuators, and computational algorithms and microcircuits for biomedical applications ranging from drug delivery to microsurgery. A second example is a wireless network of handheld or wearable computing devices that incorporates microsystem transmitters, receivers, antennas, and sensors and constitutes a complex distributed network with high bandwidth and high information-transfer requirements. Design of power grids and systems that are reliable, efficient, and environmentally benign is yet another example. Such integrative systems offer new challenges in basic research and promise for future applications. Proposals for integrative systems research may involve collaborative research among investigators to capture the breadth of expertise needed for such multidisciplinary but integrative research.

4. Human Resources and Infrastructure

In partnership with other NSF directorates and government agencies, ECS provides state-of-the-art user facilities for micro- and nanofabrication and metrology tools with the establishment of the National Nanotechnology Infrastructure Network (NNIN). The NNIN provides access to all faculty and students for research and educational use at moderate costs. ECS also offers faculty and student researchers in optoelectronics assess to precommercial devices and systems through the Photonics Technology Access Program (PTAP). NSF's Science and Technology Centers (STCs), Engineering Research Centers (ERCs), Industry/University Cooperative Research Centers (IUCRC), and Integrative Graduate Education and Research Traineeships (IGERT), Graduate Research Fellowships (GRF), and GK-12 Fellowship Programs affect overlap and supplement research areas of the electrical and communications community. Researchers and educators are encouraged to build linkages with these programs. ECS also seeks to enhance academic infrastructure through supplemental and special program opportunities such as the Grant Opportunities for Academic Liaison with Industry (GOALI) and Major Research Instrumentation (MRI) Programs, and through the international collaborations described in the overview of the Engineering Directorate. In addition, ECS encourages the participation in the development of cross-disciplinary group awards. Programs such as Centers for Learning and Teaching, Bridges between Engineering Education, Faculty Early Career Development (CAREER), and Nanotechnology Undergraduate Education offer many opportunities to infuse the latest research developments into the electrical engineering curriculum. Current principal investigators are encouraged to apply for supplemental grants via programs such as Research Experience for Undergraduates (REU), Research Experience for Teachers (RET), and underrepresented precollege students as research assistants on engineering grants.

DIRECTORATE FOR ENGINEERING

Division of Engineering Education and Centers

The Division of Engineering Education and Centers (EEC) supports centers that collaborate with industry to integrate research, education, and projects to promote innovations in engineering education and engage a diverse body of students in engineering research. These efforts integrate new knowledge across disciplines, accelerate technology development, and improve the capabilities and diversity of engineering graduates entering the technical workforce.

EEC's centers promote partnerships among researchers in different disciplines and between industry and universities. They focus on integrated engineered systems and produce technological innovations that strengthen the competitive position of industry. Their graduates are well-rounded, professionally oriented engineers with a global outlook, experience in technological innovation, and the ability to assume leadership roles in industry, academe, and government.

The educational innovation projects of EEC range from small-scale efforts that integrate research into curricula at the course level to the development and implementation of large-scale models for engineering curriculum reform. These efforts have infused knowledge of emerging technology into curriculums across the country and have provided models for systemic reform of engineering curriculum that have included freshman-year experience with design and product development. All efforts promote the diversity of the engineering workforce.

The EEC Division supports the following programs and activities:

1. Engineering Research Centers (ERCs)
2. Industry/University Cooperative Research Centers (I/UCRCs)
3. Engineering Education Programs
4. Grants for Department-Level Reform of Engineering Education
5. Supplemental Funding for Support of Women, Minorities, and Physically Disabled Engineering Research Assistants

For More Information
Write to the Division of Engineering Education and Centers, National Science Foundation, 4201 Wilson Boulevard, Room 585, Arlington, VA 22230; or contact the division by telephone, 703-292-8380; or by fax, 703-292-9051; or visit the EEC home page, http://www.eng.nsf.gov/eec.

1. Engineering Research Centers (ERCs)

Provide an integrated environment for academe and industry to focus on next-generation advances in complex engineered systems, with synergy among engineering, science, and industrial practices. ERCs integrate research and education at both the graduate and undergraduate levels and produce curriculum innovations derived from the engineering systems research focus of the ERC. ERCs build partnerships with industry, develop shared infrastructure, and increase the capacity of engineering and science graduates to contribute to U.S. competitiveness. They are supported for up to 10 years to promote the long-term perspective in engineering research and education that is required to produce new technologies and innovative products and services.

2. Industry/University Cooperative Research Centers (I/UCRCs)

Develop long-term partnerships among industry, academe, and government. The centers are university-based and catalyzed by a small investment from NSF but are primarily supported by industry members. I/UCRCs are led by faculty who have a strong desire to work with industry and who want to pursue fundamental research agendas recommended by industrial advisory boards. Center research projects are conducted primarily by graduate students; the program thus develops students who know how to conduct industrially relevant research and communicate their findings effectively.

3. Engineering Education Programs

Stimulates innovation and reform in engineering education to produce graduates who are better able to serve the evolving needs of the new century. A high priority is developing high-quality engineering curriculums that will attract and retain increased numbers of engineering students, especially women, underrepresented minorities, and people with disabilities. The Engineering Education Programs support the implementation of new approaches to educate engineers and encourage outstanding students—particularly from underrepresented groups—to enter the field. The programs build on successful innovations from the NSF Engineering Education Coalitions and other new concepts for the reform and improvement of engineering education, and seek to involve research-active scholars more actively in education innovation.

EEC supports programs through which new faculty can learn from successful scholars and practitioners in such areas as learning theories, course and curriculum design, test construction and evaluation, multimedia technologies, student mentoring, diversity, and leadership.

4. Grants for Department-Level Reform of Undergraduate Engineering Education

Supports departmental and larger units to reformulate, streamline, and update engineering and engineering technology degree programs; develop new curriculums for emerging engineering disciplines; and meet the emerging workforce and educational needs of U.S. industry. These efforts should increase the relevance of undergraduate engineering curriculum to modern engineering practice and induce an increased proportion of students who enroll to complete engineering degree programs. These goals can be accomplished by introducing modern learning strategies, expanding both the disciplinary breadth and the range of problems and problem-solving techniques to which engineering students are exposed; incorporating new laboratories and research experiences; and effectively integrating the powerful software tools used in engineering practice.

5. Supplemental Funding for Support of Women, Minorities, and Physically Disabled Engineering Research Assistants

Provides supplemental funding to include women, underrepresented minorities, and physically disabled undergraduate or high school students as research assistants on NSF-funded projects. Supplemental funding of up to $5,000, including indirect costs, may be requested for each student added to the project. 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.

If necessary, funds in excess of $5,000 may be requested to provide special equipment or modify existing equipment, or to provide other services specifically for the purpose of enabling a physically disabled person (or persons) to participate. The equipment must be directly related to the research work, such as a prosthetic device to manipulate a specific piece of equipment, not for general assistance such as wheelchairs or ramps.