V. TRANSLATING THE PLAN INTO ACTION

NSF welcomes the exciting opportunity to translate this plan into action. The Strategic Plan guides Directorate planning, the annual performance budget, and individual performance plans that link directly to NSF's mission, vision, goals and objectives. Implementation of this plan is the responsibility of the Assistant Directors, Office Heads and internal groups responsible for planning and performance. Individual performance appraisals will measure staff accountability. Annual metrics that track our progress will appear in the budget.

A. Future Investment Considerations

The overall strategic goals and objectives are set by the National Science Board and NSF senior management in consultation with the science and engineering community and with additional guidance from the Office of Management and Budget, the Office of Science and Technology Policy, and Congress. Based on our strategic goals, NSF identifies key areas for future investment by balancing a variety of concurrent and equally important factors. These areas may reflect emerging opportunities of great promise, address pressing challenges, or respond to critical national needs. They may involve NSF-wide activities and require sustained levels of investment over many years, or they may be more narrowly focused and change from year to year as promising opportunities arise. Proposed investments will be evaluated against this matrix of considerations. (Individual projects are evaluated using the merit review criteria described in the Appendix.)

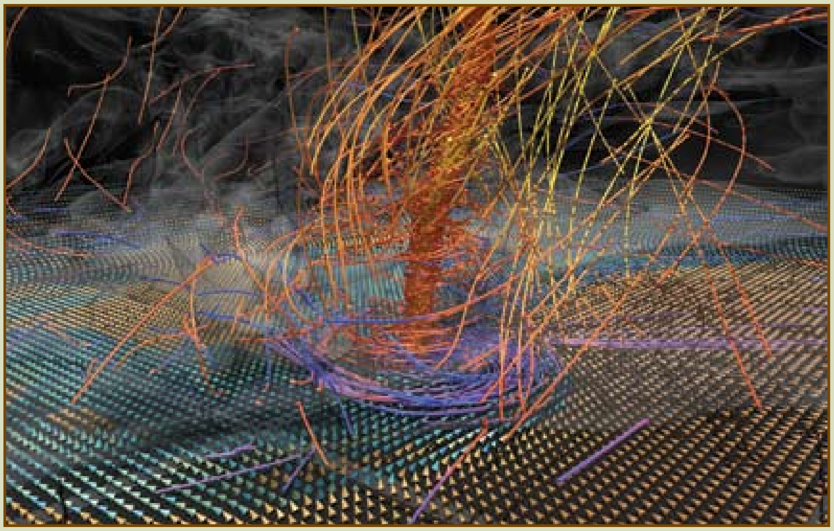
- ***Alignment:*** Align with NSF's mission, vision, goals, and objectives. Deciding factors include whether investments lie within the bounds established by the NSF Strategic Plan, effectively address multiple goals, and do not duplicate the efforts of other agencies or institutions.
- ***Budget:*** Balance investments with funding levels. Deciding factors include whether the proposed level of investment is commensurate

Complexity and Emergence

Nature abounds with examples of complex systems that show emergent phenomena, patterns of structure or behavior seen at one scale of a system that arise from interactions among system components at other scales of length, time, or number of components. Examples include the beating of a heart, the biological origin of a thought, the evolution of weather patterns, and the dynamics of some economic phenomena.

- Complex systems are ubiquitous and to understand them requires contributions from multiple disciplines. Recent mathematical achievements have advanced the study of complex problems in geospace. These problems couple phenomena occurring at atomic scales with those occurring at astronomical scales, for example through the study of electromagnetic processes that control plasmas.
- The cross-fertilization of ideas and methods from biology and chemistry with those from the physics of complex systems has led to new approaches to a variety of critical issues including the evolution and functioning of genetic regulatory networks, the specificity of protein-protein interactions, the dynamic control of cell motility, and the neural synaptic mechanisms underlying learning.
- Analogies from the life sciences are motivating the design of self-assembling and self-repairing materials.
- Communities of researchers—spanning engineering and geosciences to behavioral science—are working together to forecast, prepare for, and respond to natural and human-induced disasters.

NSF funding to improve understanding, modeling, and harnessing of complex systems will have far-reaching consequences across the entire spectrum of science and engineering.



Computer visualization techniques improve comprehension of complex phenomena such as the formation of tornadoes.

with the opportunity, level of risk, relevance, and potential impact.

- ***Integration of Research with Education:*** Strengthen connections between learning and inquiry. Deciding factors include whether investments present a rich environment for encouraging future scientists, engineers and educators, and whether they provide opportunities for teachers and students to participate in research activities at the K-12, undergraduate, graduate and postdoctoral levels.
- ***Leveraging Collaborations:*** Create a variety of opportunities for national and international collaboration. Deciding factors include whether investments augment other NSF activities; leverage other community, industry, federal agency or international investments in research, education and infrastructure; and broaden participation in science and engineering.
- ***Potential for Impact and Transformation:*** Promote ideas that are intellectually compelling, innovative and imaginative. Deciding factors include the extent to which investments may transform a field of science or engineering; are broadly significant or of great interest to the community; position the U.S. at the forefront of an emerging field; promote teaching, learning, mentoring, training and outreach; contribute to national research and development priorities; sustain economic competitiveness; or enable socially important outcomes.
- ***Urgency and Readiness:*** Capture timely opportunities. Deciding factors include whether timing is critical to achieve optimum results, or investment is necessary to maintain long-term stability and progress in critical areas.

B. Objectives

NSF has identified two crosscutting objectives—*To Inspire and Transform* and *To Grow and Develop*—that apply to each goal and are essential to advancing the mission and vision. Expert evaluations, described in the Appendix, will periodically assess the progress in working toward these two objectives for each of the four strategic outcome goals.

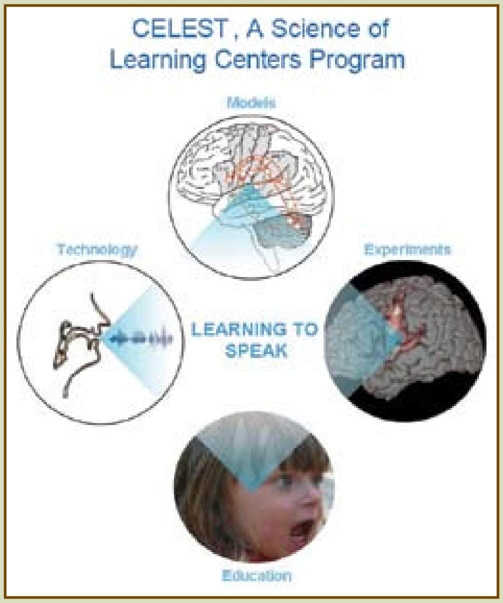
To Inspire and Transform

NSF advances scientific discovery by supporting transformational and distinctive new capabili-

NSF Centers

NSF Centers, (e.g., Science and Technology Centers, Engineering Research Centers, Science of Learning Centers) support interdisciplinary research of a scope, scale and complexity beyond the resources of any individual investigator or small group. Centers also provide rich environments for the multidisciplinary training and mentoring of undergraduate students, graduate students and postdoctoral fellows, as well as K-12 educational partnerships and public outreach. The Center model promotes opportunities for cross-fertilizations of ideas between and among theoretical and experimental scientists and students, as well as between the scientists and students and the educators and technologists who turn their results into real-world applications. One example is Boston University's Center of Excellence for Learning in Education, Science, and Technology (CELEST), a Science of Learning Center.

A Science of Learning Center seeks to advance our knowledge of learning in all its forms, from the digital to the societal, over as broad a range as possible. This may include the chemical and biological basis of learning; the psychological, social, organizational and pedagogical aspects of learning; machine learning; mathematical analyses and models of learning; and more. At CELEST, researchers study and model how the brain learns to adapt in real time to complex and changing environments. CELEST scientists address this question across multiple levels of analysis, from single neurons, to neural networks, to whole brain and behavior. To truly understand the linkages between brain and behavior, one must study each in conjunction with the other, from neurons and synapses, to sensory perception, to learning and memory, to complex behaviors. The development of new algorithms, based on knowledge of these processes, can then be used to solve outstanding technological problems presented by uncertain and ever-changing data. CELEST scientists also work with educators to bring models of how mind and brain work into math and science curricula at all instructional levels.



NSF-supported centers bring together researchers from diverse fields to investigate phenomena such as language acquisition.

ties—those innovations in research and education that move discovery well beyond the boundaries of current knowledge. NSF encourages this potential by emphasizing areas of greatest scientific opportunity, identified through input from the science and engineering community, and by igniting the creative spark that leads to revolutionary advances.

NSF cultivates the same creative spark in young people. We develop innovative pathways to engage them at the frontiers of discovery, facilitate their entry into the science and engineering workforce, and advance their early careers. NSF will inspire the next generation by promoting excellent science education, including timely access to exhilarating discoveries in classrooms, and by partnering with museums and other organizations that use informal science education to bridge the gulf between scientific advances and public understanding.

NSF supports the development and construction of infrastructure that gives researchers access to new territory impossible to explore without it, including multiple-use and distributed instruments and facilities, and comprehensive, next-generation cyberinfrastructure. We also support research on advanced tools and technologies to enable future generations of instrumentation and infrastructure.

NSF-funded centers enable academic institutions and their partners to integrate discovery, learning and innovation on scales that are large enough to transform important science and engineering fields and cross-disciplinary areas. Centers also provide unique opportunities for students to broaden their research horizons and industrial partners to interact with top academic researchers.

NSF seeks to be a trailblazer in its own administration and management, with organizational structures, learning environments, business practices and merit review processes that serve as models for research agencies around the world.

In all our activities, NSF endeavors to communicate the wonder of exploration and the excite-

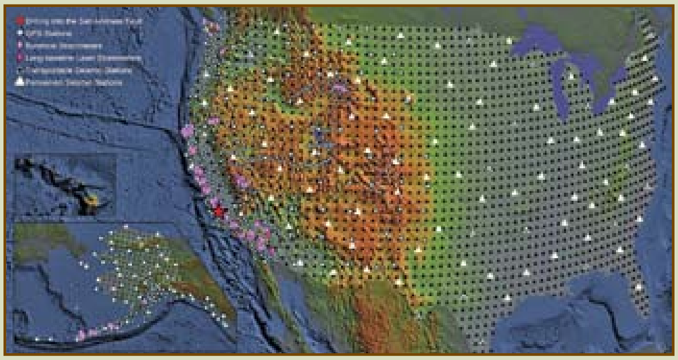
Earthquake Science and Engineering

Earthquakes are among the most complex terrestrial phenomena. Taken from end to end, the challenge comprises understanding the loading and failure of tectonic faults, the generation and propagation of seismic waves, the response of surface sites and, in application to seismic risk, the damage caused by earthquakes to the built environment and the preparation and response of communities and disaster managers. Building on decades of funding earthquake-related science and engineering and seismic measurements, NSF is now poised to contribute to great new advances in our knowledge of the structure and evolution of the North American continent and understanding of earthquakes and seismic systems.

With NSF funding, the Southern California Earthquake Center (SCEC) has developed a community modeling environment for simulating earthquake processes using terascale computing facilities. Already, simulations have delivered new predictions about seismic hazards from California's San Andreas Fault system. During its next phase, SCEC will focus on three demanding science objectives: extending simulations of ground motions to investigate the limits of ground-motion prediction; improving the resolution of dynamic rupture simulations; and computing and validating seismic hazard maps.

The Network for Earthquake Engineering Simulation (NEES) is NSF's first distributed network cyberinfrastructure research facility. It is a national, shared-use experimental resource linking together 15 facilities located at universities across the U.S. The network enables collaboration and advanced research and education based on experimentation and computational simulations of earthquakes and how buildings, infrastructure, coastal regions and geologic materials perform during seismic events. NEES will advance understanding and improve the design and performance of the Nation's constructed civil and mechanical infrastructure when subjected to earthquake excitation and tsunamis.

The EarthScope Facility, a distributed, multi-purpose geophysical instrument array, will provide the next-generation web of interrelated measurements required to fuel these and other earthquake-related research activities. The three major foci of EarthScope include a heavily instrumented drill hole that crosses the San Andreas Fault and will return unprecedented records of conditions within the seismogenic zone. Another is a dense array of permanent GPS stations and strainmeters in the western U.S. that will record deformation in and around earthquake prone regions. The third EarthScope component is the USArray, a combination of portable and permanent seismograph stations that will provide unprecedented images of the active earthquake regions throughout the continent. USArray instrumentation is expected to inhabit nearly every county within the U.S. over the lifespan of the program. Partners include USGS, NASA, the Department of Energy, and the International Continental Scientific Drilling Programme, and may also include state and local governments, geological and engineering firms, and Canadian and Mexican agencies. Over 3,000 earth scientists and students are expected to use the facility annually.



The EarthScope program's USArray will provide a comprehensive network of interconnected sensors to explore seismic activity.

ment of discovery and learning.

To Grow and Develop

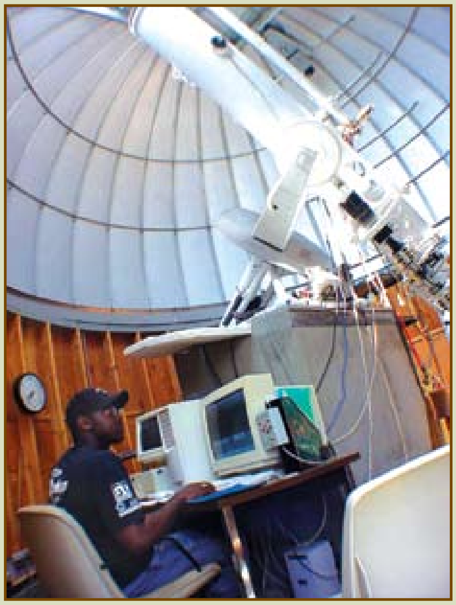
NSF will continue to strengthen fundamental research across the full spectrum of science and engineering. The majority of our research funding supports individual investigators and small groups of researchers. NSF support is particularly important in fields that are critical to the U.S. science and engineering enterprise but receive little support from other sources. NSF ensures the health of core science and engineering fields as they grow, develop and ultimately produce results that may refashion a discipline or lead to completely new fields of enquiry. We help support the underlying research enterprise that mission agencies and industry draw upon to accomplish their objectives.

NSF provides leadership within an extended network of research organizations and agencies; educational institutions, predominantly undergraduate institutions and universities; museums; professional societies; and small and large businesses—all engaged in science and engineering research and education. We encourage this broad array of institutions, in all locations throughout the nation and from every sector, to participate fully in the nation's science and engineering enterprise. NSF also broadens participation by drawing on all of the nation's talent and reaching out especially to underrepresented groups as we support programs that attract U.S. students and prepare them to be highly productive members of the global S&E workforce.

NSF is the principal source of support for investigations to improve science and engineering education from early childhood through undergraduate, graduate and postdoctoral studies, including public outreach, and for research that develops successful models for teaching and learning. Recognizing their essential partnership in this effort, NSF also supports science centers, aquaria, museums, and other organization that provide informal science education. NSF supports educational programming provided by a variety of media outlets through which many Americans acquire science information and additional learning. These efforts increase interest, engagement and understanding of science, engineering and tech-

Building Science and Engineering Capacity

NSF is exploring new models and new partnerships for encouraging the nation's young people to study science and engineering and broadening their participation in these fields. One critical time period for students considering science and engineering careers is the undergraduate years. NSF's Research Experiences for Undergraduates (REU) and Undergraduate Research Collaboratives (URC) reach out to a diverse range of science and engineering undergraduates. The excitement of participating in meaningful research can crystallize a career direction and provide the essential motivation for continued study. REU and URC awards particularly target students who might otherwise have no opportunity to participate in research during their critical undergraduate years.



Students at the Prairie View Solar Observatory get first-hand experience in gathering and analyzing research data.

The URC Program combines a focus on first- and second-year college students with striving to improve the research capacity, infrastructure and culture of participating institutions. Projects allow students to create new knowledge that is potentially publishable by providing exposure to research of contemporary scientific interest that is addressed with modern research tools and methods. The participation of two-year institutions that traditionally have been outside the research mainstream has been especially noteworthy. Nearly half of all undergraduate students attend community colleges. Without such programs, those students might otherwise overlook promising, productive careers in science and technology. Sample themes from projects already underway include biodiesel fuels; solar-energy conversion; chip-based chemical analyses; nanoscale materials; and molecular characterization of air, water and soil samples.

The REU program funds both sites and grant supplements. Supplements typically provide support for one or two undergraduate students to participate in research, as part of a new or ongoing NSF-funded research project. REU sites have a well-defined common focus that enables a cohort experience for students. One REU site is located at Prairie View A&M University in Texas, a historically black university. The students participate in frontier space weather and space physics research at the Prairie View Solar Observatory (PVSO), a one-of-a-kind facility. Undergraduates in the program have the opportunity for hands-on experience processing and analyzing data, producing professional reports, and working with multiple solar telescopes, as well as learning computer programming and computer simulation. PVSO faculty and research staff members mentor students in individual research experiences.

nology by individuals of all ages and backgrounds within a variety of different educational settings.

NSF will expand opportunities for U.S. researchers, educators and students at all levels to access state-of-the-art science and engineering facilities, laboratory instrumentation and equipment, databases, advanced computing resources, research networks and other infrastructure. We will ensure that large facilities supported by NSF, including observatories, research vessels and aircraft, large laboratories, polar facilities, distributed instrumentation networks and arrays, and other types of critical infrastructure, operate efficiently and effectively.

NSF aspires to be a learning organization that encourages, rewards and values the contributions of its talented staff. NSF leads and adapts to the changing nature of research as proposals become increasingly complex and interdisciplinary. Through constant attention, we combine business processes, human capital and information technology to continue to find and support excellence in science and engineering research and education. We promote professional integrity in this work and in the research and education we support.

C. Communication

An essential part of communicating is listening. In developing the NSF Strategic Plan, we have listened carefully to the public, the science, engineering and education community, and our staff as they have given us comments on the previous plan and on drafts of the new plan. We developed the plan in consultation with the Office of Management and Budget and Congress, and coordinated the planning process with the development of the *National Science Board 2020 Vision for the National Science Foundation.* After the release of the plan, communication with NSF staff, the National Science Board and the larger community will continue through a variety of mechanisms. We will post the plan on the NSF website and disseminate it broadly to staff and the external community. We will present the plan to the Board and our Advisory Committees at their regular meetings, and discuss it throughout NSF in staff meetings and special presentations.

NSF will use a variety of approaches to achieve our goals and, under law, evaluate our progress against a set of yearly goals and performance metrics specified in the annual budget. Basic research presents special challenges for evaluation because outcomes from basic research often take years, sometimes decades, to understand and fully appreciate. NSF supports research on fundamental questions where directions and outcomes may be unexpected. This makes retrospective assessments of portfolios by experts (see Appendix for details) valuable, particularly when combined with the prospective assessments of projects inherent in the merit review process.

Strategic planning is an ongoing process. In concert with evaluating our progress against this plan, we will continue to solicit feedback from our staff, our advisors and the broad science, engineering and education communities to inform our next plan. As the world of science and engineering continues to change, NSF will always strive to achieve the same excellence in planning, execution and evaluation that we expect from the programs we fund.

Fab Labs

Around the world, from high-school students to rural farmers, people are now being given the opportunity to design and fabricate sophisticated devices from scratch, thanks to an NSF-supported program called "Fab Lab." Short for "fabrication laboratory," a Fab Lab is a portable, dishwasher-sized array of equipment that combines highly flexible, user-friendly CAD/CAM and modeling software with a suite of industrial-grade tools including a laser cutter and milling machine. For less than the price of a compact car, it gives users the technology to describe, design and build just about anything from inexpensive and readily available materials. The goal is to help people who traditionally have lacked access to sophisticated resources use advanced information technologies to develop and produce solutions to local problems.

The idea for Fab Lab arose at MIT's Center for Bits and Atoms, launched by NSF funding to explore the interface between computer science and physical science. Fab Labs have been tested around the world. In Ghana, users have devised antennas and radios for wireless networks, and solar-powered machinery for cooking, cooling and cutting. In Norway, the units have produced wireless networks and animal radio collars to aid herding of livestock. In India, users are making agricultural instrumentation, testing milk for quality and safety, and tuning diesel engines to run more efficiently, particularly with local biofuels. And, in Boston, Fab Lab users make jewelry, toys and crafts using recycled materials from the community.

In Norway, a Fab Lab unit was used to create components of a wireless tracking system for various kinds of livestock.