NSF-Supported Research Infrastructure:

Enabling Discovery, Innovation and Learning

National Science Foundation

On the cover: a collage illustrating NSF-supported research infrastructure. Top row, from left to right: Ranger, the new high performance computing system at the Texas Advanced Computing Center at the University of Texas at Austin; the National High Magnetic Field Laboratory's 45 tesla hybrid magnet; and the first commercial prototype of a super-resolution optical microscope based on structured illumination, installed at the Center for Biophotonics Science and Technology at the University of California, Davis; middle row: the Tsunami Wave Basin at Oregon State University; a visualization of a protein from the Protein Data Bank, shown on a configurable wall for projecting images at the California Institute for Telecommunications and Information Technology at the University of California, San Diego; and the Amundsen-Scott South Pole Station with the ceremonial South Pole in the foreground; bottom row: researchers in the Arkansas Nanoscience Program using scanning probe microscopy; the High-Performance Instrumented Airborne Platform for Environmental Research (HIAPER), the nation's most advanced aircraft for environmental research; and an artist's conception of the Atacama Large Millimeter Array (ALMA), the giant international observatory under construction in the Atacama Desert in northern Chile. *Credit: Top row, from left to right: TACC, The University of Texas at Austin; Florida State University; Thomas Huser, Center for Biophotonics Science and Technology, University of California, Davis. Middle row: College of Engineering, Oregon State University; Jurgen Schulze, Calit2, UC-San Diego; Dwight Bohnet, National Science Foundation. Bottom row: Nanoscience Program, University of Arkansas; The National Center for Atmospheric Research (NCAR); ALMA/ESO/NRAO/NAOJ*

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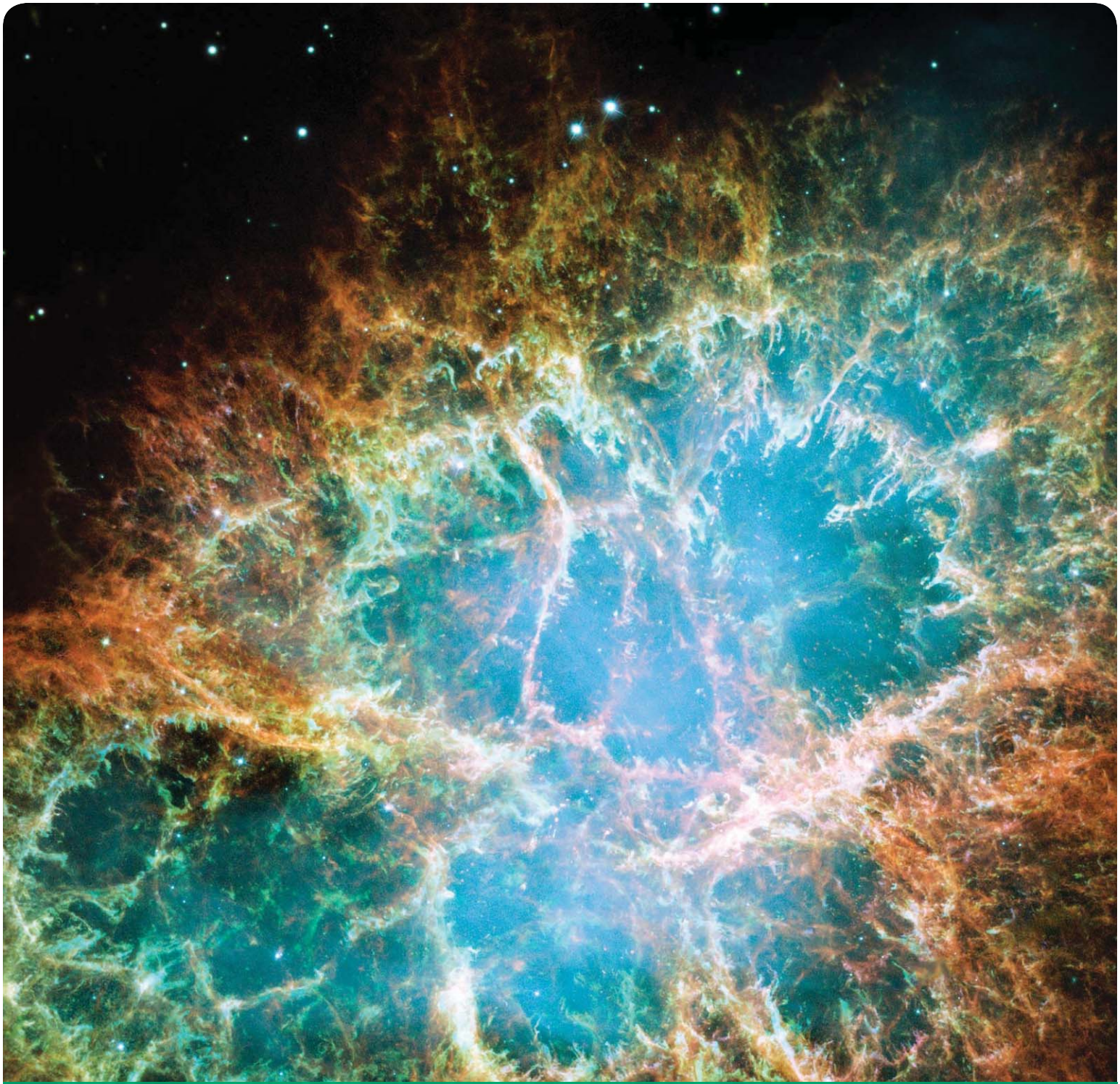


Introduction

A composite image of the Crab Nebula taken by the Hubble Space Telescope. After analyzing data from observations with NSF's Laser Interferometer Gravitational-Wave Observatory (LIGO), scientists concluded that only four percent of the energy from the Crab pulsar could be in the form of gravitational waves. *Credit: NASA, ESA, J. Hester and A. Loll, Arizona State University*

Advancing the frontiers of science and engineering depends, in part, on transformational facilities and instruments, and on the ability to use them effectively. For the National Science Foundation (NSF)—the only federal agency that supports fundamental research and education across all fields of science and engineering—providing a world-class research infrastructure is essential to the furthering of discovery, innovation and learning. Through advances in research infrastructure and collaborative environments, we ensure that the nation's scientists, engineers, teachers and students have opportunities to explore areas of exceptional promise.

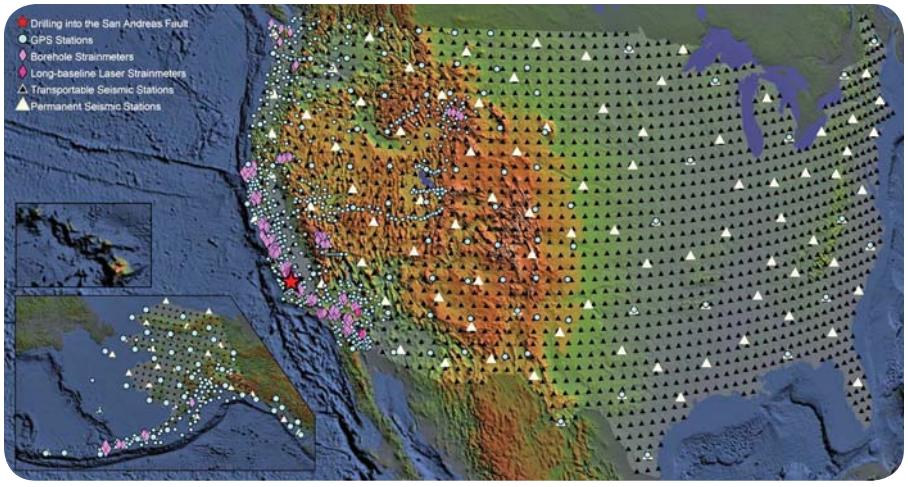
NSF is known for supporting science and engineering ideas, but, perhaps, less well known for our support of new and powerful tools and dynamic research centers. And yet, NSF has a mission to make advanced equipment, facilities, and shared cyberinfrastructure broadly available to the entire research community. Infrastructure and center investments have enabled researchers and educators to pursue fundamental questions, unravel newly revealed mysteries, transform fields and disciplines, and expand people's understanding of the universe and their place in it. These investments are essential to maintaining the overall leadership of the U.S. science and engineering enterprise.

A few examples demonstrate the potential for unprecedented discoveries and transformative innovations:

- Using NSF's Laser Interferometer Gravitational-wave Observatory (LIGO) facility based in Hanford, Wash., and Livingston, La., scientists are moving closer to detecting gravitational waves—Einstein's long-theorized ripples in the fabric of space and time. An analysis of the Crab Pulsar in the Crab Nebula by LIGO scientists found that no more than four percent of the pulsar's energy loss is caused by the emission of gravitational waves, disproving one theory that gravitational waves significantly slow down the spinning of neutron stars. While LIGO has not yet detected any actual gravitational waves, this analysis did provide an exciting first look at the interior of a neutron star.

- Massachusetts Institute of Technology researchers and colleagues, partially funded by NSF's Materials Research Science and Engineering Centers (MRSEC) program, have created a waterproof adhesive bandage that is inspired by the gecko's uniquely adhesive feet. The bandage's surface has nanoscale hills and valleys similar to those on the gecko's foot that enable the lizard to cling to walls and ceilings. The new bandages could join sutures and staples as a basic operating room tool for patching up surgical wounds.

Close-up views of gecko feet, showing different toe pad structures. A team of researchers reported evidence for dry adhesion of gecko setae (hair-like structures) by the weak molecular attractive forces known as van der Waals forces. The discovery paved the way for researchers to design synthetic dry adhesives inspired by geckos. *Credit: Image courtesy professor Kellar Autumn, from Autumn, K., et al. 2002. Evidence for van der Waals adhesion in gecko setae. Proc. Natl. Acad. Sci. USA 99, 12252-12256.*



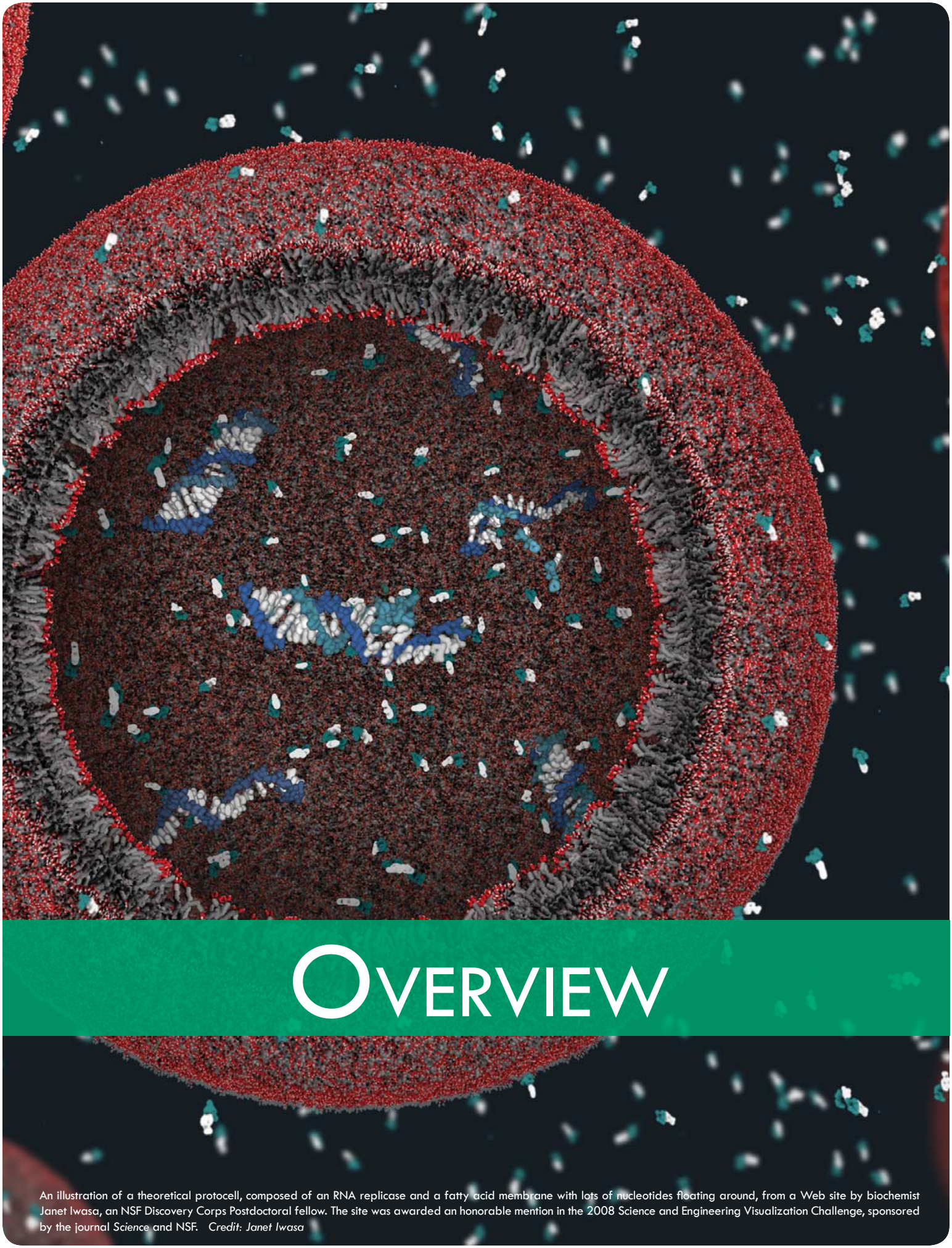
This map depicts the footprint of EarthScope, a distributed, continental-scale, multipurpose, geophysical instrument array that enables researchers to study the structure and dynamics of the North American continent. *Credit: EarthScope*

- Scientists working with seismic data from NSF's continental-scale EarthScope facility are gaining important insights into the processes in the Earth's crust that give rise to Episodic Tremor and Slip (ETS) events, such as those that occur regularly in the Pacific Northwest. In contrast to a "typical earthquake" with a duration of just seconds, these recently discovered "slow earthquakes" may have a duration that extends from two to several weeks. In one part of the Cascadia zone, ETS events have been detected with a regular 14-month period, allowing successful prediction of 5 additional events. ETS events are very important to understand because they are believed to influence the size and timing of future large earthquakes.

- A joint team of physicists and ophthalmologists from the NSF-supported Center for Ultrafast Optical Science at the University of Michigan and the university's Kellogg Eye Center developed a procedure that significantly improved LASIK surgery procedures. The improvement involves using an ultrafast laser to make clean, high-precision surgical cuts in the human cornea. Using the ultrafast laser instead of a mechanical blade enables surgeons to create a precise corneal flap. The femtosecond laser "scalpel" provides surgeons much higher precision and accuracy. The Michigan center was an NSF Science and Technology Center (STC) from 1990-2001; today, it's an interdisciplinary research center in the university's College of Engineering. The researchers' work has already benefited hundreds of thousands of people who have undergone vision correction procedures since 2001. Two members of the Michigan research team founded the IntraLase Corporation to commercialize the femtosecond laser technology. Advanced Medical Optics, Inc. agreed to acquire IntraLase for about $808 million in 2007.

- Students and staff members at the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign, one of the early NSF-supported supercomputer centers, developed NCSA Mosaic, the first freely available Web browser. Mosaic allowed Web pages to include text and graphics, significantly improving the utility of Internet applications. Mosaic and its successors spurred a revolution in communications, business, education, and entertainment that has had a trillion-dollar impact on the global economy.

This small selection of examples demonstrates the returns to the nation from NSF's investments in research infrastructure. Many more such examples are presented in the main section of this report. As they illustrate, the knowledge generated at NSF-funded centers and using NSF-funded facilities, equipment and shared cyberinfrastructure contribute daily to discovery, innovation and learning in the U.S.



Overview

An illustration of a theoretical protocell, composed of an RNA replicase and a fatty acid membrane with lots of nucleotides floating around, from a Web site by biochemist Janet Iwasa, an NSF Discovery Corps Postdoctoral fellow. The site was awarded an honorable mention in the 2008 Science and Engineering Visualization Challenge, sponsored by the journal *Science* and NSF. *Credit: Janet Iwasa*

NSF is a primary supporter of forefront instrumentation, facilities and infrastructure for the academic research and education communities across all areas of science and engineering.

NSF major research infrastructure investments provide state-of-the-art equipment and multi-user research facilities, such as distributed instrumentation networks, arrays, accelerators, telescopes, research vessels, aircraft, and earthquake simulators for research and education. In addition, investments in Internet-based and distributed user facilities are increasing as a result of rapid advances in computer, information and communication technologies.

NSF also supports shared cyberinfrastructure projects, integrative research and education centers programs, and programs to fund the acquisition and/or development of mid-scale scientific and engineering equipment for research and research training, all of which strengthen the U.S. research and educational enterprise.

Major Research Infrastructure

Construction of most large-scale facilities is supported through our Major Research Equipment and Facilities Construction (MREFC) appropriation. Established in 1995 as the Major Research Equipment account (and renamed MREFC in fiscal year (FY) 2002), the account provides an NSF-wide mechanism for funding large facility construction projects, costing tens of millions to hundreds of millions of dollars over a multi-year period.

In order for a project to be considered for MREFC funding, it must represent an exceptional opportunity for research and education, and provide the potential for transforming scientific understanding, technology or infrastructure. Over the years, awards have funded the construction of such diverse projects as accelerators, telescopes, vessels, aircraft, and geographically distributed but networked earthquake engineering simulation equipment.

Once a project is identified—but before it is selected—for construction, there are extensive discussions to establish priorities and multi-stage planning, design, cost and schedule reviews (see the *Large Facilities Manual,* available at http://www.nsf.gov/pubs/2007/nsf0738/nsf0738.pdf, for more information). The process includes multiple opportunities for input from the research community whose members alert NSF to the most promising areas of inquiry and the tools or facilities needed to explore them. NSF program officials and senior management, including the National Science Board (NSB), play key roles in the MREFC process, as described in the manual.

After a project is selected for construction and funds have been appropriated, NSF makes an award for the development of the new MREFC facility. With one exception, NSF does not construct or operate the facilities it funds, but the agency does provide technical and program oversight and closely monitors financial and administrative performance throughout the life cycle of each facility. The exception is for U.S. government facilities in Antarctica. For the full interagency Antarctic Program, NSF was assigned via presidential mandate (Presidential Memorandum 6646, 1982) to acquire construction, operating, logistics and maintenance services.

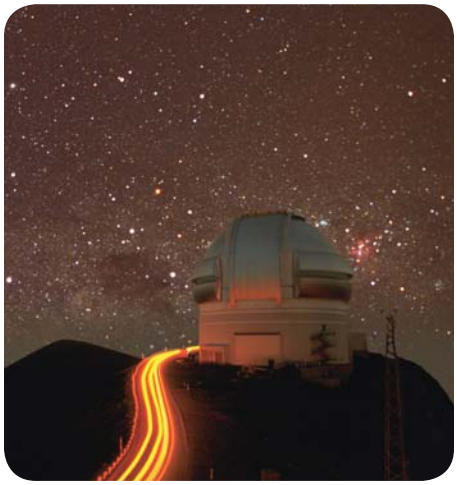
In FY 2008, the following MREFC projects (which are described in detail in the *Selected Investments* section of this document) were ongoing:

- Advanced Laser Interferometer Gravitational Wave Observatory (AdvLIGO)
- Alaska Region Research Vessel (ARRV) - *Proposed*
- Atacama Large Millimeter Array (ALMA)
- EarthScope
- IceCube Neutrino Observatory
- National Ecological Observatory Network (NEON) - *Proposed*
- Ocean Observatory Initiative (OOI) - *Proposed*
- Scientific Ocean Drilling Vessel (SODV)
- South Pole Station Modernization (SPSM) Project

One new project—the Advanced Technology Solar Telescope (ATST)—was proposed for MREFC funding in FY 2009. For more information on MREFC projects, see the *NSF 2008 Facility Plan* (available at http://www.nsf.gov/pubs/2008/nsf0824/nsf0824.pdf).

Construction and acquisition of additional large facility or infrastructure projects, though generally of a smaller scale than those funded through the MREFC account, are supported through NSF's Research and Related Activities (R&RA) appropriation, and also can be supported through the Education and Human Resources (EHR) appropriation. Additionally, operations and maintenance of multi-user facilities, including those developed through the MREFC account, are supported through the R&RA account. These unique facilities provide scientists, engineers and educators with access to world-class tools that are essential to the progress of research. Major NSF-supported multi-user research facilities currently providing unprecedented access to advanced tools and capabilities include:

- Academic Research Fleet
- Cornell Electron Storage Ring (CESR)
- EarthScope
- Gemini Observatory
- Incorporated Research Institutes for Seismology (IRIS)
- Integrated Ocean Drilling Program (IODP)
- Large Hadron Collider (LHC)
- Laser Interferometer Gravitational-Wave Observatory (LIGO)
- National High Magnetic Field Laboratory (NHMFL)
- National Nanotechnology Infrastructure Network (NNIN)
- National Superconducting Cyclotron Laboratory (NSCL)
- George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES)
- Other physics and materials research facilities
- Polar Facilities and Logistics
- National Astronomy and Ionosphere Center (NAIC)
- National Center for Atmospheric Research (NCAR)
- National Optical Astronomy Observatory (NOAO) and National Solar Observatory (NSO)
- National Radio Astronomy Observatory (NRAO)

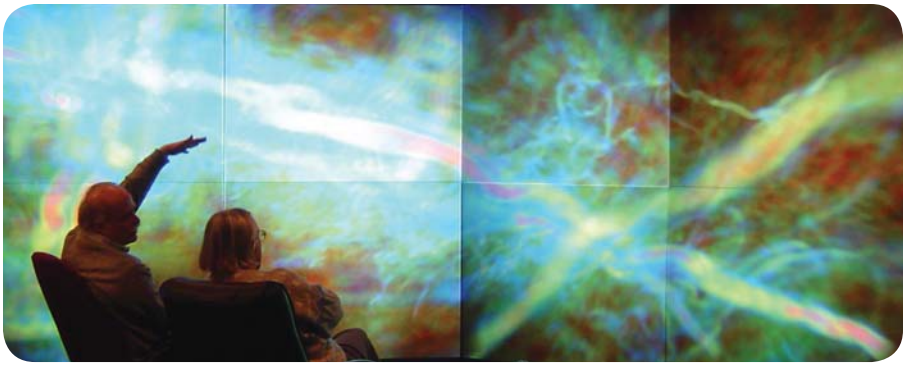


This composite image shows the sky over Gemini North. The 8-meter optical/infrared telescope is located on Hawaii's Mauna Kea, a long dormant volcano. *Credit: Gemini Observatory*

These facilities and others are described in the *Selected Investments* section of this document.

Twenty-first Century Cyberinfrastructure

NSF's portfolio of cyberinfrastructure activities, funded through the R&RA account, is designed to deliver high-performance computing, systems for mass storage, productivity-enhancing software suites and scientific programming tools, scalable interactive visualization tools, large-scale data repositories, networking, and related information technology capabilities to the research and education community, providing unprecedented power and connectivity to tackle challenges and problems that were beyond reach just a few years ago. The goal is a transformational cyberinfrastructure that enhances the usability and accessibility of computational, observational and experimental infrastructure, that powers virtual environments allowing researchers and educators located around the world to collaborate on projects as if they are in the same location, and that enables advances through modeling and simulation at unprecedented scales and complexities across a broad range of scientific and engineering disciplines.



At the Laboratory for Computational Science and Engineering at the University of Minnesota's Digital Technology Center, scientists view a movie of a simulation of fluid dynamics conducted at the Pittsburgh Supercomputing Center, one of the TeraGrid's partner sites. High-bandwidth connections between supercomputers and visualization facilities help researchers explore computationally complex phenomena. *Credit: Paul Woodward, Laboratory for Computational Science and Engineering, University of Minnesota*

Building on the successful deployment of NSF's TeraGrid infrastructure, the agency has begun acquisition and deployment of the next generation of high-performance computing systems to enable sustained petascale performance—computing at sustained rates on the order of 10^{15} floating point operations per second (petaflops) or working with petabytes of data for science and engineering research and education. The efforts are guided by NSF's Cyberinfrastructure Council (see *Cyberinfrastructure Vision for 21st Century Discovery,* at http://www.nsf.gov/pubs/2007/nsf0728/nsf0728.pdf) as well as the previous administration's American Competitiveness Initiative (ACI) and the America COMPETES Act (P.L. 110-69). Responding to outstanding designs that will provide world-class computing system capabilities for the research and education community, NSF's High Performance Computing System Acquisition solicitation—*Towards a Petascale Computing Environment for Science and Engineering*—led to funded awards to a University of Tennessee-Knoxville/Oak Ridge National Laboratory partnership, a Texas Advanced Computing Center at the University of Texas at Austin/Arizona State University/Cornell University partnership, and a University of Illinois at Urbana-Champaign/Great Lakes Consortium for Computing partnership.

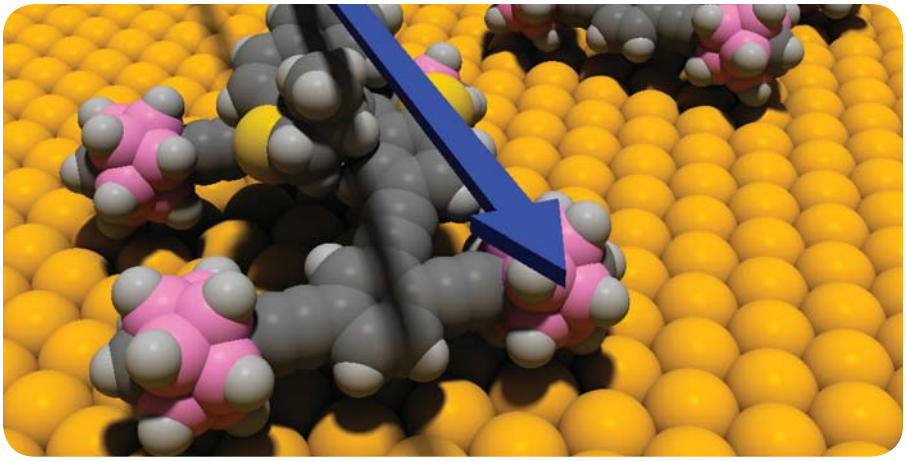
At the Centers: Interdisciplinary Research

The defining characteristic of NSF's centers programs is interdisciplinary research— addressing today's abundance of important science and engineering challenges that occur at the intersections between two or more disciplines. NSF-supported centers are designed to afford unparalleled opportunities for diverse scientists, engineers and students to conduct investigations of important research questions, while facilitating the involvement of multiple universities, other academic institutions, industry and others. The centers emphasize risk-taking and transformative ideas, and embody a commitment to forge new pathways for integrating science and engineering research with education and public outreach.

Some of the center programs are cooperatively managed by NSF's Office of Integrative Activities (OIA) together with our other research directorates and offices. The Science and Technology program is one example of such collaboration. The STC research portfolio reflects the broad spectrum of science and engineering disciplines supported by NSF. In addition to the integration of cutting-edge research and excellence in education, STCs seek to advance discovery and innovation in science and engineering through targeted knowledge transfer and the development of a diverse workforce—broadly advancing the goals and objectives of the ACI and the America COMPETES Act. The centers tackle such issues as cyber-security, advanced nano/microfabrication capabilities, new materials and technologies for monitoring water resources and water quality, medical devices, modeling and simulation of complex earth environments for improving their sustainability, and weather/climate prediction. NSF now supports 17 STCs (listed in Appendix I), and is soliciting proposals for 5-7 new centers that we expect to launch in 2010.

NSF also supports, directly through the research directorates and offices, the following center programs:

- Centers for Analysis and Synthesis (CEAS)
- Centers for Chemical Innovation (CCI)
- Engineering Research Centers (ERC)
- MRSECs
- Nanoscale Science and Engineering Centers (NSEC)
- Science of Learning Centers (SLC)



An animation showing two nanometer-scale cars on a gold surface. Developed by a research team at Penn State University's Materials Research Science and Engineering Center (MRSEC), each vehicle is slightly wider than a strand of DNA. Nanocars could one day deliver molecular cargo for nanoscale construction. *Credit: Yasuhiro Shirai, Rice University*

NSF supports centers for specific durations of time, usually five years. Following satisfactory performance, they often have the option of a one-time renewal for an additional fixed period of time. Ultimately, many centers "graduate" from NSF support and are then sustained by funding from existing or new partnerships. Some centers may evolve into entirely different entities focusing on another emerging issue in science and engineering, and still other centers may be phased out.

NSF updated our principles for managing centers programs in 2005. Among the key elements of the updated principles is that the value of supporting the targeted research using the center mode of funding versus the individual investigator mode will be evaluated as one of the merit review criteria. Another is that NSF's support for centers will be of limited duration, with a built-in phase-out period.

A Unique Role in the Polar Regions

The United States Antarctic Program (USAP) supports U.S. scientific research in Antarctica and the Southern Ocean. NSF manages the USAP under Presidential Memorandum 6646 (1982) that directs an "active and influential presence in Antarctica designed to support the range of U.S. Antarctic interests." The memo states that the U.S. presence "shall include the conduct of scientific activities in major disciplines." The world's southernmost continent offers unique opportunities to advance understanding in wide-ranging scientific fields, including astronomy and astrophysics, oceanography, geology, glaciology, biology and climate studies. NSF provides the facilities, research infrastructure and logistics to support researchers who are advancing knowledge in these and other vital areas of science and engineering. The USAP operates three year-round scientific stations in Antarctica: Amundsen-Scott South Pole Station, McMurdo Station and Palmer Station.

Amundsen-Scott South Pole Station

In January 2008, NSF dedicated the Amundsen-Scott South Pole Station at the South Pole. The third station since 1956, it is the result of the South Pole Station Modernization, a MREFC project. The new elevated structure is a state-of-the-art research station that is larger and more sophisticated than any previous structure built at the bottom of the world. The station's size and capabilities respond to an ever growing requirement for logistical support to carry out the range and quantity of research taking place at the South Pole, from

In January 2008, honored guests joined with NSF to dedicate the Amundsen-Scott South Pole Station. The new, elevated station is larger and much more sophisticated than any previous structure built at the Pole—a reflection of the logistical support needed for the ever-increasing range and diversity of the research taking place there. *Credit: Peter Rejcek, National Science Foundation*

investigations into the origin of the universe to work aimed at determining the status of global climate change. Features of the new station include a "quiet sector" to support monitoring of the Earth's seismicity, a "clean air sector" for research in atmospheric chemistry, and a "dark sector" to support astronomy and astrophysics. The new station replaced an aging structure built three decades ago. Approximately 50-60 science and support personnel winter over at the South Pole Station to carry out and support ongoing research projects, while the population during the three-month austral summer swells to about 150 people.

McMurdo Station
Located on the Ross Sea, Antarctica's largest station serves as a "gateway" to Antarctica for U.S. scientific field teams, as well as the hub for most of the U.S. scientific activity. During the austral summer, the population of scientists and support personnel at McMurdo often exceeds 1,000 people.

Palmer Station
Located on Anvers Island in the Antarctic Peninsula region, Palmer Station is the only U.S. Antarctic station north of the Antarctic Circle. More than 40 people can occupy Palmer in the summer; wintering population is about 10, although Palmer does not have the long period of winter isolation that McMurdo and South Pole have.

In addition to these permanent sites, the USAP provides other facilities including ships, aircraft and research platforms that are described in the *Selected Investments* section and Appendix I of this document.

Like its counterpart at the bottom of the world, the Arctic region provides unique opportunities for transformative research and discovery. As chair of the Interagency Arctic Research Policy Committee (IARPC), NSF acts as the lead agency for implementing Arctic research policies. NSF's Arctic Research Support and Logistics (RSL) program assists the field component of research projects that focus on gaining a better understanding of the Arctic's physical, biological, chemical, social and cultural processes, as well as work exploring the interactions of ocean, land, atmosphere, biological and human systems in the Arctic. The program funds base support of the Arctic Research Consortium of the U.S., Toolik Field Station, procurement and maintenance of instrumentation on the U.S. Coast Guard Cutter *Healy*, and the development of a digital elevation model of the Kuparuk Watershed in northern Alaska. Additional information about Arctic-related research infrastructure is presented in the *Selected Investments* section and in Appendix I.

An intense international scientific campaign to explore new frontiers in polar science is currently underway in both the Arctic and Antarctic. The International Polar Year (IPY) 2007-2009 began in March 2007 and extends through March 2009, and its activities are already improving our understanding of the critical role of the polar regions in global processes and educating students, teachers and the public about the importance of these regions. NSF was designated by the President's Office of Science and Technology Policy (OSTP) as the lead federal agency in organizing U.S. IPY activities. (A list of U.S. agencies and organizations participating in IPY is available at http://www.us-ipy.gov.) IPY supports projects that are multi- and interdisciplinary in scope, expand international cooperation, attract and train the next generation of scientists and engineers, and engage the public in polar discovery. Among IPY's legacies will be a significant expansion of infrastructure and data for studying these unique regions of the globe.

Mid-Range Instrumentation

Scientific advances in many fields are critically dependent on access to sophisticated instruments at the nation's universities and colleges, and at other entities that conduct research and education. NSF's Major Research Instrumentation (MRI) program is one of the agency's approaches for funding the acquisition and development of key instrumentation for research and training in U.S. institutions of higher education, research museums and independent, nonprofit research organizations. The primary focus of the agency-wide program is to improve the quality and expand the scope of research and research training in science and engineering, and foster the integration of research and education, by

providing advanced instrumentation for research-intensive learning environments. Expanding the capabilities of the research community to develop new instruments is another key focus of the MRI program. A third focus is building up the science and engineering infrastructure for research and research training at smaller and minority-serving institutions. Academic researchers and others benefit from new generations of sophisticated research instrumentation. The right design, development and manufacturing processes can yield new instruments that are more widely used, open up new areas of research and training, and have potential as commercial products.

MRI awards are for mid-range instrumentation. Responding to recommendations made by the National Academy of Sciences Committee on Advanced Research Instrumentation in a 2005 study and codified in Sec. 7036 of the ACI, NSF recently increased the upper limit for an MRI proposal from $2 million to $4 million. Proposals requesting more than $2 million must be for the acquisition of a single instrument. Requests for $2 million or less can support instrument development or the acquisition of a single instrument, a large system of instruments, or multiple instruments that share a common or specific research focus. The minimum that institutions may request is generally $100,000. But organizations that do not award doctoral degrees, as well as the disciplines of mathematical science and social, behavioral and economic sciences at any eligible organization, may submit proposals requesting less than $100,000.

In FY 2007 (the latest year for which complete information is available), NSF received 774 proposals for MRI grants and funded 221 of them. Of the 221 proposals funded, non-Ph.D. granting institutions received 87 awards totaling $21.1 million. Minority-serving institutions received 36 awards totaling $11.66 million. The FY 2007 awards are listed in Appendix I.

Examples abound of the benefits from MRI investments:

- A team of researchers using a supercomputing cluster at Northwestern University's Theoretical Astrophysics Group that was partly acquired through an MRI grant ran a range of sophisticated simulations tracking the important parts of the planet formation process from different types of starting conditions. In August 2008, they announced the surprising finding that the formation of planetary systems like our solar system is unusual.

- With support from an MRI award, Hampton University, one of the country's Historically Black Colleges and Universities (HBCU), is acquiring a high performance computing cluster that will provide substantial capability to faculty and students to expand their ability to investigate computationally complex challenges including carrying out computations that will solve equations that simulate and model phenomena in nature, and visualize computational data.

- An NSF MRI award enabled Central Michigan University to acquire a three-dimensional laser scanner that is being used to help build a database about the human body. The scanner is one of just a handful available at U.S. universities. So far, Central Michigan University researchers have collected more than 400 scans of people ranging in age from 8 to 87.

The first commercial prototype of a super-resolution optical microscope based on structured illumination. The instrument was installed in March 2008 at the Center for Biophotonics Science and Technology at the University of California, Davis (see page 12). *Credit: Thomas Huser, Center for Biophotonics Science and Technology, University of California, Davis*

- With support from another MRI grant, the first commercial version of the world's highest resolution wide-field light microscope is now in operation at the NSF-funded Center for Biophotonics Science and Technology's headquarters on the Sacramento campus of the University of California, Davis. The new system uses an imaging technology called Structure Illumination that was invented by University of California, San Francisco scientists to overcome the long-standing barrier that the diffraction limit of light presents to significant increases in the resolution of light microscopes. The system installed at the Center for Biophotonics Science and Technology has already demonstrated a two-fold improvement in resolution compared to the best conventional light microscopes and further improvements are expected. The higher resolution light microscopes will help scientists to visualize living cells and how they interact in real-time.

NSF also has programs supporting the acquisition and development of instrumentation and facilities for specific discipline areas. Examples include: Atmospheric Sciences Mid-Size Infrastructure Opportunity, Advanced Technologies and Instrumentation, Chemistry Research Instrumentation and Facilities, Directorate for Computer and Information Science and Engineering (CISE) Computing Research Infrastructure, Cyberinfrastructure for Environmental Observatories: Prototype Systems to Address Cross-Cutting Needs, Earth Sciences: Instrumentation and Facilities, Improvements in Facilities, Communications and Equipment at Biological Field Stations and Marine Laboratories, Instrument Development for Biological Research, Instrumentation for Materials Research, Next Generation Cyberinfrastructure Tools, Oceanographic Technology and Interdisciplinary Coordination, Program for Research and Education with Small Telescopes, and Scientific Computing Research Environment for the Mathematical Sciences.

Other Facilities, Equipment and Infrastructure Funding

By stimulating partnerships for innovators, two small business research programs—the Small Business Innovation Research (SBIR) program and the Small Business Technology Transfer (STTR) program—bring about infrastructure advances and also catalyze the transformation of discoveries into societal benefits. Another program to advance development of the nation's research infrastructure is the Experimental Program to Stimulate Competitive Research (EPSCoR)'s Research Infrastructure Improvement (RII) initiative. EPSCoR helps promote scientific progress nationwide by directing support to jurisdictions that have historically received lesser amounts of NSF research and development (R&D) funding. Twenty-five states, the Commonwealth of Puerto Rico and the U. S. Virgin Islands currently participate in EPSCoR. In addition to the basic RII awards to a single EPSCoR jurisdiction, RII-Track 2 awards provide funds to consortia of EPSCoR jurisdictions to support innovation-enabling cyberinfrastructure of regional, thematic or technological importance.

Researchers in the Arkansas Nanoscience Program use scanning probe microscopy to observe the nanostructure of a chloroplast. The Arkansas program is supported by NSF's Experimental Program to Stimulate Competitive Research (EPSCoR). *Credit: Nanoscience Program, University of Arkansas*

In addition to these programs, NSF research directorates and offices have the discretion to fund facilities, equipment, centers, and other research infrastructure on a case-by-case basis from R&RA program funds. They may also include funds to cover acquisition of instrumentation as part of a research grant to an individual investigator or group of investigators.

Education and Public Outreach

Educating the next generation of scientists and engineers, training the science, technology, engineering and mathematics (STEM) workforce of the 21st century, and engaging the public are crucial for the health of our nation's future science and engineering enterprise. All activities described above promote the strong integration of research and education and embody the concepts of broader impact and public outreach. Here, we note a few examples of the strong outreach programs that our supported facilities and centers offer:

- The NHMFL provides opportunities and mentorship experiences for teachers and students at all academic levels. The lab's annual regional K-12 outreach efforts engage more than 7,000 students from across Florida and neighboring Georgia in hands-on science activities and tours.

- The Natural History Museum of Los Angeles County acquired a state-of-the-art Scanning Electron Microscope (SEM), with support from NSF's MRI program, for use by the museums research staff and also by its Education Division for activities to enhance public understanding of science and highlight the work of museum scholars. The museum's "Adventures in Nature" summer program for children in grades pre-K through 8 provided youngsters with hands-on experience using the SEM to zoom in on small objects.

- The Center for Behavioral Neuroscience in Atlanta, one of NSF's STCs, has developed a series of outreach programs, including "Brain Camps" for middle school students, seminars and summer research programs for undergraduates, teacher workshops, and an annual exposition held in partnership with the Atlanta zoo, that bring advances in neuroscience and the work of center researchers to all segments of the public.

- The Team for Research in Ubiquitous Secure Technology (TRUST) sponsors a number of education and outreach activities, including the Women's Institute in Summer Enrichment and the Summer Undergraduate Program in Engineering Research, both at the University of California, Berkeley. The women's institute brings together graduate students, post-doctoral fellows, and professors from all disciplines for a week-long, residential program in the summer. Topics, such as cybersecurity, privacy and sensor networks, and health care, are selected to complement TRUST's research areas. The summer undergraduate program provides students from historically underrepresented populations with opportunities to gain research experience by participating in projects with engineering faculty and graduate students as mentors.

- Students and faculty of the Texas A&M University at Kingsville's Center for Research on Environmental Sustainability of Semi-Arid Coastal Areas, one of NSF's Centers of Research Excellence in Science and Technology (CREST), partnered with the Corpus Christi Museum of Science and History on an exhibit to educate the citizens of South Texas about local air quality. The kid-friendly exhibit was designed to teach elementary and middle school students about air pollution and ozone levels. The exhibit included an HDTV screen showing near real-time air quality data captured from an air monitoring station located on the museum's rooftop in downtown Corpus Christi.

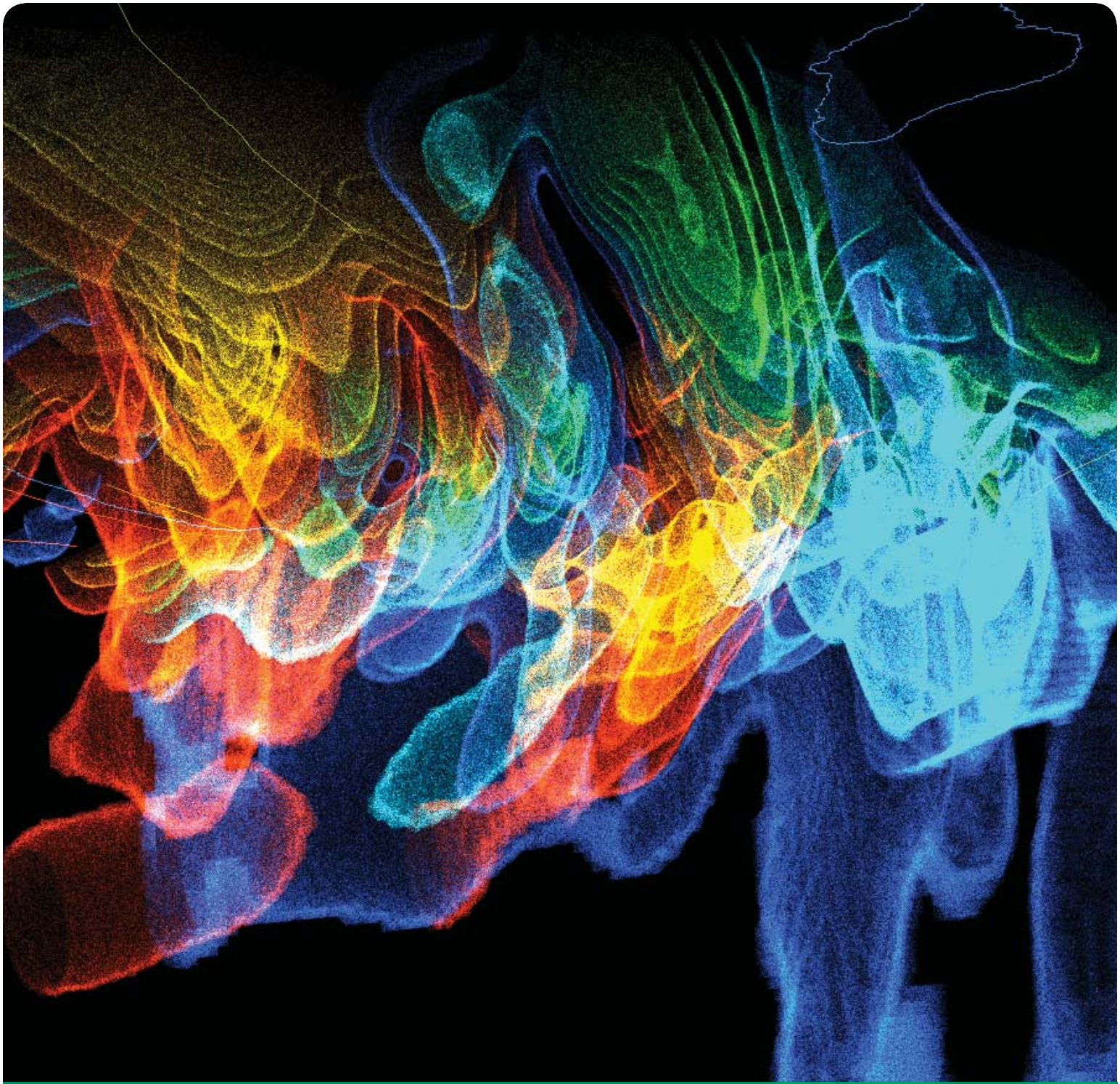
- Participants and staff at the Northwestern University NSEC developed DiscoverNano, a Web site to introduce the public to nanoscale objects, nanoscience, and nanotechnology. Besides a basic primer (Nano 101), the site (http://www.discovernano.northwestern.edu/) features a timeline tracing the history of nanotechnology, video interviews with researchers, a Nano Art Gallery, a searchable glossary, and a section for educators that includes a video introduction to the center's nanoscience and nanotechnology module of classroom activities.

- The Arkansas EPSCoR joined with the Winthrop Rockefeller Foundation to support teams competing in the Frontiers Rails BEST Robotics Competition, a program that uses a series of competitions to excite junior and senior high school students about science, engineering, and technology fields. They were able to fund three robotics hubs (each serving up to 30 schools) in the northern and eastern part of the state, with teams competing at local and regional levels.

A World Class Research Infrastructure

In summary, NSF has spent approximately $1.6 billion in FY 2008 for the activities described above, our contribution towards a world-class research infrastructure for the nation.

The next section presents brief descriptions of some of the current NSF-supported equipment, facilities, shared cyberinfrastructure and centers that contribute so much to today's and tomorrow's advances in science and engineering. The profiles are grouped by theme area. A more comprehensive list is found in Appendix I.



Selected Investments

TeraShake is the largest and most detailed simulation of ground motion during a major earthquake along the San Andreas Fault in southern California. Researchers used the 10 teraflops DataStar supercomputer and large-scale data resources of the San Diego Supercomputer Center (SDSC) at the University of California, San Diego to produce the simulation. The center is a partner site in the TeraGrid. TeraShake is a vivid example of cyberinfrastructure's ability to advance science and engineering. *Credit: Marcus Thiebaux, Information Sciences Institute, USC*

Selected NSF Investments in Research Infrastructure

NSF's investments in equipment, facilities, shared cyberinfrastructure and centers ensure that the U.S. maintains a world-class science and engineering research infrastructure that is second to none. The scale of what we support ranges from small and mid-size instruments in the laboratories of U.S. academic institutions to unique national centers and multiuser facilities to global computer-sensor-communication networks and international partnerships that build and operate state-of-the-art equipment, facilities and experimental tools. The following are examples of NSF investments in research infrastructure (including leading-edge facilities in planning or under construction) and the research they enable, organized by broad theme areas. These examples are representative of the investments made by NSF in research infrastructure, but they are not intended to serve as a complete list of everything we support. Many of the agency's smaller awards are omitted. Also, NSF is making new awards on a continuous basis. A more comprehensive (but still not complete) list of NSF research infrastructure investments is found in Appendix I.

Earth's environments are diverse, ranging from polar ice caps to hot, dry deserts, from dark ocean depths to high mountaintops. NSF invests in research infrastructure to support scientists and educators as they seek to advance our understanding of the planet's physical, chemical, biological and geological processes; the complex interactions among atmosphere, land surface and oceans; and the impacts of human activities on the environment. Researchers need national and global observation facilities and platforms, cutting-edge instrumentation, and advanced computational and networking capabilities to collect, store, transmit and analyze vast data about complex, interdependent geophysical processes and produce new knowledge. These investments, as well as support for related environmental research and education, primarily are made by NSF's Directorate for Geosciences (GEO) and the Division of Environmental Biology (DEB) in the Directorate for Biological Sciences (BIO). NSF's facilities in the Arctic and Antarctic, supported by the Office of Polar Programs (OPP), enable researchers to make unique observations from some of the Earth's most unusual natural laboratories.

Earth, from the Depths of the Oceans to the Sky Above

This illustration shows how the Scientific Ocean Drilling Vessel (SODV) will look once refurbishing is complete. After 20 years of service, the pioneering scientific drillship JOIDES Resolution underwent a refit that is expected to extend the vessel's operational lifetime by at least 15 years. *Credit: Charles Floyd, Integrated Ocean Drilling Program*

Academic Research Fleet

The Academic Research Fleet consists of 23 vessels in the University-National Oceanographic Laboratory System (UNOLS). These vessels are varied in size, endurance and capabilities, and they make it possible for scientists supported by NSF and other federal agencies to conduct marine research in coastal and open waters. Funding for the Academic Research Fleet includes investments in ship operations; shipboard scientific support equipment; oceanographic instrumentation and technical services; and submersible support. NSF owns seven of the fleet's ships (listed below) and has another vessel proposed for construction. The NSF-owned research ships are:

- ***R/V Marcus Langseth***, a 235-foot research vessel operated by Lamont-Doherty Earth Observatory of Columbia University. The ship was built in 1991 as a seismic vessel and, in 2004, it was acquired and outfitted as a research ship. A large ship with a global area of operation, the *Langseth* is equipped with extensive seismic recording equipment and sound source arrays, affording the academic community unique geophysical research capabilities. It can accommodate 35 researchers and a crew of 20.

- ***R/V Wecoma***, a 185-foot research vessel operated by Oregon State University's College of Oceanic and Atmospheric Sciences. The intermediate-size ship was built in 1975 and underwent a mid-life refit and general upgrade in 1993-1994. It features specialized oceanographic research equipment including wet and dry labs and a CTD system (an instrument package with cylindrical sampling bottles and instruments for measuring the conductivity, temperature and depth of water). The *Wecoma* can accommodate 18 researchers and a crew of 13.

- ***R/V Endeavor***, a 185-foot ship operated by the University of Rhode Island's Graduate School of Oceanography. The vessel was built in 1975 and underwent a mid-life refit in 1993. The intermediate-size ship features a main lab, wet lab, special purpose lab, deck lab and portable isotope lab. The *Endeavor* can accommodate 18 scientists including a marine technician and a 12-member crew.

- ***R/V Oceanus***, a 177-foot ship operated by the Woods Hole Oceanographic Institution. The vessel was built in 1975 and in 1994, it underwent a mid-life refit. The intermediate-size ship features a main lab, wet lab and a lab on the upper (01) deck. It is also outfitted with three winches and a crane, and is often used for deploying oceanographic buoys and moorings, and for hydrographic surveys. The *Oceanus* can accommodate 19 researchers and a crew of 12.

- ***R/V Point Sur***, a 135-foot ship operated by Moss Landing Marine Laboratories for the San Jose State University Foundation. The laboratories are run by a consortium of California State Universities. The *Point Sur* was built in 1980. Much of the ship's marine research is conducted within the region of central California, and especially in Monterey Bay at the head of the deep undersea Monterey canyon. The ship can accommodate 13 researchers and technicians and a crew of 8. For day cruises, it has a capacity of 40 researchers.

- ***R/V Cape Hatteras***, a 135-foot ship operated by the Duke University/University of North Carolina Oceanographic Consortium. The ship was built in 1981. It's used for regional operations, primarily off the coast of North America from Nova Scotia to the Caribbean. Its scientific equipment includes CTD and other instruments for seawater sampling and analysis, corers and related seafloor sampling equipment, echo sounding and seismic equipment, and other instruments and sensors. The *Cape Hatteras* can accommodate 14 scientists including a marine technician and a crew of 10.

- ***R/V Clifford A. Barnes***, a 66-foot ship operated by the University of Washington's School of Oceanography. The ship is used primarily in the inland waters of the Puget Sound region and lower British Columbia. This small vessel can accommodate six scientists and a two-person crew.

The proposed Alaska Region Research Vessel (ARRV) is designed to operate up to 300 days per year in the harsh, icy waters around Alaska. The ship would provide a much needed platform for addressing critical regional and global ecosystem issues including ocean circulation and climate change. *Credit: The Glosten Associates, Inc.*

Alaska Region Research Vessel (ARRV)–Proposed

The Alaska Region Research Vessel will be the newest addition to NSF's complement of research ships. This technologically advanced, highly capable, 242-foot ship is designed to operate in both seasonal ice and the harsh open waters surrounding Alaska. It will provide a crucial support platform to enhance scientific understanding of the polar regions and their impact on global climate change. The project is approaching the final design review and ship construction is expected to get underway in early 2010. If all goes as planned, scientific operations could begin in late 2013 following extensive sea trials and equipment testing. The ARRV will be able to accommodate 24 researchers on missions lasting up to 45 days. The ship will be able to spend up to 300 days per year at sea. The ARRV was proposed as a new start in FY 2007; continuation of design and future construction depends upon successful project design reviews, continued prioritization by NSF, NSB approval and the availability of federal funds.

Vessels for Research at the Earth's Poles

Ships provided by the USAP and the RSL program offer research and logistical support for the activities of scientists, engineers and educators conducting research in the Antarctic and Arctic regions. The vessels include:

- ***R/V Nathaniel B. Palmer (NBP)***, an icebreaking research ship that began science operations in late 1992 when it sailed from Punta Arenas, Chile, in support of the Russian-U.S. Ice Camp Weddell. The 94-meter vessel provides a first-rate platform for global change studies, including biological, oceanographic, geological and geophysical components. It can operate safely year-round in Antarctic waters that often are stormy or covered with sea ice. It accommodates 37 scientists, has a crew of 22, and is capable of 75-day missions. The *Palmer* is owned and operated by Louisiana-based Edison Chouest Offshore (ECO), and is chartered by the USAP.

- ***R/V Laurence M. Gould (LMG),*** an ice-strengthened research ship that began its service in Antarctica in January 1998. A multi-disciplinary research platform, the *Gould* is designed for year-round polar operations and can accommodate 26 research scientists for missions up to 75 days long. Its primary mission is to support research in the Antarctic Peninsula region and to resupply and transport researchers and staff between Palmer Station and South American ports. Owned and operated by ECO, the *Gould* is chartered by the USAP.

- **U.S. Coast Guard Cutter (USCGC) *Healy,*** an icebreaker designed to support scientific research. It has been used in a number of research cruises, mostly in the Arctic Ocean region. The ship is able to accommodate 35-50 scientists and is equipped with more than 5,000 square feet of science lab and support space. The *Healy*'s first science cruise was in 2001, as part of the Arctic Mid-ocean Ridge Expedition (AMORE).

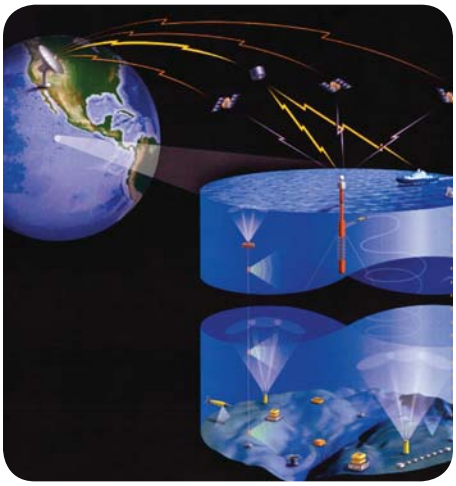
Integrated Ocean Drilling Program (IODP)

About 70 percent of the Earth is seafloor. The Integrated Ocean Drilling Program is an international marine research program that explores Earth's history and structure, as recorded in seafloor sediments and rocks. The program also monitors sub-seafloor environments. The IODP is led by NSF and Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT). Japan and the U.S. are providing drillships to the program. Japan's vessel, the *Chikyu* (Earth), was launched in January 2002, underwent outfitting and testing in 2003-2006 and began IODP operations in 2007. The U.S.-provided SODV is undergoing an extensive refitting and is scheduled to begin IODP operations in early 2009. The European Consortium for Ocean Research Drilling is a contributing member of the IODP, and two other partners—the People's Republic of China Ministry of Science and Technology and the Interim Asian Consortium, represented by the Korea Institute of Geoscience and Mineral Resources—are associate members.

Scientific Ocean Drilling Vessel (SODV)

The Scientific Ocean Drilling Vessel project is refurbishing the *JOIDES Resolution*, the pioneering scientific ocean drilling vessel. The next-generation research ship will support the recovery of sediment and crustal rock from the seafloor; the placing of observatories in drill holes to study the deep biosphere; the study of fluid flow in sediments and the crust; and long-term efforts of the IODP to investigate solid Earth cycles, geodynamics, and the processes contributing to and affecting environmental change. During its 20 years of service, *JOIDES Resolution* expeditions produced significant contributions and discoveries, including the first recovery of igneous rocks (known as gabbros) from intact ocean crust, the discovery of the deepest-living microbes on earth, and the discovery of "frozen" natural gas at unexpectedly shallow depths below the seafloor. Core samples brought up during research expeditions have helped scientists validate the theory of plate tectonics, provided extensive information about earth's past climate, and recovered evidence of the catastrophic asteroid impact that is believed to have wiped out the dinosaurs 65 million years ago. The new vessel, which promises to improve the quality and rate of core samples brought up from the deep, will include a large increase in laboratory space, allowing for greater instrumentation to analyze core samples while at sea. The refit also will result in enhanced ship stability. Work began in September 2006 and is expected to conclude in early 2009, with sea trials scheduled for early 2009.

A highly trained crew and specialized engineering equipment aboard the *JOIDES Resolution* make it possible to target and core the seafloor. *Credit: Integrated Ocean Drilling Program*



An artist's illustration of the proposed Ocean Observatories Initiative (OOI). The OOI will provide an integrated array of communications devices and sensors placed on or below the sea floor and throughout the water column. Instruments will transfer data to buoys on the sea surface that will transmit the information to the mainland by satellite. *Credit: John Orcutt, Scripps Institute of Oceanography*

Ocean Observatories Initiative (OOI)–Proposed

The Ocean Observatories Initiative has the potential to revolutionize ocean science by providing the means to collect unique, sustained, time-series data sets that will enable researchers to study complex, interlinked physical, chemical, biological, and geological processes operating throughout the global ocean. The OOI would help researchers make significant progress in understanding such critical processes as climate variability, ocean food webs, coastal ocean dynamics and ecosystems, and global and plate-scale geodynamics. Scientific discoveries arising from the OOI would also provide exciting opportunities for ocean education and outreach through the capabilities for real-time data transmission and, particularly, real-time display of visual images from the seafloor. If constructed, the OOI would provide a globally distributed and integrated observatory network of platforms and sensors to obtain measurements within the ocean and below the seafloor, at temporal and spatial scales beyond the capability of tools and methods currently used to study ocean processes. As planned, the integrated observatory system would have three elements: a global component consisting of deep-sea buoys with capabilities appropriate to the experiments; a regional electro-optical cabled network consisting of interconnected sites on the seafloor

spanning several geological and oceanographic features and processes; and new fixed and relocatable coastal observatories. OOI infrastructure would be deployed in the deep ocean at locations west of Canada and southern Chile, and south of Greenland, in the region of the Juan de Fuca plate in the Pacific Northwest and near the adjacent shore, and in the northeastern U.S. coastal region. Researchers would be able to access and control these marine assets in real or near real-time through an interactive cyberinfrastructure. OOI was proposed as a new start in FY 2007; continuation of design and future construction depends upon successful project design reviews, continued prioritization by NSF, NSB approval and the availability of federal funds. The reviews will include the identification of optimal sites for the extensive sensor network.

Antarctic Research Facility

The Antarctic Marine Geology Research Facility at Florida State University is a national repository for geological materials collected in and around Antarctica. It houses and curates over 20,000 meters of deep-sea core sediment, 6,000 meters of rotary drilled continental and shallow-water cores and over 5,000 kilograms of dredge, trawl and grab samples—the largest such Antarctic and Southern Ocean collection in the world. These materials have been acquired from over 90 USAP research cruises and field expeditions.

3-D Seismic Data Depicts Layers of Ocean Crust, Helps to Reveal the Inner Workings of a Tsunami Factory

Debris from the Indian Ocean tsunami of Dec. 26, 2004. The wave came from the distance and left nearly nothing standing in Banda Aceh, Sumatra. *Credit: © Jose C. Borrero, University of Southern California Tsunami Research Group http://www.usc.edu/dept/tsunamis/2005/index.php*

Research by a team of U.S. and Japanese scientists may help explain why earthquakes below some parts of the seafloor trigger large tsunamis, while earthquakes elsewhere do not. NSF-supported geoscientists from the University of Hawaii and University of Texas and their colleagues collected three-dimensional seismic data that reveals the structure of Earth's crust below a region of the Pacific seafloor known as the Nankai Trough. That area of the seafloor near the southwest coast of Japan is particularly good at generating devastating tsunamis. The researchers were able to reconstruct how layers of rock and sediment have cracked and shifted over time. They found two things that contribute to big tsunamis. First, they confirmed the existence of a major fault that runs from about 10 kilometers (6 miles) deep right up to the seafloor in a region known to unleash earthquakes. When an earthquake happens, the fault moves the seafloor up or down, carrying a column of water with it and setting up a series of tsunami waves that spread outward. Second, and most surprising, the team discovered that the recent fault activity has shifted landward, and the fault is shallower and steeper than it was in the past. This geometry increases the potential for tsunamis.

HIAPER—the High-Performance Instrumented Airborne Platform for Environmental Research—is the nation's most advanced aircraft for environmental research. *Credit: NCAR*

High-performance Instrumented Airborne Platform for Environmental Research (HIAPER)

A medium-altitude, long-duration jet has been a requirement of the science community since the 1980s. NSF funded development of the High-performance Instrumented Airborne Platform for Environmental Research to meet those needs, and HIAPER has become the premier plane for scientific discovery. The modified Gulfstream V jet is capable of reaching an altitude of 51,000 feet and can cruise for 7,000 miles. It is equipped with advanced instrumentation for environmental research. NSF and the University Corporation for Atmospheric Research entered into a cooperative agreement to develop the aircraft, and its operations are managed by NCAR. HIAPER began operational science missions in

2006. Its first major scientific project was the Terrain-Induced Rotor Experiment (T-Rex), a project to learn more about rotors, the dangerous whirlwinds that develop on the lee side of high, steep mountains like California's Sierra Nevada range. (See the sidebar on page 24 for more on HIAPER.)

National Center for Atmospheric Research (NCAR)

The National Center for Atmospheric Research, a Federally Funded Research and Development Center (FFRDC), is a focal point for research in the field of atmospheric science. Its research programs include: studies of large-scale atmospheric and ocean dynamics that contribute to an understanding of the past and present climate processes and global climate change; global and regional atmospheric chemistry; the variable nature of the Sun and the physics of the corona and interactions with the Earth's magnetic field; the physics of clouds, thunderstorms, precipitation formation and their interactions and effects on larger-scale weather; and the examination of human impact on and response to global environmental change. Facilities available to university and other scientists include world-class supercomputing services, research aircraft, airborne and portable ground-based radar systems, and atmospheric sounding and other surface sensing systems. The supercomputing resources enable the development and production of large models and afford capabilities for archiving, manipulating and visualizing large data sets. The center emphasizes education and outreach activities as an integral part of its mission. Some 40 scientists from NCAR participated in the United Nation's Intergovernmental Panel on Climate Change (IPCC), which was named recipient of the 2007 Nobel Peace Prize, along with former U.S. Vice President Al Gore. NCAR is managed under a cooperative agreement between NSF and the University Corporation for Atmospheric Research (UCAR), a nonprofit consortium of 68 North American universities with graduate programs in the atmospheric sciences.

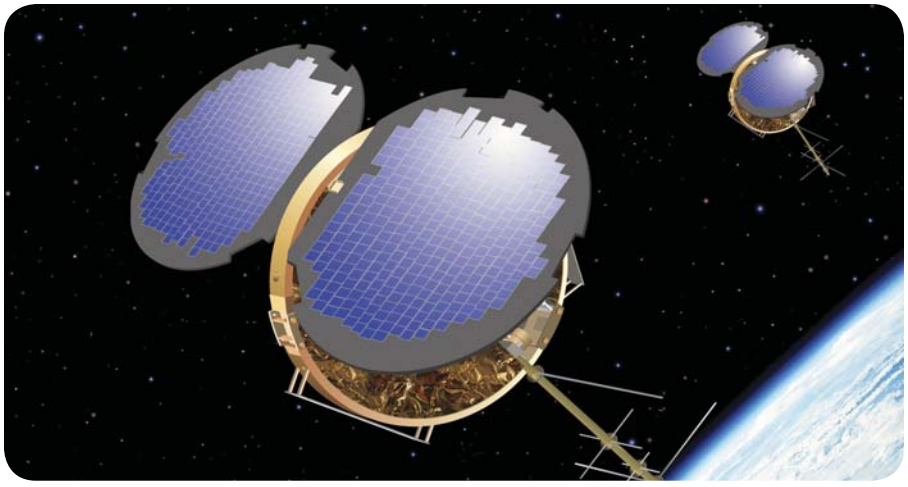
Advanced Modular Incoherent Scatter Radar (AMISR)

The Advanced Modular Incoherent Scatter Radar is a solid-state, phased array incoherent scatter radar for measuring basic properties of the upper atmosphere and ionosphere with unprecedented versatility and power. The AMISR's advanced capabilities include rapid steering provided by the phased array antenna, giving it significant advantages over existing incoherent scatter radars. The phased-array design allows pulse-to-pulse beam steering, thus enabling 3-D "imaging" of ionospheric properties, such as electron density, electron and ion temperatures, and ion drift velocities. The modular design facilitates reconfiguration of the radar antenna, as well as relocation in response to changing scientific priorities. Designed and built with NSF support, AMISR is operated by SRI International under a cooperative agreement that runs through September 2011. The AMISR systems are deployed at Poker Flat, Alaska, and Resolute Bay, Canada.

Other Radar, Sensing Facilities

NSF supports additional facilities for studying the Earth's upper and lower atmospheres. Upper atmosphere facilities include the Millstone Hill Incoherent Scatter Radar Facility, Sondrestrom Radar Facility, incoherent scatter radar facilities at Arecibo Observatory and Jicamarca Radio Observatory, and the Super Dual Auroral Radar Network (SuperDARN). Ground-based and airborne facilities and instrumentation for studying the Earth's lower atmosphere include the Atmosphere Surface Turbulent Exchange Research (ASTER) facility, Cross-chain Loran Atmospheric Sounding System (CLASS), Integrated Sounding System (ISS), Portable Automated Mesonet (PAM III and Flux PAM), S-POL Radar, CHILL Radar, P3Dora Radar (ELDORA), and Dropsondes.

The Sondrestrom Upper Atmospheric Research Facility in Greenland is used to study the Earth's upper atmosphere. Pictured is the Aurora Borealis, or Northern Lights, over the facility. *Credit: Craig J. Heinselman*



An artist's illustration of COSMIC, the Constellation Observing System for Meteorology, Ionosphere and Climate. The system of micro-satellites in low-Earth orbit is expected to greatly improve data for space weather and climate monitoring, and global weather forecasts. *Credit: Courtesy Orbital Sciences Corporation*

Constellation Observing System for Meteorology Ionosphere and Climate (COSMIC)

The Constellation Observing System for Meteorology Ionosphere and Climate, an international collaboration between Taiwan and the U.S., is a constellation of 6 satellites built and launched by Taiwan into low Earth orbits. The satellites' GPS receivers detect delays in the propagation of GPS signals when the signals pass through the atmosphere. Temperature, humidity, and, in the ionosphere, electron density, can be obtained from these radio occultations. COSMIC provides 2,500 atmospheric soundings per day, distributed nearly uniformly over the globe. These data are being used for weather prediction and climate monitoring. NSF is the lead agency for U.S. COSMIC activities. The U.S. partners include the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Air Force Space Test Program, the Office of Naval Research, and the Department of Defense Space and Missile Systems Center's Rocket Systems Launch Program of the U.S. Air Force, which provided logistical support.

Center for Multi-Scale Modeling of Atmospheric Processes (CMMAP)

The Center for Multi-Scale Modeling of Atmospheric Processes, an NSF STC, focuses on improving the representation of cloud processes in climate models. The need for accurately describing cloud processes has been one of the most challenging limitations on the reliability of climate-change simulations. The center, based at Colorado State University, is using extremely powerful computers and new mathematical methods to address the problem. CMMAP researchers hope to harness enough computing power and resources to gain the ability to simulate individual clouds and atmospheric circulation, and tackle long-standing phenomena that are known but not well understood, such as the Madden-Julian Oscillation and the boundary layer of thunderstorms.

Center for Integrated Space Weather Modeling (CISM)

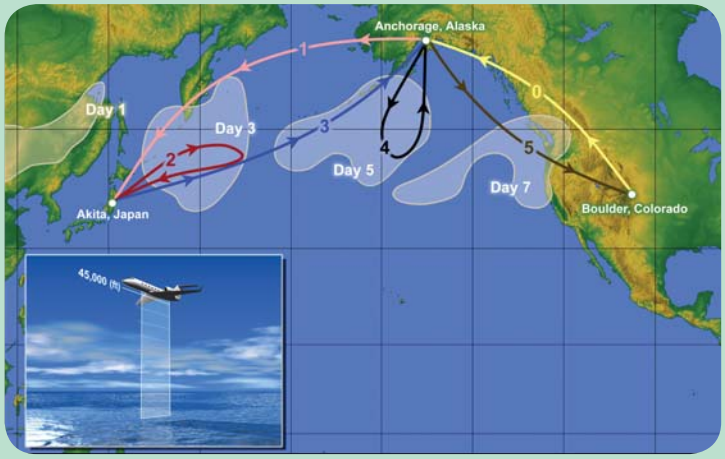
The mission of the Center for Integrated Space Weather Modeling, another STC, is to develop a better understanding of the dynamic Earth-Sun system and how it affects life and society. Researchers at CISM are working to develop next-generation models that should improve the quality of space weather forecasting in the near future. The work is vital since satellites, electrical grids and other systems on Earth are all vulnerable to radiation damage caused by solar flares or coronal mass ejections.

Atmospheric Research Observatory

The Atmospheric Research Observatory at the South Pole, part of the USAP, was developed to track changes in the Earth's atmosphere.

Tracking the Impact of Asian Dust and Pollution on Clouds and Weather

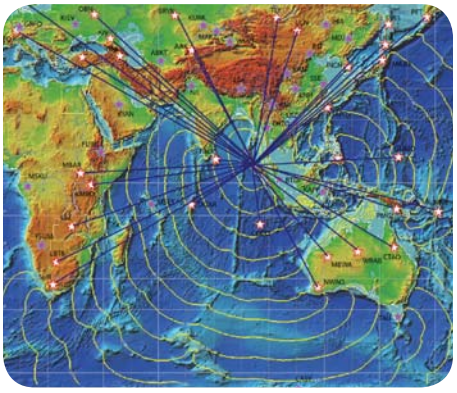
Scientists using HIAPER, one of the nation's newest and most capable research aircraft, launched a far-reaching field project known as PACDEX (for Pacific Dust Experiment) to study plumes of airborne dust and pollutants that originate in Asia and journey to North America. The plumes, among the largest such events on Earth, are so great in scope that scientists believe they might affect clouds and weather across thousands of miles while interacting with the Sun's radiation and playing a role in global climate. For more information, see the NSF news release at http://www.nsf.gov/news/news_summ.jsp?cntn_id=108742.



An illustration of a hypothetical plume and series of HIAPER flight patterns considered for the 2007 Pacific Dust Experiment (PACDEX). Researchers conducted a number of flights as part of the field project to examine the massive plumes of airborne dust and pollutants that originate in Asia and travel to North America. *Credit: Illustration by Steve Deyo; University Corporation for Atmospheric Research*

Incorporated Research Institutions for Seismology (IRIS)

The Incorporated Research Institutions for Seismology program enables the rapid collection and distribution of seismological data for studies of earthquakes and earth structure. The distributed national facility, in operation since 1984, provides for the development, deployment, and operational support of modern digital seismic instrumentation for earthquake and other earth sciences research, and for nuclear test ban monitoring. The Earth's interior is a major scientific frontier, and IRIS data have played a vital role in scientists' work to develop a better understanding of the physical processes underlying our restless planet. For example, researchers mining the data archive from IRIS' Global Seismographic Network (GSN)—a network of 138 permanent seismic stations spread out around the world, most providing real-time access to data—discovered glacial earthquakes, a previously unknown class of low frequency "earthquakes" produced by sudden glacial sliding. Further research could determine if the strong seasonality and increasing frequency of these glacial earthquakes are indicative of a glacial response to climate change. In addition to the GSN, IRIS has three other major elements: the Program for the Array Seismic Studies of the Continental Lithosphere (PASSCAL), which manages a pool of portable seismometers that are made available to the seismology research community for scheduled regional and local scale studies; the IRIS Data Management System (DMS), which provides the national and international seismic research community with timely access to some 70 terabytes of data from the GSN and PASSCAL, as well as data contributed by U.S. and international sources; and an education and outreach program that enables audiences who aren't seismologists to access and use seismological data and research for educational purposes, including teacher workshops, student internships, museum exhibits, educational materials, and programs for under-resourced schools.



The IRIS Global Seismographic Network (GSN) stations used by the Pacific Tsunami Warning Center during the Indian Ocean tsunami. The December 2004 catastrophe raised awareness of the importance of global earthquake monitoring. *Credit: The IRIS Consortium*

A researcher checks out a Global Positioning System (GPS) station in the Aleutian Islands. EarthScope's Plate Boundary Observatory (PBO) uses an array of permanent, continuously recording GPS stations and strainometers installed across the North American continent to monitor Earth motion. *Credit: EarthScope*

EarthScope

The EarthScope facility is a distributed, continental-scale, multipurpose geophysical-instrument array, with the capability to provide a coherent 3-D image of the lithosphere and deeper earth. It functions as a unique downward-looking "telescope" and gives geologists unparalleled means to investigate the structure and dynamics of the North American continent. EarthScope data are used by researchers studying earthquakes and seismic hazards, magmatic systems and volcanic hazards, lithospheric dynamics, regional tectonics, and fluids in the crust. The EarthScope facility is composed of three major elements: the Plate Boundary Observatory (PBO), a dense array of permanent global positioning system (GPS) stations and strainometers in the Western U.S. for recording deformation in and around earthquake-prone regions; the San Andreas Fault Observatory at Depth (SAFOD), a heavily instrumented drill hole that crosses the fault and will provide records of conditions within the seismogenic zone; and the USArray, a combination of portable and permanent seismograph stations that will provide a comprehensive network of sensors to explore seismic activity. The data and related products from EarthScope have already resulted in interesting findings. In one instance, researchers using EarthScope GPS and seismic data reported surprising insights into slow earthquakes (also known as ETS) along the Cascadia subduction zone. EarthScope data are freely and openly available via the Internet, and are also being used in earthquake response planning, for presentations to researchers and the public, and in university and other educational settings.

Critical Zone Observatories (CZO)

Critical Zone Observatories operate at the watershed scale to significantly advance understanding of the integration and coupling of Earth surface processes as mediated by the presence and flux of fresh water. Since 2006, a number of sites have been established, including a long-term hydrologic observatory above the seismogenic zone offshore from Japan's Kii Peninsula; a snowline CZO in the Kings River Experimental Watershed (KREW) in the Sierra National Forest; an observatory in the Boulder Creek watershed in the Front Range of the Rocky Mountains in Colorado; and an observatory in central Pennsylvania named the Susquehanna/Shale Hills Observatory. The Critical Zone Exploration Network (CZEN) links the field sites.

Consortium for Materials Properties Research in Earth Science (COMPRES)

The goal of the Consortium for Materials Properties Research in Earth Science is to enable Earth science researchers to conduct the next generation of high-pressure science on world-class equipment and facilities. The consortium is charged with the oversight and guidance of important high-pressure laboratories at several national facilities, such as synchrotrons and neutron sources. COMPRES facilitates the operation of beam lines and the development of new technologies for high-pressure research.

Students measure evaporation rates in Patagonia, Ariz. Data collection is a vital part of the work of the Center for Sustainability of Semi-Arid Hydrology and Riparian Areas (SAHRA), an NSF Science and Technology Center. *Credit: Jonathan Petti, SAHRA, University of Arizona, Tucson*

Center for Sustainability of Semi-Arid Hydrology and Riparian Areas (SAHRA)

The Center for Sustainability of Semi-Arid Hydrology and Riparian Areas, one of NSF's STCs, has as its mission to furnish new knowledge to help elected officials, water managers and policy experts at the local, state and national levels by supporting their ability to improve the sustainability of water resources in the U.S. and around the world. The Center's primary geographical focus is on two river basins: the Rio Grande/Rio Bravo river basin and the Upper San Pedro river basin in Arizona. Center researchers from multiple disciplines are working to understand the impacts of human population centers, agricultural activities and biodiversity in these semi-arid or arid regions, and are tackling emerging issues such as water markets and water banking. The center's partners include Arizona State University, New Mexico Tech, Scripps Institution of Oceanography, United States Geological Survey, the University of New Mexico in Albuquerque, Penn State University, Los Alamos National Laboratory, U.S. Department of Agriculture's (USDA) Agricultural Research Services, Desert Research Institute, University of California, Irvine, University of California, Merced, University of California, Riverside, Northern Arizona University, U.S. Army Corps of Engineers, University of California, Los Angeles, and Sandia National Laboratories. In 2007, SAHRA was one of two institutions to receive an award made annually by the United Nations Education, Science and Culture Organization (UNESCO). UNESCO cited SAHRA for its research into water usage and water management in arid regions.

Center for Coastal Margin Observation and Prediction (CMOP)

The Center for Coastal Margin Observation and Prediction has as its mission the integration of innovative interdisciplinary research, technology and education to answer complex questions about the interactions between the ocean, Earth's climate and human activities. The center, an STC, is led by Oregon Health and Science University, Oregon State University, and the University of Washington. CMOP researchers are focusing their studies on the Oregon-Washington coastal margin, the region where the Columbia River meets the Pacific Ocean.

National Center for Earth-Surface Dynamics (NCED)

The National Center for Earth-Surface Dynamics, another STC, seeks to develop an integrated and predictive understanding of the processes shaping the surface of the Earth in order to transform management of ecosystems, resources, and land use. The center's multidisciplinary approach involves everything from hydrology and ecology to the social sciences. Center researchers and others could develop new insights into the history of the Mississippi Delta region from data collected by major oil companies and now being made available to the NCED. The data–detailed information about the region's subsurface obtained by bouncing sound off the layers under the delta–had been kept largely in-house by the oil companies.

U.S. National Ice Core Laboratory

Ice cores are powerful tools in paleoclimate research. They can contain uninterrupted, detailed records of climate history going back hundreds of thousands of years. NSF continues to co-fund, with the U.S. Geological Survey (USGS), the U.S. National Ice Core Laboratory, a repository for storage, curation and study of ice cores recovered from the polar regions. The lab allows scientists to conduct examinations and measurements on ice cores, and it preserves the integrity of the ice cores in a long-term repository for current and future investigations. Marine core repositories are coordinated by the IODP.

An assistant curator at the U.S. National Ice Core Lab in Littleton, Colo., holds up a piece of ice taken from above Antarctica's Lake Vostok. The cores are recovered and studied in a variety of scientific investigations. *Credit: Melanie Conner, National Science Foundation*

Byrd U.S. Polar Rock Repository

Existing Antarctic rock samples can be valuable resources for researchers. The U.S. Polar Rock Repository at Ohio State University's Byrd Polar Research Center houses and makes available for research rock samples from Antarctica, the Arctic, southern South America and South Africa. The polar rock collection and database include field notes, photos, maps, cores, powder and mineral residues, and thin sections, as well as microfossil mounts, microslides and residues.

Paleobotany Collection

The Paleobotany Collection of Kansas University houses more than 7,000 specimens of Antarctic fossil plants from throughout the Transantarctic Mountains of Antarctica.

U.S. Antarctic Program Data Coordination Center

The U.S. Antarctic Program Data Coordination Center, at Lamont-Doherty Earth Observatory of Columbia University, coordinates the management of data collected by U.S.-funded scientists in Antarctica and the Southern Ocean. The goal is to help scientists find Antarctic scientific data of interest and help them submit data for long-term preservation.

U.S. Antarctic Resource Center (USARC)

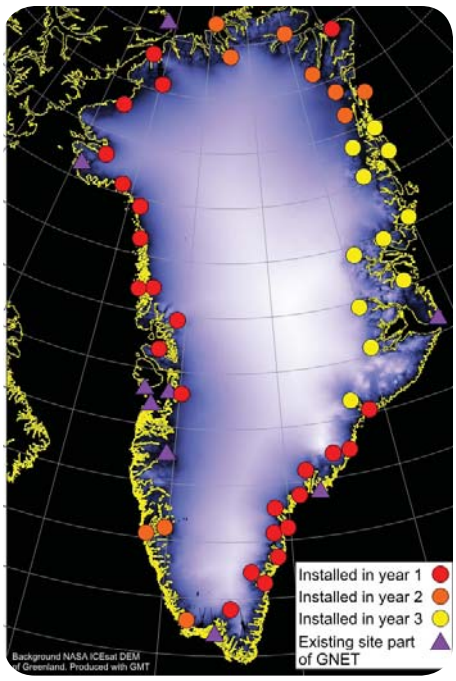
The U.S. Antarctic Resource Center is a joint venture between NSF and USGS. The center maintains the nation's most comprehensive collection of Antarctic maps, charts, satellite images and photographs produced by the U.S. and other member nations of the Scientific Committee on Antarctic Research (SCAR).

Center for Remote Sensing of Ice Sheets (CReSIS)

The Center for Remote Sensing of Ice Sheets (CReSIS), an NSF STC established in 2005, engages in technology development, and creates series datasets of the accumulation rate, surface elevation, ice thickness and velocity, and melt rate for the Greenland ice sheet.

Polar Earth Observatory Network (POLENET)

NSF-supported researchers are part of the international Polar Earth Observatory Network project, a consortium involving people from 28 nations who are engaging in field work to improve the collection of geophysical data across the Earth's poles. The project is a core activity of IPY. In the south, researchers are constructing a network of GPS and seismic stations in West Antarctica to understand how the mass of the West Antarctic ice sheet (WAIS) changes with time. The information will be used to predict sea level rise accompanying global warming and interpret climate change records. And in the Arctic, another NSF-funded research team is constructing a network (GNET) of 38 continuous Global Positioning System (GPS) stations in Greenland to collect better data on ice sheets.



As part of the International Polar Year 2007-2009, POLENET researchers are deploying a seismic and GPS network around Greenland. This map shows the planned and completed installations. POLENET also is deploying, monitoring and updating instruments in Antarctica. Greenland and Antarctica offer natural laboratories for studying the solid earth processes that influence ice sheet dynamics. *Credit: Dr. Terry Wilson and Dr. Mike Willis, The Ohio State University*

Summit Camp

NSF supports Summit Camp, a scientific research station in Greenland. The camp, located at the peak of the Greenland ice sheet—the largest ice sheet in the Northern Hemisphere—enables year-round operations to study air-snow interactions, which are crucial for interpreting data from ice cores drilled in the area and elsewhere. The site has proven to be a nearly ideal location for studies of climate change and snow chemistry.

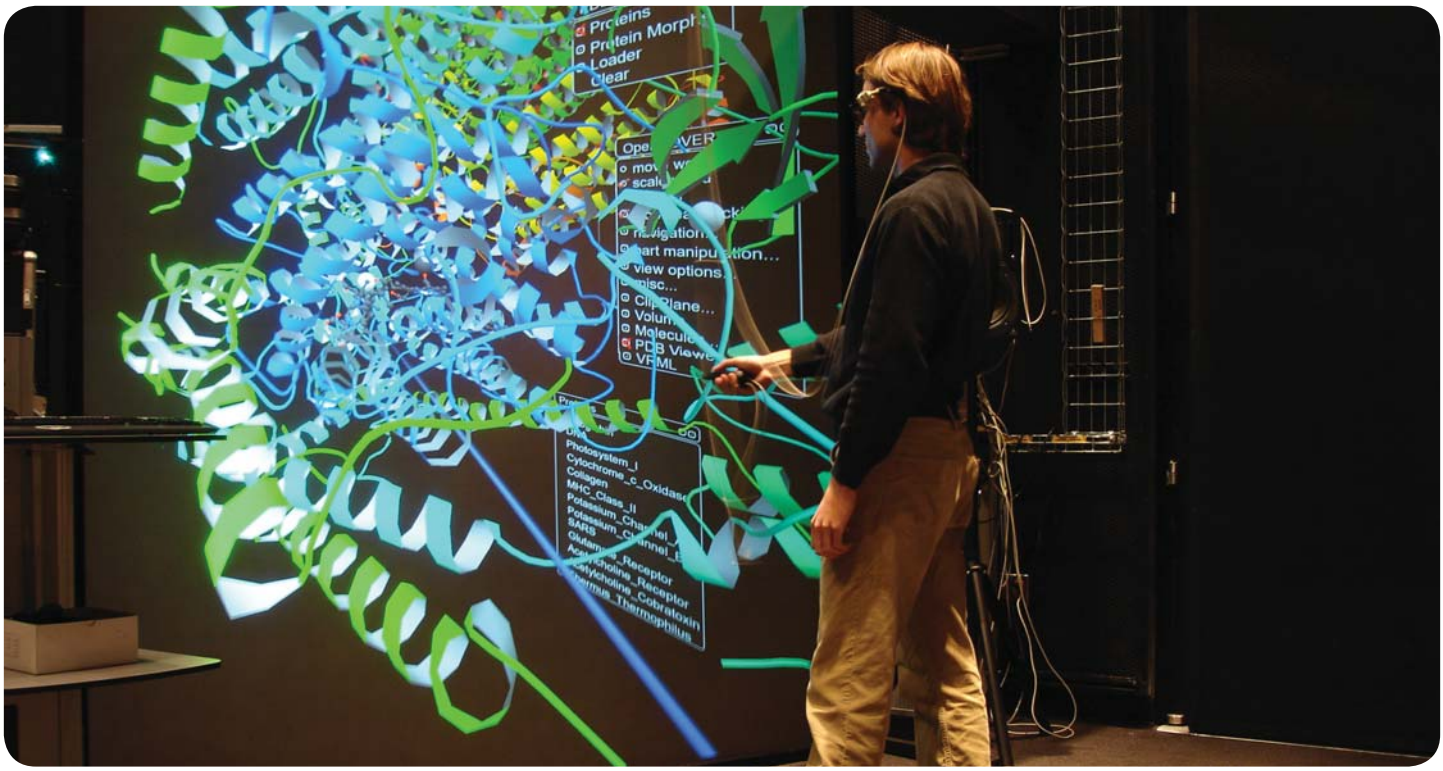
A Sudden Rise in the Yellowstone Caldera

The last time the Yellowstone super-volcano underwent a major, giant eruption was about 640,000 years ago when the caldera was formed. Scientists from the University of Utah and USGS have observed an accelerated rate of uplift of the Yellowstone Caldera during the time span from 2004-2006. The research team took advantage of EarthScope's Plate Boundary Observatory to isolate vertical and horizontal ground motion in the Yellowstone area from GPS measurements. They then coupled this data with InSAR measurements to develop a model of magma (and magmatic fluid) migration to explain the observed deformation. While the scientists do not feel that this increased uplift is indicative of an impending eruption, the data provide insight into the life cycle of a super-volcano. Since its original eruption, the Yellowstone supervolcano has experienced several recent periods of uplift and subsidence, indicating that the area is still active. The researchers reported their findings in the Nov. 9, 2007 issue of the journal *Science.*

A view of the Yellowstone River flowing through Hayden Valley, with the Yellowstone caldera rim in the distance. *Credit: Gwendolyn Morgan*

The convergence of powerful new technologies and fresh insight is contributing to a robust and expansive research infrastructure for biologists and others seeking a better understanding of living things. New tools that make use of approaches from other disciplines, such as computational thinking, together with the launch of new kinds of observatories for collecting and integrating data and the efforts of multidisciplinary teams are also adding to an explosion of new knowledge about living systems. Most of these investments are provided and/or managed by NSF's Directorate for Biological Sciences.

ALIVE: UNLOCKING THE SECRETS OF LIVING THINGS



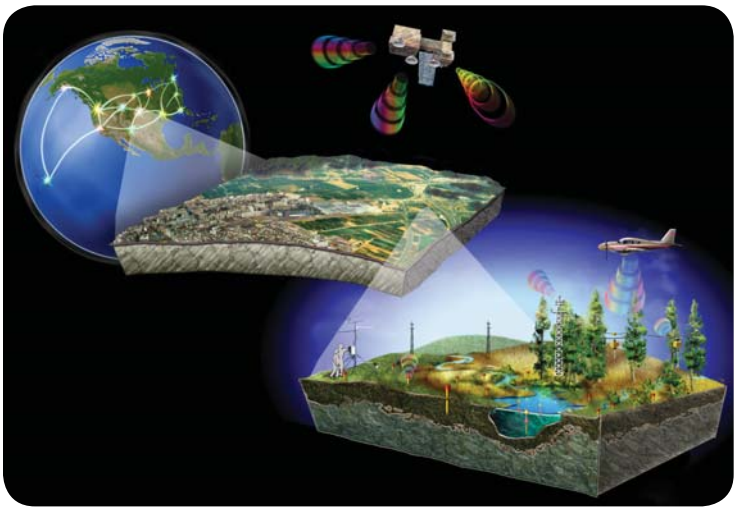
A visualization of a protein from the Protein Data Bank (PDB), shown on a C-Wall (a configurable wall for projecting images) at the California Institute for Telecommunications and Information Technology (Calit2) at the University of California, San Diego. The work on the interactive visualization of proteins from the PDB was performed by Jürgen P. Schulze, project scientist, in collaboration with Jeff Milton, Philip Weber and Philip Bourne. *Credit: Jurgen Schulze, Calit2, UC-San Diego*

Protein Data Bank (PDB)

The assets of the Protein Data Bank just keep growing. In 2004, when NSF announced a new management era designed to ensure open access to the worldwide collection of deposits of molecular structure data, the PDB held the three-dimensional structures of nearly 24,000 proteins and other macromolecules in its collection. In April 2008, the PDB added the 50,000th molecule structure. The holdings profile DNAs, RNAs, viruses, and various proteins, such as enzymes central to photosynthesis, growth, development and brain function. NSF has supported the Protein Data Bank continuously since 1975. A multi-agency support partnership was first formed in 1989. For the past five years, that partnership has included NSF, the National Institute of General Medical Sciences (NIGMS), the Department of Energy (DOE) and the National Library of Medicine (NLM). The partnership later was expanded to include the National Cancer Institute (NCI), the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), and the National Institute of Neurological Disorders and Stroke (NINDS).

iPlant Collaborative

A team led by the University of Arizona was selected to create a cyberinfrastructure collaborative to address grand challenges in the plant sciences that are concerned with the environment, agriculture, energy and the very organisms that sustain our existence on earth. The iPlant Collaborative will bring together researchers in every area of plant science—from molecular and cellular biologists to those working at the ecosystem and global levels—as well as computer and information scientists, engineers, mathematicians and social scientists, and the activity will enable specialists from different fields to work together more effectively than ever before. The iPlant center will be located at the University of Arizona's BIO5 Institute. Other institutions working with the University of Arizona include Cold Spring Harbor Laboratory, Arizona State University, the University of North Carolina at Wilmington, and Purdue University. The iPlant Collaborative is a $50 million, five-year project that is potentially renewable for a second five-year period and a total of $100 million. The award is greater than three times the size of any other NSF award received in Arizona to date. The iPlant Collaborative is expected to transform the study of plant science, with cyberinfrastructure and computational science and thinking playing key roles. The iPlant cyberinfrastructure could serve as a model for solving problems in fields outside of plant biology as well. One iPlant feature to be developed is the ability to map the full expanse of plant biology research in much the same way as Google Earth, Microsoft Virtual Earth and Mapquest utilize mapping technology. Like users of those applications, users of iPlant may one day be able to "zoom" in and out among various levels of plant biology, from the molecular to the organismic to the ecosystem level. For example, a researcher might "zoom in" to analyze the carbon fixed, oxygen produced, and water utilized by individual leaves, then "zoom out" to analyze how all of these might effect large-scale changes in ecosystems and how that could, in turn, affect air quality and climate.



An artist's conception of the National Ecological Observatory Network (NEON), a proposed Earth-observing system. NEON's distributed sensor networks and experiments, linked by advanced cyberinfrastructure, will record and archive ecological data. *Credit: Nicolle Rager Fuller, National Science Foundation*

National Ecological Observatory Network (NEON) – Proposed

The National Ecological Observatory Network, a regional-to-continental network of sensors and shared technology in the final planning stages, will provide the infrastructure needed to address the most complex environmental challenges facing the U.S. Through remote sensing, *in situ* observation, experimentation, synthesis and modeling, NEON will offer multidisciplinary teams of researchers the unique tools, technologies and data needed to advance our understanding of ecological theory and the interconnectedness of life. Investigators expect to conduct real-time studies at unprecedented scales and produce significant advances in our understanding of the consequences of the

interplay among air, water, land and biota. If constructed, NEON will be a "shared use" research platform consisting of geographically distributed field and laboratory research infrastructure that is connected via cyberinfrastructure to an integrated research instrument. NEON infrastructure will include instrumented towers and sensor arrays, remote sensing capabilities, cutting-edge laboratory instrumentation, natural history archives and facilities for data analysis, modeling, visualization and forecasting–all networked onto a cyberinfrastructure backbone. Infrastructure would be deployed across the continental U.S., Alaska, Hawaii and Puerto Rico using a statistically determined design. NEON was proposed as a new start in FY 2007; continuation of design and future construction depends upon successful project design reviews, continued prioritization by NSF, NSB approval and the availability of federal funds.

National Center for Ecological Analysis and Synthesis (NCEAS)

Researchers at the NSF-funded National Center for Ecological Analysis and Synthesis at the University of California, Santa Barbara are helping people see the "big picture" when it comes to Earth's systems. The center is focused on the development and testing of important ecological ideas and theories using existing data. Other major focuses are cutting-edge analysis of ecological information; research on data access and use; promoting the use of sound science in policy and management decisions; investigating sociological issues that pertain to the science of ecology; projects involving the state of California; and education and outreach. (See sidebar, below.)

Study Presents the "Big Picture" of Human Impacts on the Oceans

Coral reefs are just one of many ocean habitats that have been impacted by human activity. *Credit: Joe Pawlik, University of North Carolina at Wilmington*

Researchers conducting the first global-scale study of human influence on marine ecosystems found more than 40 percent of the world's oceans are heavily impacted and that few, if any, areas remain untouched by human activities. By overlaying maps of 17 different activities, such as fishing, the researchers produced a composite map of the toll that humans have exacted. Past studies focused largely on single activities or single ecosystems in isolation, and rarely at the global scale. In this study, the scientists were able to look at the total influence of human activities across marine ecosystems. The study found that the most heavily affected waters in the world include large areas of the North Sea, the South and East China Seas, the Caribbean Sea, the east coast of North America, the Mediterranean Sea, the Red Sea, the Persian Gulf, the Bering Sea and several regions in the western Pacific. The least affected areas are largely near the poles. The work, published in the journal *Science* in February 2008, was conducted at NSF's NCEAS at the University of California, Santa Barbara. For more information, see the NSF news release at http://www.nsf.gov/news/news_summ.jsp?cntn_id=111113.

National Evolutionary Synthesis Center (NESCent)

The National Evolutionary Synthesis Center enables collaborative biological research efforts by three universities in North Carolina's Research Triangle: Duke University, North Carolina State University and the University of North Carolina at Chapel Hill. The center, located in Durham, has as its central goal fostering greater conceptual synthesis in biological evolution by bringing together researchers and educators, existing data and information technology resources. To achieve this goal, the center

will develop new tools and cross-disciplinary standards for management of biological information and meta-information, support data analysis capabilities with broad utility, and host and curate databases. The center will support postdoctoral fellows, sabbatical faculty and computer scientists on site. Researchers will have primary projects of their own design, but as a whole, the group will have a great deal of independence to take advantage of new opportunities for synthesis and collaboration as they arise. In addition, NESCent will coordinate and sponsor a number of working groups tasked with making progress on significant issues in evolutionary biology where opportunities for synthesis have been identified. The center will also support education and outreach activities to enhance public understanding of the science of biological evolution and foster interactions between evolutionary biologists and members of the broader community.

National Institute for Mathematical and Biological Synthesis (NIMBioS)

The National Institute for Mathematical and Biological Synthesis is a new NSF-funded center established to foster research and education at the interface of the mathematical and biological sciences. The center will bring together researchers in small working groups to tackle problems and produce insights into such issues as the control of invasive species, how to limit impacts of infectious diseases, and new methods for drug design. NIMBioS will be located at the University of Tennessee-Knoxville, and one of its unique aspects will be a partnership with the Great Smoky Mountains National Park that will enable researchers to use the park as a testing ground for emerging ideas.

Center for Behavioral Neuroscience (CBN)

At the Center for Behavioral Neuroscience at Georgia State University—one of NSF's STCs—researchers are studying animals such as voles to shed light on the roles of nature and nurture in animal behavior. Scientists in the vole study have found that genes for vasopressin and oxytocin play important roles in the formation of social attachments between animals. The findings could someday help with better treatments of human conditions such as autism and depression. In addition to the group studying affiliation issues, there are other collaboratories—research environments for 15-20

The Center for Behavioral Neuroscience (CBN), an NSF Science and Technology Center, has developed a comprehensive education program to train the next generation of neuroscientists and increase science literacy. *Credit: Atlanta Center for Behavioral Neuroscience*

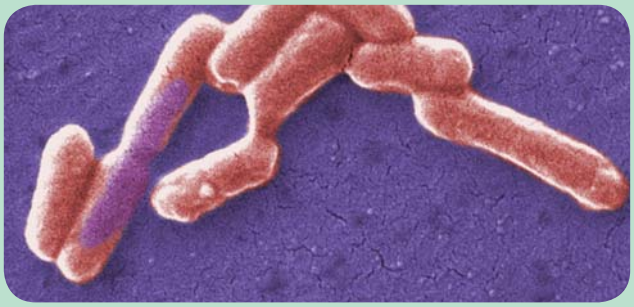
researchers focusing on similar issues—at the center including a group investigating how systems in the brain are involved in conditioned emotional responses that lead to fear and anxiety. One potential outcome of the work could be applicable to helping people overcome post-traumatic stress disorder (PSD), phobias and anxiety disorders. Besides Georgia State, Clark Atlanta University and Emory University, Georgia Institute of Technology, Morehouse College, Morehouse School of Medicine and Spelman College are partners in the CBN.

Center for Environmental Implications of Nanotechnology (CEIN)

NSF and the U.S. Environmental Protection Agency (EPA) have partnered to establish two Centers for the Environmental Implications of Nanotechnology. Announced in September 2008, the centers—one at Duke University and the other at the University of California, Los Angeles—will study how nanomaterials interact with the environment and with living systems, and will translate this knowledge into risk assessment and mitigation strategies useful in the development of nanotechnology. The centers will work as a network, connected to other research organizations, industry and government agencies and will emphasize interdisciplinary research and education. The University of California, Los Angeles CEIN will explore the impact of nanomaterials on the environment and on interactions with biological systems at all scales, from cellular to ecosystem. Duke University CEIN researchers plan to define the relationship between a vast array of nanomaterials—from natural to man-made to incidental, byproduct nanoparticles—and their potential environmental exposure, biological effects and ecological consequences.

A Speedier—And Cheaper—Method for Identifying Strains of *E.Coli*

Researchers at the University of Wisconsin-Oshkosh developed a new method of identifying strains of bacteria in environmental samples, such as water from recreational lakes. *E. coli* is found in water that has been contaminated by fecal material. Many different strains exist naturally in the wild, but a few strains cause serious illnesses in people. The researchers, supported by an MRI grant, developed a special type of mass spectrometer that distinguishes between bacterial strains based on analysis of proteins in the cells. This approach is faster and less costly than DNA fingerprinting, the traditional means of strain identification. Faster identification of the bacterial strains will allow a quicker response to possible health threats. For more information, see the NSF award abstract at http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0321545.



A colorized, scanning electron micrograph (SEM) depicting a number of Gram-negative *Escherichia coli* bacteria under high magnification. Although most strains of *E.Coli* are harmless, this strain (*E. coli* O157:H7) produces a powerful toxin that can cause severe illness. *Credit: Janice Haney Carr, Centers for Disease Control and Prevention*

Long-Term Ecological Research (LTER)

Beginning with an initial set of six sites in 1980, Long-Term Ecological Research project sites are a vital part of the agency-supported research infrastructure. NSF established the LTER program to conduct research on long-term ecological phenomena. Currently, there are 26 sites, located primarily in the U.S., but there are locations in the Arctic, Antarctic and tropics. The sites represent Earth's major ecosystems, including deserts, grasslands, forests, tundra, urban areas, agricultural systems, freshwater lakes, coastal estuaries and salt marshes, coral reefs and coastal ocean zones, and a broad array of research emphases. Research conducted at the LTER sites is contributing to our understanding of climate change, biodiversity, human's impact on the environment and other major ecological challenges. Some studies produce results in a relatively short timeframe. For example, the Sevilleta LTER in New Mexico helped solve a medical mystery in the Four Corners area, when people suddenly started dying of a mysterious respiratory disease. Blood tests of the victims revealed that people had become infected with a previously undetected kind of hantavirus. Hantaviruses were known to spread from rodents to humans in Asia and Europe, but hadn't been seen in the U.S. prior to the 2003 outbreak. The Sevilleta LTER researchers answered key questions about the sudden appearance of the virus and how it spread. They found that El Niño, a periodic pattern of change in the circulation of oceans and atmosphere, had substantially boosted plant productivity after several years of drought, and that more plants led to more rodents which in turn increased the probability of people's exposure to infected rodents. Other LTER research requires many years of sustained observations to produce important results. Examples of LTER sites are presented below; all of the LTERs are listed in Appendix I.

Arctic LTER

The Arctic LTER site at Toolik Lake Field Station is located in the foothills region of the North Slope of Alaska and includes the entire Toolik Lake watershed and the adjacent watershed of the upper Kuparuk River, down to the confluence of these two watersheds. The area features continuous permafrost—no trees, complete snow cover for seven to nine months, winter ice cover on lakes, streams and ocean, and

The NSF-supported research station at Toolik Lake in Alaska, part of the Arctic Long-Term Ecological Research (LTER) site. Researchers study the ecology of the surrounding tundra, streams, and lakes to gain a better understanding of the controls of ecosystem structure and function. *Credit: © 2002 James H. Barker and Institute of Arctic Biology*

cessation of river flow during the winter. The LTER site enables research aimed at understanding how tundra, streams and lakes function in the Arctic. Researchers are studying the movement of nutrients from land to stream to lake, changes due to human influences, and controls of ecological processes by nutrients and by predation. The Toolik Lake Field Station is operated by the Institute of Arctic Biology at the University of Alaska Fairbanks.

Baltimore Ecosystem Study (BES)

Initiated as an LTER site in 1997, the Baltimore Ecosystem Study is led by Institute of Ecosystem Studies. It is one of two LTERs that focuses on a metropolitan region as an ecosystem (the other is the Central Arizona-Phoenix LTER). Researchers at the University of Maryland, Baltimore County, Johns Hopkins University, and the USGS are key members of the BES LTER team. BES received a Phase II award in 2005 to continue work on research topics that include patch dynamics of built, social, biological and hydrological components of the metropolitan area; feedbacks between social, economic and ecological components of an urban ecosystem; and the effects of infrastructure and development on fluxes of nutrients, energy, and water in upland, stream, and coastal regions of metropolitan Baltimore. The ecological knowledge resulting from research helps support educational and community-based activities. Interactions between the project and the Baltimore community are important components of the LTER's work.

Bonanza Creek LTER

The Bonanza Creek LTER site is located in the boreal forest of Alaska's interior, with facilities centered in the city of Fairbanks, Alaska. The LTER includes two research areas—the Bonanza Creek Experimental Forest and the Caribou-Poker Creeks Research Watershed. Researchers at the LTER site are focusing on improving our understanding of the long-term consequences of changing climate and disturbance regimes in the Alaskan boreal forest. The overall objective is to document the major factors controlling forest dynamics, biogeochemistry and disturbance and their interactions in the face of a changing climate.

McMurdo Dry Valleys LTER

The McMurdo Dry Valleys LTER site is located on the western coast of McMurdo Sound. The dry valleys form the largest, relatively ice-free area on the Antarctic continent. The perennially ice-covered lakes, ephemeral streams and extensive areas of exposed soil within the McMurdo Dry Valleys LTER

Beacon Valley field camp, located in the Dry Valleys of the Transantarctic Mountains. The McMurdo Dry Valleys are one of the NSF Long-Term Ecological Research (LTER) sites. The research group pictured above was studying the landscape features and soils of Antarctica's Dry Valley region to provide a more complete understanding of past global climatic and environmental conditions. *Credit: Josh Landis, National Science Foundation*

are subject to low temperatures, limited precipitation and salt accumulation. Thus, the dry valleys represent a region where life approaches its environmental limits, and is an "end-member" in the spectrum of environments included in the LTER Network. Ohio State University is the lead institution for the McMurdo Dry Valleys LTER.

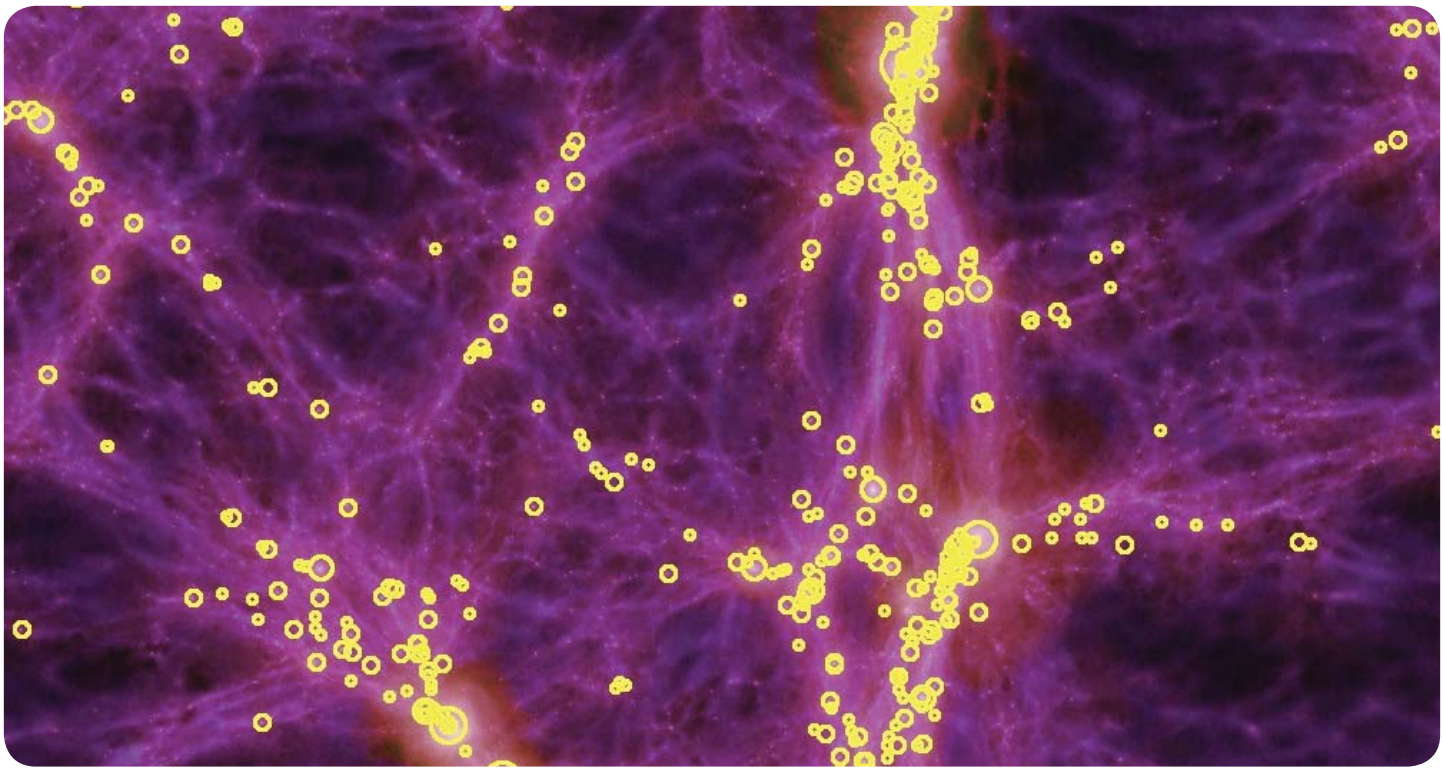
Diverse Native Prairie Plant Species as Better Biomass Fuel Source

At Minnesota's Cedar Creek Natural History Area, one of NSF's Long-Term Ecological Research (LTER) sites, researchers identified mixed prairie grasses as a leading source for producing environmentally friendly, bio-based fuel. *Credit: Cedar Creek LTER Site*

Plant-based (biomass) sources of fuel have emerged in recent years as promising alternatives to fossil fuel. Ethanol, made from corn, is in the marketplace, but production of ethanol has raised questions about its efficiency, as well as the impact of diverting cropland from growing food to growing biofuel. Biodiesel from soybeans faces similar concerns. Is there a better alternative? Recent research has identified diverse mixtures of native prairie grasses and other flowering plants as a leading option. Researchers conducting a study over a 10-year period at Minnesota's Cedar Creek Natural History Area found that the biomass mixture produced more usable energy per acre than corn- and soybean-based sources, and that prairie plant biomass would be "carbon negative," meaning that producing and using the prairie grass mixture would reduce the amount of carbon dioxide, a greenhouse gas, in the environment. The Cedar Creek area is one of the 26 LTER sites supported by NSF. The research results were reported in the Dec. 8, 2006, issue of the journal *Science*. For more information, see the NSF news release at http://www.nsf.gov/news/news_summ.jsp?cntn_id=108206.

It's nearly impossible to imagine a field of science and engineering that has not been impacted by advances in computing, communications and information technology. In fact, it's hard to imagine any area of society that hasn't been affected. According to a 2007 report by the President's Council of Advisors in Science and Technology, "since 1995, networking and information technology industries have accounted for 25 percent of the nation's economic growth…." In science and engineering, advances in computing and related information technology are providing researchers with the ability to explore questions that were previously out-of-reach. NSF is working to ensure the U.S. has a world-class cyberinfrastructure that enables researchers to advance the frontiers of what is known. Besides being the principal source of government-funding for university-based computer science research, the foundation also funds the acquisition, development and operation of high performance computers, storage systems, programming, scalable interactive visualization tools, virtual environments, networking and more. NSF's Office of Cyberinfrastructure (OCI) and Directorate for Computer and Information Science and Engineering are primarily responsible for investing in shared cyberinfrastructure to continue the successful efforts, begun more than 20 years ago, to give the academic research community open access to supercomputing capabilities.

The Continuing Computing and Storage Revolution



A snapshot from a simulation showing the evolution of structure in a large volume of the universe. The simulation relied on the resources of the TeraGrid, using the Pittsburgh Supercomputing Center's 2,000 Cray XT3 processors—the whole system—over four weeks of run time. This is the first simulation to incorporate black hole physics, according to theoretical cosmologist Tiziana Di Matteo of Carnegie Mellon University. The model has yielded new insight into the role played by black holes in galaxy formation. *Credit: Tiziana Di Matteo, McWilliams Center for Cosmology, Carnegie Mellon University*

TeraGrid

NSF's TeraGrid (actually the Extensible Terascale Facility) is the world's leading high-end computing environment for open research. It integrates high-performance computers, data resources and tools, and high-end experimental facilities around the world. The advanced cyberinfrastructure, which entered full production mode in 2004, combines the resources of 11 partner sites—Indiana University, the Louisiana Optical Network Initiative, the National Center for Atmospheric Research, the National Center for Supercomputing Applications at the University of Illinois at Urbana-Champaign, the National Institute for Computational Sciences (NICS), the Oak Ridge National Laboratory, the Pittsburgh Supercomputing

Ultra-high resolution display systems such as the one pictured to the left—the Highly Interactive Parallelized Display Space, or HiPerSpace, wall at the California Institute for Telecommunications and Information Technology (Calit2) at the University of California, San Diego—provide scientists using the TeraGrid with a better way to view real-time, rendered graphics of large data sets and collaborate in their research. *Credit: Falko Kuester, California Institute for Telecommunications and Information Technology (Calit2), University of California, San Diego (UCSD)*

Center (PSC), Purdue University, the San Diego Supercomputer Center (SDSC), the Texas Advanced Computing Center and the University of Chicago/Argonne National Laboratory—to create an integrated, persistent, computational resource. The TeraGrid supports more than 1,000 projects and more than 4,000 researchers across the U.S. Currently, TeraGrid integrated resources include more than 750 teraflops of computing capability and more than 30 petabytes (quadrillions of bytes) of online and archival data storage, with rapid access and retrieval over high-performance networks. The TeraGrid also provides researchers with access to more than 100 discipline-specific databases.

Ranger Supercomputer

Ranger, the new high performance computing system at the Texas Advanced Computing Center at the University of Texas at Austin, was ranked as the fourth fastest supercomputer, according to the June 2008 list of the top 500 supercomputers worldwide. The list is compiled twice a year, and the three machines ranked as faster than Ranger are owned by the DOE and reserved primarily for nuclear weapons research and related tasks. Ranger is the most powerful supercomputer available to the open science research community–it's used for computational research in all scientific disciplines–and the system has more memory than any other supercomputer on the Top 500 list. As part of NSF's four-year initiative to fund the

Ranger, the new high performance computing system at the Texas Advanced Computer Center at the University of Texas at Austin, has been ranked as one of the world's fastest supercomputers. *Credit: TACC, The University of Texas at Austin*

deployment and operation of leading-edge systems to greatly increase the availability of computing resources to U.S. researchers, the new system provides the first petascale computing platform based within the U.S. university research community, with peak performance of one-half petaflop per second. Ranger is specifically designed to provide unprecedented power to meet very large science and engineering computational requirements, and is currently supporting some 150 research projects, ranging from earthquake simulation and advanced biology to nanoelectronics and particle physics. Ranger significantly boosts the computational

capacity of the TeraGrid. In its final configuration, Ranger will have a peak performance of some 504 teraflops. The system architecture includes an unusually large total system memory. With 125 terabytes of memory and 1.7 petabytes of raw disk storage, Ranger makes possible very data-intensive and memory-intensive calculations. Ranger began normal operations this year, following its dedication in February 2008.

National Institute for Computational Sciences (NICS) Kraken

The newest NSF high performance supercomputer for transformational research projects is National Institute for Computational Sciences Kraken**,** led by the University of Tennessee at Knoxville, in collaboration with the Oak Ridge National Laboratory. If petascale computing is the gold standard for the next generation of academic cyberinfrastructure, this mid-range high performance system will move U.S. researchers toward that goal, providing peak performance of just under one petaflop. The new near-petascale system's computing capability significantly expands the capacity of the TeraGrid and enables investigators to pursue breakthrough science and engineering research in a wide range of computationally demanding areas including: life sciences, earth, atmospheric and ocean sciences, chemistry and biochemistry, materials research and nanoscale engineering, computational fluid dynamics, high-energy physics, astronomy and astrophysics, space physics, economics, neuroscience and social science.

Blue Waters

Blue Waters is being built to be the world's most powerful "petascale" system for academic science and engineering research, capable of making arithmetic calculations at a sustained rate in excess of 1,000-trillion operations per second. It will have more than 200,000 processor cores coupled to more than a petabyte of memory and more than 10 petabytes of disk storage. This leadership class computing system will provide unprecedented computing resources to enable the next generation of science and engineering applications, those that use multiple models at multiple scales to describe complex processes. The system will help investigators advance studies of some of the world's most challenging science and engineering research problems, such as the formation and evolution of galaxies in the early universe; the interaction of the Sun's coronal mass ejections with the Earth's magnetosphere and ionosphere; the chains of reactions that occur with living cells, organs and organisms; and the design of novel materials. The Blue Waters system will be located at the University of Illinois at Urbana-Champaign and will be operated by the National Center for Supercomputing Applications and its partners in the Great Lakes Consortium for Petascale Computing. NCSA finalized a contract with IBM to build the system in August 2008. Blue Waters is expected to come online in 2011.

High Performance Wireless Research and Education Network (HPWREN)

With NSF support, researchers at the University of California, San Diego developed the High Performance Wireless Research and Education Network (HPWREN). The research project includes creating, demonstrating and evaluating a non-commercial, prototype, high-performance, wide-area, wireless network in San Diego, Riverside and Imperial counties in California. The versatile network research project functions as a collaborative cyberinfrastructure on research, education and first responder activities. The network includes backbone nodes at the University of California, San Diego, and San Diego State University campuses, and a number of "hard to reach" areas in remote environments. HPWREN has proven its value to scientists, educators and many others, including firefighters. The network has provided next-generation communications services to firefighters battling California wildfires in recent years, while the network's cameras and sensors provide real-time images and current data, enabling better decision making about the use of resources to fight the

With relays like this one on Palomar Mountain, the High-Performance Wireless Research and Education Network (HPWREN) brought connectivity to firefighters at the scene of the 2003 Coyote wildfire, allowing them to receive weather notices and submit incident summaries in real-time. Before it was brought under control, the fire burned more than 17,000 acres in southern California. *Credit: High Performance Wireless Research and Education Network (HPWREN)*

wildfires. The high performance network has also aided astronomers, giving researchers at the California Institute of Technology's Palomar Observatory the speed they needed to pinpoint the location of short-lived gamma ray bursts and observe them as they exploded. More recently, data collected from observations of a supernova explosion by the robotic telescope at the Palomar Observatory were transmitted from the remote mountain site in southern California to astronomers via HPWREN.

Global Ring Network for Advanced Applications Development (GLORIAD)

The Global Ring Network for Advanced Applications Development is a high-speed (10-gigabit-per-second) optical network around the entire Northern Hemisphere, supported by a consortium of government agencies and science organizations to enable increased science and education support among the U.S., Russia, China, Korea, Canada and Netherlands, as well as broader Europe and Eastern and Central Asia. GLORIAD supports increased science and education cooperation and ensures a rational, coherent strategy and architecture for the future of science and education networking. In addition to the jointly managed, hybrid circuit-switched and routed production environment, the project provides services to support increased science and education cooperation for both general and highly advanced (in terms of network needs) user communities.

Grid Physics Network (GriPhyN)

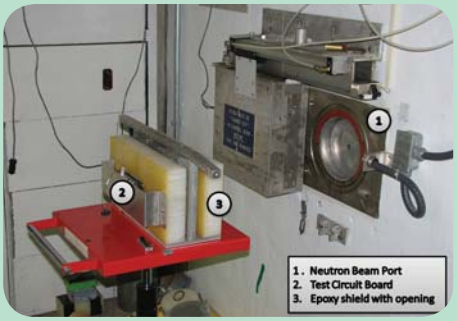
The Grid Physics Network is a collaboration of experimental physicists and information technology researchers to implement the first petabyte-scale computational environments for data intensive science in the 21st century. The project is developing grid technologies for scientific and engineering projects that need to collect and analyze distributed petabyte-scale datasets. Examples of areas of science which will produce very large collections of measured data include the Sloan Digital Sky Survey, LIGO and experiments of the LHC.

Data Intensive Science University Network (DISUN)

The Data Intensive Science University Network is a distributed cyberinfrastructure for applications requiring data-intensive, distributed computing technology. The grid-based facility comprises computing, networking, middleware and personnel resources from four universities—California Institute of Technology, the University of California, San Diego, the University of Florida and the University of Wisconsin-Madison.

One of a Kind Test Facility to Reduce Chip Errors

Some computer chips, such as field programmable gate array (FPGA) components, are subject to radiation-induced errors, called soft errors. An FPGA is an integrated circuit that can be programmed in the field after manufacture. Cosmic rays and other radiation can cause unwanted state changes in the integrated circuits. For an FPGA at 3,600 meters above sea level–approximately the altitude of a commercial airplane–soft errors can occur as frequently as four errors per every 28 days. The number of soft errors is expected to increase as chip feature sizes become smaller, voltages lower, clock speeds increase and systems incorporate greater numbers of chips. An NSF-supported interdisciplinary research team at Penn State University has established an accelerated test facility, the only one of its kind in an academic environment, to conduct research aimed at understanding the phenomenon of radiation-induced errors. Facility collaborators have access to the university's Breazeale TRIGA nuclear research reactor to gather actual data on radiation effects on computer chips. The researchers' results were the first to show correlation between soft errors and power optimizations, aging, process and environmental variations. Experiments have confirmed that there is a strong correlation between higher failure rates and lower voltages. Aging has been shown to not affect soft error rates, while higher temperatures reduce soft errors. The researchers are developing models for soft error analysis and design methods that mitigate the effects of these errors.



At Penn State University's accelerated soft error testing facility, a digital circuit board is aligned for exposure from the neutron beam port, enabling researchers to study the impact of radiation on microprocessor reliability. *Credit: © Vijaykrishnan Narayanan*

Collaborative Center for Internet Epidemiology and Defenses (CCIED)

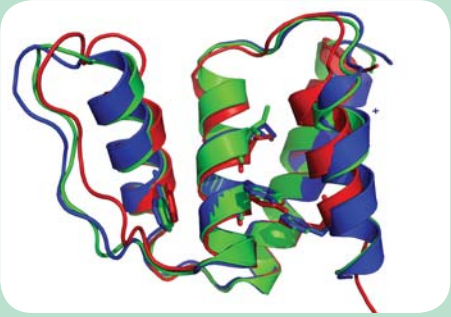
The Collaborative Center for Internet Epidemiology and Defenses is an NSF-supported joint effort between researchers at the University of California, San Diego, and the International Computer Science Institute's Center for Internet Research to address critical challenges posed by large-scale Internet-based pathogens, such as worms and viruses. CCIED efforts focus on analyzing the behavior and limitations of Internet pathogens, developing early-warning and forensic capabilities, and developing technologies that can automatically defend against new outbreaks in real-time. One of the important tools used is the University of California, San Diego's network telescope that looks at the literal dark side of the Internet—Internet traffic destined for an unoccupied section of the Internet, with legal addresses but no active computers.

Cooperative Association for Internet Data Analysis (CAIDA)

The Cooperative Association for Internet Data Analysis was established to foster engineering and technical collaborations among Internet providers, vendors and user groups. It was launched in 1997 with an NSF seed grant to the University of California, San Diego, and today, its primary support comes from NSF and the Defense Advanced Research Projects Agency (DARPA). Based at the San Diego Supercomputer Center, CAIDA's members represent the commercial, government and research sectors. Its primary focus is on the development of measurement, analysis and visualization tools of benefit to the community and pursuit of initiatives to improve the robustness and scalability of the Internet.

Speeding Simulations for Drug Design

Proteins are one of the building blocks of the body. Determining the 3-D shapes of proteins—crucial to understanding the ways proteins function—has been a slow and exacting process. To enable researchers to accelerate their predictions of 3-D protein structures, which can play a crucial role in endeavors such as rational drug design, SDSC and NCSA researchers worked to optimize the Rosetta code used for such predictions. Using 1.3 million processor hours on TeraGrid Condor resources at NCSA and 730,000 processor-hours on the SDSC's BlueGene, 22 targets were determined and used to generate the high-resolution structures. SDSC also worked with the researchers for extreme-scaling modifications that allowed the Rosetta code to run its largest-ever computation on 40,960 processors of the 114 peak teraflop IBM Blue Gene Watson system. In an important step toward petascale computing, the computation allowed a complete, from scratch, prediction of a protein structure to be completed in less than three hours, something that requires several days on a 1,000-processor machine.



Discovering the 3-D structure of proteins opens the door to understanding their life-giving functions. Computational scientists from the San Diego Supercomputer Center at the University of California, San Diego collaborated with researchers in Howard Hughes Medical Institute investigator David Baker's group at the University of Washington to compute the high-resolution protein structure shown here. *Credit: Courtesy of R.C. Walker, SDSC/ UCSD; S. Raman, U. Washington Source: San Diego Supercomputer Center, UC San Diego*

Wireless Open-Access Research Platform for Networks (WARPnet)

Rice University is developing an experimental platform to advance high-speed wireless technology. The Wireless Open-Access Research Platform for Networks will help researchers develop and test next-generation wireless technology. It is expected to lead to collaborations among researchers and industry to design smarter, more robust and more efficient hardware and software for tomorrow's wireless applications. The work is supported by an MRI grant.

Cluster Exploratory (CluE)

A new Cluster Exploratory initiative will provide NSF-funded researchers with access to software and services running on a Google-IBM data cluster to explore innovative research ideas in data-intensive computing. The two companies created a large-scale computer cluster of approximately

1,600 processors to give the academic community access to the otherwise prohibitively expensive resources (also called data centers and server farms). NSF joined the project and will allocate cluster computing resources for a broad range of proposals to explore the potential of the massively scaled, highly distributed computing resources to contribute to science and engineering research and produce applications which promise to benefit society as a whole.

Team for Research in Ubiquitous Secure Technology (TRUST)

The Team for Research in Ubiquitous Secure Technology, another of NSF's STCs, addresses the need for the integration of secure, robust computing and communications capabilities across crucial infrastructures. Computer technologies are now part of the critical infrastructure for everything from telecommunications and finance to energy distribution and transportation. The need for security and reliability is of paramount importance in these modern, interconnected times. The center, located at the University of California, Berkeley, brings together computing experts, social scientists and the legal and policy communities to explore approaches to strengthening the security and trustworthiness of the nation's computing and critical infrastructures. Besides the University of California, Berkeley, TRUST's partners include Carnegie Mellon University, Cornell University, Stanford University, Vanderbilt University, Mills College, San Jose State University and Smith College.

Center for Embedded Networked Sensing (CENS)

The Center for Embedded Networked Sensing is an NSF STC at the University of California, Los Angeles that makes it possible for researchers to use embedded networked sensing systems to derive knowledge about the world around us. The large-scale, distributed systems are composed of smart sensors and actuators embedded in the physical world. Besides embedding sensor systems to learn about the natural systems, center researchers are also learning how to design better embedded systems. (See sidebar, below.)

Digital River Captures Data Flow

Scientists and engineers from the Center for Embedded Networked Sensing at the University of California, Los Angeles have tested a sensor deployment campaign at the confluence of California's Merced and San Joaquin Rivers. Their objective was to create a system for rapidly characterizing a complex river not only in terms of its bathymetry (underwater depth) and floodplain, but also its flow and water quality parameters. Using a robotic sensing device, researchers scanned flow and water quality conditions across transects taken upstream, downstream and within the confluence zone. Over a five-day period, they collected substantial data that resulted in a 3-D map of the confluence zone, which will be used with the transect data to create a multidimensional river model that scientists can use to analyze and forecast river conditions. CENS is one of NSF's STCs. For more information, see the NSF award abstract at http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0120778.

A robotic sensor node deployed over the Merced River in Washington State allows researchers to directly visualize the distribution and flow of contaminants. The sensor node is part of the University of California, Los Angeles' Network Infomechanical Systems (NIMS) project of the Center for Embedded Networked Sensing (CENS). *Credit: Network Infomechanical Systems (NIMS)/Center for Embedded Networked Sensing (CENS) (http://www.cens.ucla.edu/*

Arctic Observing Network (AON)

The Arctic Observing Network is an internationally supported network for providing critical observations of the Arctic environment and uses cyberinfrastructure tools to form a true network from the existing sites. AON responds to the need to understand the causes and consequences of Arctic change, and is part of the legacy of the IPY.

Exchange for Local Observations and Knowledge of the Arctic (ELOKA) Project

The Exchange for Local Observations and Knowledge of the Arctic project is another IPY-related activity supported by NSF. The data management and networking project facilitates the collection, preservation, exchange and use of observations and knowledge of the Arctic by local Arctic residents and indigenous peoples. NSF is also funding the National Snow and Ice Data Center's (NSIDC) participation in IPYDIS (International Polar Year Data and Information Service), a global partnership of data centers, archives and networks working to ensure proper stewardship of IPY and related data.

NSF investments in research infrastructure span the continuum from basic research and discovery to the development of new technologies, systems and other engineering solutions that make people's lives better, safer and more productive. Investments in fundamental research leading to emerging technologies such as sensors and sensor systems, photonics, metabolic engineering, bioengineering and manufacturing build and strengthen the nation's capacity to lead the world in innovation. Funding for research centers and networks, advanced instrumentation and facilities are enabling scientists and engineers to better understand the natural world and improve the ability of the built environment to adapt. NSF's Directorate for Engineering (ENG) is primarily responsible for providing and/or managing these investments.

Innovation Inspired by Human Need

The Tsunami Wave Basin at Oregon State University is the world's largest facility for investigating the effects of large waves. By studying the impact of tsunamis on model buildings (the boxes, above) and other structures, engineers and scientists can develop better designs and materials to mitigate damage to people and property. The Tsunami Wave Basin is part of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). *Credit: College of Engineering, Oregon State University*

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

Almost from the agency's start, NSF has been a key player in supporting research to understand earthquakes and prevent or mitigate the damage they cause. The George E. Brown, Jr. Network for Earthquake Engineering Simulation is a centerpiece of ongoing efforts. Constructed during FYs 2000-2004 and opened for operations on Oct. 1, 2004, NEES comprises a network of 15 earthquake engineering experimental equipment sites available for experimentation on-site, in the field and through remote operations. The sites, which include shake tables, geotechnical centrifuges, a tsunami wave basin, unique large-scale testing laboratory facilities, and mobile and permanently installed field equipment, help researchers understand how earthquake and tsunami forces affect ground motion and soil liquefaction, the built environment—buildings, bridges, utility systems—and nearshore and coastal environments. The NEES networking cyberinfrastructure connects, via Internet2, the equipment sites as well as provides telepresence, a curated central data repository, simulation tools and collaborative tools for facilitating on-line planning, execution and post-processing of experiments. The 15 NEES sites are:

- Cornell University - Large Scale Structural Lab
- Lehigh University - Large Scale Structural Lab
- Oregon State University - Tsunami Wave Basin
- Rensselaer Polytechnic Institute - Geotechnical Centrifuge Lab
- University at Buffalo - Shake Table and Large Scale Structural Lab
- University of California, Berkeley - Large Scale Structural Lab
- University of California, Davis - Geotechnical Centrifuge Lab
- University of California, Los Angeles – Mobile Field Testing Equipment
- University of California, San Diego - Shake Table Lab
- University of California, Santa Barbara – Instrumented Field Sites
- University of Colorado at Boulder - Large Scale Structural Lab
- University of Illinois at Urbana-Champaign - Large Scale Structural Lab
- University of Minnesota - Large Scale Structural Lab
- University of Nevada, Reno - Shake Table Lab
- University of Texas at Austin – Mobile Field Testing Equipment

Researchers at NEES sites are addressing critical challenges. The following examples are illustrative:

- In 2006, several months after Hurricane Katrina devastated New Orleans, a team of researchers used the centrifuge at Rensselaer Polytechnic Institute to model a section of the city's levees and subject it to forces similar to those that lead to the Katrina-related failure of the 17th Street Canal levee. The effort was part of the U.S. Army Corps of Engineers Hurricane Katrina Interagency Performance Evaluation Task Force.

- As part of a national effort to help make buildings safer in earthquakes, a team of engineering researchers concluded three months of earthquake simulation tests on a half-scale, three-story garage-like structure and are now sifting through the data. The goal is to help improve U.S. building codes. The NEES shake table at the University of California, San Diego, subjected the one-million pound, pre-cast concrete building to jolts as powerful as magnitude 8.0. The tested structure has one of the largest footprints of any structure ever tested on a shake table in the U.S.

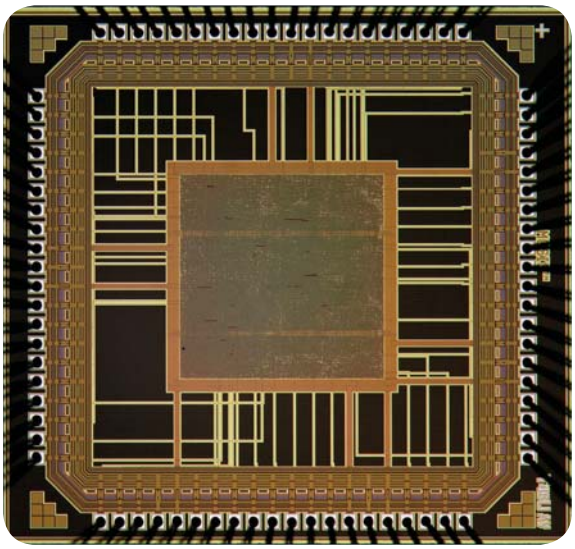
When the Ground Shakes, Is the Bridge Safe?

Researchers using the multiple shake table facility at the University of Nevada, Reno–part of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES)–are investigating the performance of large-scale models of four-span bridges and full-scale bridge components. *Credit: Lyle Carden, University of Nevada, Reno*

In a first-of-its-kind type of testing, researchers at the University of Nevada at Reno, one of the NEES sites, are examining the performance of entire four-span bridges along with the performance of individual bridge components to better understand the structures' ability to withstand earthquakes and other hazards. In cooperation with several other universities in the U.S. and abroad, the researchers are building large-scale models of bridges in the University of Nevada laboratory and subjecting them to simulated earthquake ground motions. They plan to study three models that are constructed with different materials and design details, and are built at about one-fourth the size of real bridges. The first bridge model, a conventional reinforced concrete structure about 110 feet long, was tested in February 2007. Two other bridge models that incorporate innovative seismic-resistant features will be tested over the next two years. Researchers from other NEES-supported facilities are contributing to the research. For example, researchers at the University of California, San Diego are using the large high-performance outdoor shake table there to study the seismic performance of full-scale bridge abutments. Engineers at Florida International University are fabricating, testing and modeling innovative piers, which will be incorporated in the bridge model. The project also involves a unique international collaboration with researchers at Japan's Tokyo Institute of Technology who are working with the University of Nevada team on the design of isolators that will be tested in the bridge columns. The project's results are expected to lead to improved design criteria and seismic codes, and they in turn should ensure better bridge performance in future earthquakes.

Engineering Research Centers (ERC)

NSF's Engineering Research Centers program was established in 1984 to develop a new interdisciplinary culture in engineering research and education in partnership with industry. The overarching objective was to strengthen the competitiveness of U.S. industry in the face of challenges from other countries. Now there have been three generations of this successful program that, among other advances, is credited with revolutionizing U.S. engineering education. The centers bring knowledge of industrial practices and needs to universities, and speed the translation of their research into useful products and processes. The partnerships have educated thousands of ERC engineering graduates who have proven to be more effective in speeding innovation in industry. The Gen-3 ERCs,



Researchers at the University of Southern California's Center for Biomimetic MicroElectronic Systems (BMES), an Engineering Research Center (ERC), developed this novel, mixed-signal system on a chip as a platform for implantable prosthetic devices. The goal is to create platforms for an entire range of implantable devices, including chips for use in restoring vision, reanimating paralyzed limbs and overcoming certain cognitive impairments. *Credit: USC BMES ERC*

starting with the Class of 2008, have been designed to build on the well-developed understanding laid down by the two previous generations, with several new dimensions designed to speed the innovation process and prepare engineering graduates who are innovative, creative and understand how to function in a global economy where engineering talent is broadly distributed throughout the world. These new dimensions include the engagement of small firms in the research programs to carry out translational research to speed innovation, partnerships with organizations devoted to entrepreneurship and innovation, and partnerships in research with foreign universities. NSF currently supports 15 ERCs:

- Biomimetic Microelectronic Systems - University of Southern California
- Biorenewable Chemicals - Iowa State University (Gen-3)
- Collaborative Adaptive Sensing of the Atmosphere - University of Massachusetts Amherst (see sidebar, next page)
- Compact and Efficient Fluid Power - University of Minnesota
- Extreme Ultraviolet Science and Technology - Colorado State University
- Future Renewable Electric Energy Delivery and Management Systems - North Carolina State University (Gen-3)
- Integrated Access Networks - University of Arizona (Gen-3)
- Mid-Infrared Technology for Health and the Environment - Princeton University
- Quality of Life Technology - Carnegie Mellon University/University of Pittsburgh
- Revolutionizing Metallic Biomaterials - North Carolina Agricultural and Technical State University (Gen-3)
- Smart Lighting - Rensselaer Polytechnic Institute (Gen-3)
- Structured Organic Composites - Rutgers University
- Subsurface Sensing and Imaging Systems - Northeastern University
- Synthetic Biology - University of California, Berkeley
- Wireless Integrated MicroSystems - University of Michigan

The mission of the ERC for Biomimetic Microelectronic Systems (BMES) is to restore neural function through the coordinated efforts of multidisciplinary research groups at the University of Southern California, the California Institute of Technology and the University of California, Santa Cruz. Center researchers are working on an implantable artificial retina that could help people who lose their sight due to genetic retinal diseases. The device was developed by Mark Humayun's research team at the University of Southern California and Second Sight Medical Products Inc. The prosthetic uses a tiny external camera and transmitter mounted on eyeglasses, an implanted receiver, and an electrode-studded array that is secured to the retina with a microstack the width of a human hair to send signals through an individual's still healthy neural pathways. The researchers are currently enrolling subjects for clinical trials of the second generation of the prosthetic implant (ARGUS II). Six patients were implanted with earlier prototypes in 2002 and were able to perceive light and detect motion. A clinically approved version of the prosthesis could be available within a few years, offering hope of restored vision for the millions of people who lose their sight due to macular degeneration and other eye diseases.

Research conducted at the Emerging Cardiovascular Technologies Center at Duke University has improved electrodes and biphasic waveforms, important to devices designed to shock the heart out of arrhythmia. The breakthroughs reduced the energy needed to defibrillate, which means less tissue damage and reductions in the size of defibrillators and the time needed to charge them, plus extended battery life. The developments made implantable defibrillators an option for a wider range of patients. Similarly, the improvements made external, portable defibrillators easier to use and cheaper to manufacture. Portable defibrillators are now found on airplanes, in shopping malls and in other public places. The worldwide market for implantable and portable defibrillators is estimated to be in the billions of dollars. The Duke center, which also developed the first 3-D ultrasound system that allowed physicians to examine a beating heart in real-time, was one of the ERCs started by NSF in 1987; the center graduated from agency support in 1996.

New Radar Network Evaluated for Detecting Severe Weather

Researchers at the NSF ERC for Collaborative Adaptive Sensing of the Atmosphere (CASA), located at the University of Massachusetts Amherst, have developed a new method of weather sensing that uses dense, low-cost radar networks to scan the lower atmosphere, an important area that is under-sampled by existing technologies. CASA researchers installed a prototype four-node distributed collaborative adaptive sensing system in the area known as tornado alley in southwestern Oklahoma. During the 2007 tornado season, they transmitted real-time data to National Weather Service (NWS) forecasters for evaluation in the Experimental Warning Program. The testbed radar network's finely grained observations allowed forecasters to see small meteorological structures that were close to the ground, such as mini-wind clusters that are embedded in larger storms. NWS classified one of these observed circulations as an EF1 tornado (having wind gusts of 86-110 miles per hour). The center's data continued to be evaluated in the Experimental Warning Program during the 2008 tornado season. The research could lead to better predictions of when and where tornados and other weather disturbances will occur. For more information, see the NSF highlight at http://www.nsf.gov/eng/highlights/eec/0313747.McLaughlin.pdf.

Damaged houses are all that remain after a powerful tornado tore across central Oklahoma in May 1999, killing 36 people and causing a billion dollars in damage. Researchers are working to develop new and better radar systems in an effort to improve predictions of when and where severe weather will strike. *Credit: © University Corporation for Atmospheric Research, photo by Bob Henson*

Industry/University Cooperative Research Centers (I/UCRC)

NSF's Industry/University Cooperative Research Centers program develops long-term partnerships among industry, academia and government. The centers focus on research in crucial areas of interest to both industry and university researchers such as advanced electronics, advanced manufacturing, advanced materials, biotechnology, civil infrastructure systems, information-communication-computing systems, energy and environment, fabrication and processing technology, health and safety, and system design and simulation. I/UCRCs are catalyzed by a small investment from NSF and are primarily supported by the center's members. NSF supports 47 existing and planned centers (listed in Appendix I) and, in July 2008, the agency released a solicitation for new center proposals. The following are just three examples of the wide-ranging activities and impacts of I/UCRCs:

- Since its founding in 1986, the Berkeley Sensor and Actuator Center (BSAC) has been a pioneer in the world of microelectromechanical systems (MEMs). One of the most common uses of the micro-sized machines today is in accelerometers to trigger the release of airbags in automobiles. Other unique devices fabricated by BSAC include microresonators, microphotonic systems, ultrasonic sensors, microhypodermic injection needles, microsignal processing filters, microencapsulation shells, micropumps and micromixers that employ both low-stress membranes and piezoelectric films. Center researchers are also developing wireless networks of "smart dust" sensing nodes that can be interrogated remotely.

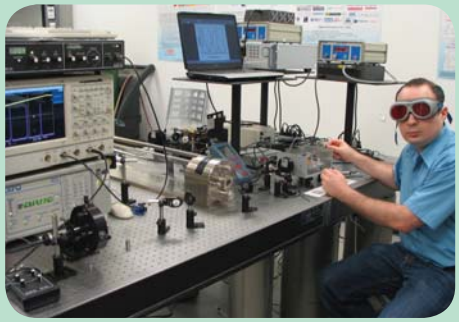
- The Center for Repair of Buildings and Bridges with Composites (RB2C), the I/UCRC based at the University of Missouri at Rolla and North Carolina State University, focuses on civil infrastructure systems. Using new fiberglass-polymer materials, contractors in Springfield, Mo., subjected a decaying, 70-year-old bridge to a makeover that was as quick as it was dramatic. The workers used prefabricated plates and cages developed by RB2C researchers and

others to finish the bridge reconstruction job in a mere five days. The Missouri researchers joined with their industry partners and colleagues at the University of Wisconsin-Madison to develop the new construction solution. Before the renovation, local officials had imposed weight restrictions on vehicles using the old bridge on Farm Road 148 near Springfield because of the structure's dangerous condition.

- With help from an MRI grant, plus other program support, researchers at the University of Minnesota-Twin Cities have developed a new generation of miniature robot "scouts" that can be thrown or placed in buildings, hazardous areas or hostile territory to collect and provide intelligence. Equipped with multiple sensors, including a camera, the robots drive to a particular location and transmit video to handheld receivers up to 300 feet away. The first robot scouts were developed at the Center for Safety, Security and Rescue Research, an I/UCRC located at the University of South Florida and the University of Minnesota. Researchers at the University of Minnesota, the University of Pennsylvania and the California Institute of Technology are now working to develop software that will allow groups of small robots to coordinate their actions and carry out complex commands from a human operator.

Researchers Develop Mid-infrared Laser "Optical Nose"

Researchers at the University of Alabama at Birmingham, supported by an MRI grant, have developed a powerful system combining three types of lasers that could rapidly detect a wide range of substances in complex mixtures, including trace gases at the parts-per-trillion level. Designed to detect and identify many types of organic molecules, the system combines high power, low noise and coverage of the infrared spectrum that matches a large library of molecular energies. Potential uses for the "optical nose" include detecting the presence of oil, pollutants in the atmosphere, harmful chemical or biological substances, or the early stages of disease. For more information, see the NSF award abstract at http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0521036.



A team of researchers at the University of Alabama at Birmingham, led by physics professor Sergey Mirov, developed a novel laser-based "optical nose" for the rapid identification and quantification of organic trace-gases in multi-compound gas mixtures with full biochemical specificity and high sensitivity. Above, Dmitri Martyshkin uses the optical nose for sensing hydrogen fluoride molecules. *Credit: Courtesy Sergey Mirov, University of Alabama at Birmingham*

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs

NSF continues to play a major role in encouraging innovation by small companies, and the results contribute to both the nation's research infrastructure and American competitiveness. The primary objective of the Small Business Innovation Research and Small Business Technology Transfer programs is to increase the incentive and opportunity for small firms to undertake cutting-edge, high risk, high quality scientific, engineering or science/engineering education research that would have a high potential economic payoff, if the research is successful. With SBIR support, engineers created a solid-state micro-fan that is the most powerful and energy efficient fan of its size. The device produces three times the flow rate of a typical small mechanical fan and is one-fourth the size. It could provide a low-power, low-maintenance cooling system for laptop computers and

For the first time, a robot, acting independently and without a human operator, aided doctors performing surgery in 2005. The Penelope Surgical Instrument Server (SIS), developed in part with funding from NSF's Small Business Innovation Research (SBIR) program, successfully delivered and retrieved instruments during the procedure to remove a tumor. *Credit: Courtesy of New York-Presbyterian Hospital*

other electronic devices. The engineers began work on the device as NSF-supported graduate students at Purdue University, and they continued their work with an SBIR award. The STTR program further expands the public/private partnership to include joint venture opportunities for small businesses and nonprofit research institutions. A significant difference between the SBIR and STTR programs is that the STTR requires researchers at universities and other research institutions to play a significant intellectual role in the conduct of each STTR project. By joining forces with a small company, the university-based researchers can spin-off their commercially promising ideas while they remain primarily employed at the research institution.

Center of Advanced Materials for the Purification of Water With Systems (WaterCAMPWS)

The Center of Advanced Materials for the Purification of Water With Systems, one of NSF's STCs, was established to develop revolutionary new materials and systems for safely and economically purifying water for human use, while simultaneously developing the diverse human resources needed to exploit the research advances and the knowledge base created. The center is led by the University of Illinois at Urbana-Champaign. Its primary objectives are desalination/reuse, decontamination, and disinfection. A team of researchers at WaterCAMPWS has developed a promising new photocatalyst called TiON. There have been several versions of the nitrogen-doped titanium oxide material and the latest has achieved tremendous increases in disinfection rates, plus it works in visible light instead of the ultraviolet range that is necessary for today's technologies for water decontamination. The Metropolitan Water Reclamation District of Greater Chicago is currently testing TiON using real wastewater in a laboratory setting.

NSF's investments in research infrastructure are not limited to equipment and facilities. Developing and maintaining longitudinal surveys, panel studies and large data sets for use by researchers to better understand human actions and decision making are another way NSF provides the tools most needed by social scientists and other researchers. The studies described below, and supported by NSF's Directorate for Social, Behavioral and Economic Sciences (SBE), are examples of what is available to researchers to help them develop a panoramic view of the economic, political and social indicators that define American life and gain a better understanding of how society functions and changes over time. Analyses of the data help policymakers shape important programs and policy recommendations. SBE also coordinates a cross-directorate centers program that helps researchers gain new insights into how people acquire knowledge. As the principal source of federal support for strengthening science and engineering education through education research and development, NSF invests in educational research infrastructure and centers to attract people to science, technology, engineering and mathematics, help prepare future generations of scientists and engineers, and broaden participation of underrepresented groups, geographic regions and types of institutions involved in science and engineering fields. NSF's EHR Directorate is a primary supporter of many of these activities.

The Human Element

The NSF-supported research infrastructure enables researchers and educators to study and develop a deeper understanding of human actions and decision making, the social dimensions of knowledge and technology, and how people learn. *Credit: Photos.com*

The General Social Survey (GSS)

At the core of America's social science research infrastructure, the General Social Survey of the National Data Program for the Social Sciences has chronicled the attitudes, beliefs and opinions of more than 44,000 adults from a cross-section of American households since 1972. Recent GSS enhancements have incorporated Spanish language capability and data collection on social context and social units other than individuals and households. Researchers at the National Opinion Research Center (NORC) at the University of Chicago conduct the GSS, and have documented over 8,500 uses of the GSS among researchers. Considered the "gold standard" of social science research, the GSS has inspired such cross-cultural surveys as the International Social Science Program and the European Social Survey. NSF, in collaboration with the U.S. Department of Homeland Security (DHS), has funded the addition of a new module to the ongoing survey to measure the public's preparedness for disasters and acts of terrorism, and reasons for action/inaction. The new data could assist policymakers in crafting effective public education efforts.

The Panel Study of Income Dynamics (PSID)

The Panel Study of Income Dynamics is the world's longest running, nationally representative panel survey. With nearly 40 years of data on the same families and their descendents, the PSID can justly be considered a cornerstone of the data infrastructure for empirically-based social science research in the U.S. and the world. The study began with 4,800 individuals and their family units in 1968, and has grown to nearly 8,000 families with over 65,000 individuals, some of whom have participated for nearly 40 years. Frank Stafford, a professor of economics at the University of Michigan, directs PSID data collection efforts. The longitudinal study's design and content variables, which focus on economic and demographic data, income, employment, family composition changes and residential location, have remained largely unchanged over time. Consistent and comparable data is what makes the study so valuable to researchers. Newer topics in the PSID include housing and food expenditures, housework time, health, wealth, child development, family dynamics and issues related to aging. The PSID data archive is among the world's most advanced and heavily used.

Science Resources Statistics (SRS)

The NSF Division of Science Resources Statistics (SRS) produces publications, data and analyses about the U.S. science and engineering enterprise. As mandated by the National Science Foundation Act, the division collects and analyzes data to inform the public and to assist policymakers in the development of national science policy. SRS designs, supports and directs about 11 periodic surveys as well as a variety of other data collections and research projects. These activities yield the materials for SRS staff to disseminate quantitative information about domestic and international resources devoted to science, engineering and technology. SRS has primary responsibility for *Science and Engineering Indicators*, the biennial publication of the NSB. Called the "gold standard," *Indicators* provides a comprehensive source of information on the state of science and engineering research and education in the U.S. SRS data have provided insight into the value of investing in research and development (R&D). If R&D spending were treated as investment in the U.S. national income and product accounts, the nation's gross domestic product (GDP) would be nearly 3 percent higher each year between 1959 and 2004, according to a joint analysis in 2007 by the Commerce Department's Bureau of Economic Analysis (BEA) and NSF. BEA and NSF's SRS developed the R&D satellite account as a supplemental set of data that can be factored into economic measurements to determine the impact of R&D spending on U.S. growth and productivity. In 2004 alone, the U.S. GDP would have been $284 billion more with the R&D satellite account.

Science and Engineering Indicators, published every other year by the National Science Board, provides a wealth of information about the state of science and engineering in the U.S. The 2008 edition's cover celebrates International Polar Year 2007-2009 with images from the Arctic and Antarctic regions. *Credit: Ice cave: Zenobia Evans, National Science Foundation (NSF). Images right to left: Josh Landis, NSF; Katrin Iken and Bodil Bluhm, University of Alaska, Fairbanks; The Hidden Ocean, Arctic 2005 Exploration; Ariana Owens, NSF; Patrick Smith; Ken Ryan, NSF; Jerry Marty, NSF).*

Preserving and Making Available Endangered Languages

An illustration showing "Mopan" as a Mayan glyph. *Credit: Andrew Hofling, Southern Illinois University*

Of the estimated 6,500 to 7,000 languages that exist in the world, some 3,000 will become extinct in the next century. Globalization, strife and political turmoil are among the factors contributing to language losses. Once a language's native speakers are gone, understanding the history and culture of that population becomes more difficult, if not impossible. We also lose what those languages could have taught us about human cognition. NSF-supported researchers are working against time to document, preserve and make available to others as many of these endangered languages as possible. For example, Andrew Hofling of Southern Illinois University has compiled digital databases for the Yukatekan branch of Mayan languages, and he is currently conducting field research to produce bilingual Mopan-Spanish and Mopan-English dictionaries, of the Mopan Maya language, spoken in the Petén region of Guatemala and southern Belize. Meslissa Axelrod and others from the University of New Mexico are working with a Native American community north of Santa Fe, the Nanbé Tewa, to document its language and populate an Internet-based archive with materials, including conversations, stories and historical narrative; a dictionary with full lexical and grammatical coverage; and a video production showing traditional bread-making, with accompanying fully annotated dialog. Nanbé Tewa is one of the most endangered of currently spoken languages: out of 650 tribal members, there are only 36 fluent speakers and their average age is around 70 years old. NSF also is helping to make endangered language materials more widely accessible. In 2004, the Rosetta Project, a global collaboration to build a publicly accessible digital library of human languages, became a National Science Digital Library collection. With more than 100,000 pages of material documenting over 2,500 human languages, the Rosetta Archive is thought to be the largest resource of its kind on the Internet. The Rosetta Project is sponsored by the nonprofit Long Now Foundation, with support from the Stanford University Libraries and NSF.

Science of Learning Centers (SLC)

While all of NSF's investments in research infrastructure have an educational component, other investments have education as their main focus. The Science of Learning Centers are an example. They are built around a unifying research focus on the science of learning, and they incorporate diverse, multidisciplinary environments involving appropriate partnerships with academia, industry, international partners, all levels of education and other public and private entities. NSF supports the following SLCs:

First Group of SLC Awards

- Center for Learning in Education, Science and Technology - Boston University
- Pittsburgh Science of Learning Center: Studying Robust Learning - Carnegie Mellon University
- LIFE Center-Learning in Formal and Informal Environments - University of Washington

Second Group

- Visual Language and Visual Learning - Gallaudet University
- Spatial Intelligence and Learning Center - Temple University
- Temporal Dynamics of Learning Center - University of California, San Diego

Centers of Research Excellence in Science and Technology (CREST)

One of NSF's goals, as set forth in the *NSF Strategic Plan FY 2006-2011*, is the cultivation of a world-class, broadly inclusive science and engineering workforce, and expansion of the scientific literacy of all citizens. The Centers of Research Excellence in Science and Technology play a vital role in efforts to broaden participation by all individuals in science and engineering. The program makes resources available to enhance the research capabilities of minority-serving institutions through the establishment of centers that effectively integrate education and research. CREST promotes the development of new knowledge, enhancements of the research productivity of individual faculty, and an expanded presence of students who have been historically underrepresented in STEM disciplines. The list of CREST centers is included in Appendix I.

CREST Center Contributes to TerraFly Project

Florida International University in Miami is the lead institution for the CREST Center of Emerging Technologies for Advanced Information Processing. The Florida International University center produces some 20 percent of the nation's computer science Ph.D.s among Hispanic students. In 2001, Florida International University launched TerraFly, an Internet-based technology it developed that uses spatial data sets including high-resolution imagery collected by the USGS to allow users to virtually "fly-over" most locations in the U.S. using only a Web browser. Florida International University's CREST center contributed major research and development to the TerraFly project.

TerraFly makes high-resolution, aerial imagery layered with street, business and demographic data available to anyone using a Web browser. The Center of Emerging Technologies for Advanced Information Processing, an NSF Center of Research Excellence in Science and Technology (CREST) led by Florida International University, contributed major research and development to the TerraFly project. *Credit: Naphtali Rishe, Florida International University*

North Carolina Agricultural and Technical State University's Center for Advanced Materials and Smart Structures conducts research in the areas of nanoengineered and surface-engineered coatings and materials, nanocomposites and other innovative composites, and electronic and smart materials and structures. Jagannathan Sankar, distinguished professor of mechanical engineering, received Phase I and II CREST awards and is now the principal investigator for the new Gen-3 ERC for Revolutionizing Metallic Biomaterials. The center, to be located at North Carolina Agricultural and Technical State University, will develop interdisciplinary research and education programs to revolutionize medical implants and related health care issues, and provide the foundation for new industries through innovation. It is the first ERC to be headquartered at a historically black college or university.

Historically Black Colleges and Universities Research Infrastructure for Science and Engineering (HBCU-RISE)

The Historically Black Colleges and Universities Research Infrastructure for Science and Engineering program is another part of NSF's efforts to strengthen the science and engineering research and education capabilities of minority-serving institutions. Program support helps to develop the research capability at HBCUs that offer doctoral degrees in science and engineering disciplines. The HBCU-RISE centers are listed in Appendix I.

National Science Digital Library (NSDL)

The National Science Digital Library is the nation's online library for education and research in science, technology, engineering and mathematics. It was established by NSF in 2000, under the auspices of the multiagency Digital Library Initiative. NSDL provides organized access to high quality resources and tools that support innovations in teaching and learning at all levels of science,

technology, engineering and mathematics education. More than 200 projects have been funded to create collections and services for teachers and learners at all levels, and to perform targeted research in digital libraries and their application to education. NSDL can be accessed at http://nsdl.org/ .

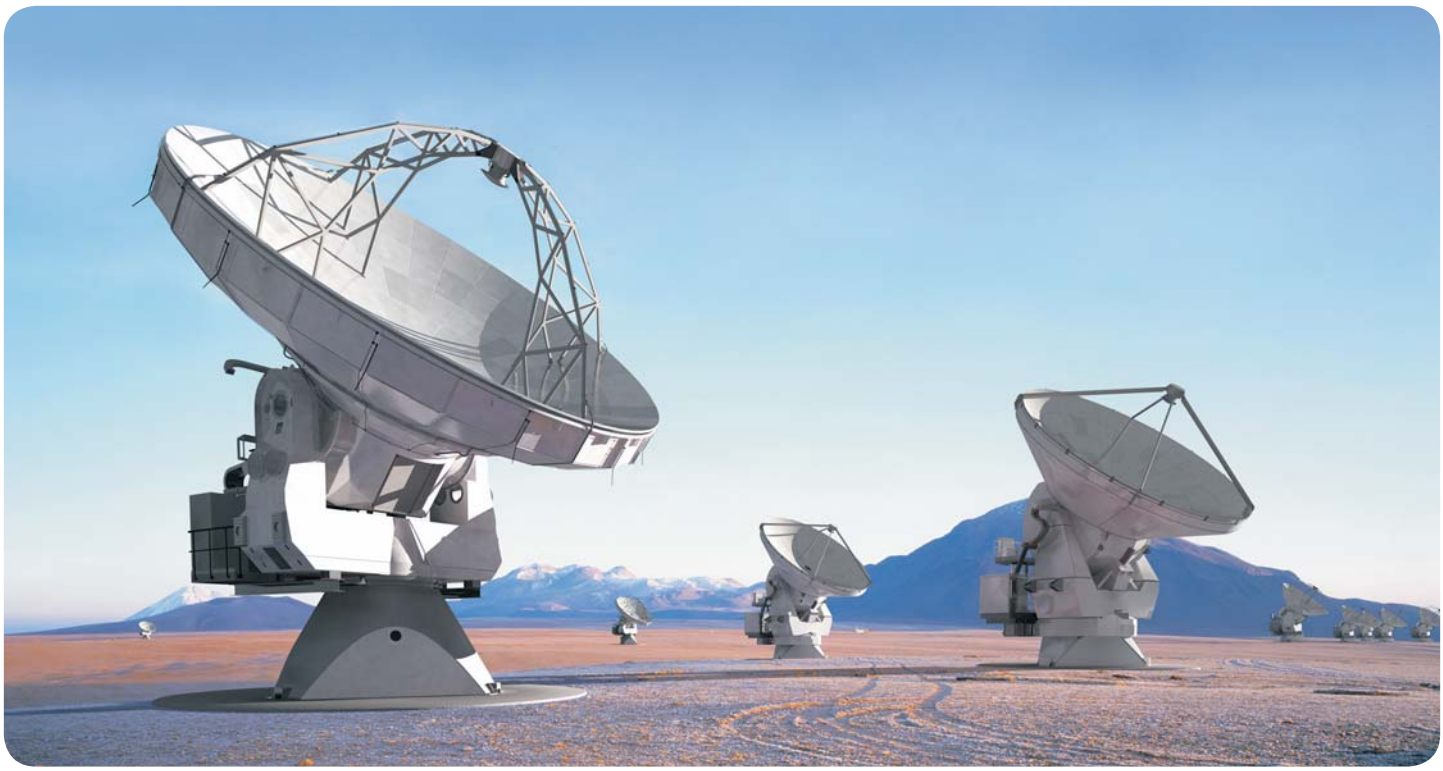
The Fun Works: A Dynamic Digital Library for STEM Careers

The Fun Works (http://www.thefunworks.org/) is an innovative digital library that engages young people in the exploration of career opportunities in STEM fields. Developed by the Education Development Center, the Fun Works is supported by NSF's National Science, Technology, Engineering and Mathematics Education Digital Library. The Fun Works is designed for–and by–middle school students. The Education Development Center first consulted approximately 300 middle-school students from diverse backgrounds in Boston to learn about student Web site preferences and interest in science-related careers. Then, a middle-school team of four girls and four boys from a Boston community technology center worked with the center to develop the site's contents. The result is a dynamic digital library that uses music, sports and other "real world" contexts to interest young people in science-related careers.

The Fun Works, a Web site for middle-school students, encourages young people to think about becoming the scientists and engineers of tomorrow. Part of NSF's National Science Digital Library initiative, the site uses the students' current interests and passions, including sports and music, to help younger visitors explore future science, technology, engineering and mathematics careers. *Credit: Education Development Center Inc.*

Powerful radio and optical telescopes are providing scientists with a better look at the universe. Astronomers have discovered new "dwarf planets" within our solar system, more than 300 extra-solar planets orbiting stars other than our own, and a black hole at the center of the Milky Way. Meanwhile, a startling discovery by astronomers in 1998—that the rate of the expansion of the universe is accelerating—continues to excite and energize the field. Many of these developments and other cutting-edge results relied on ground-based telescopes and related facilities supported by the Division of Astronomical Sciences (AST) in NSF's Mathematical and Physical Sciences (MPS) Directorate. The facilities listed below have been essential to the nation's progress in astronomical science. Meanwhile, the National Research Council of the National Academy of Sciences and others have proposed new facilities needed to pursue emerging areas of scientific interest and to ensure that the U.S. astronomy program remains a world-leader. Anticipating concern that support of new facilities might limit NSF's ability to maintain the current research infrastructure, senior AST program managers asked an external group of experts to conduct an extensive review of the division's portfolio of facilities, and, in November 2006, this group of experts provided a number of recommendations (the Senior Review) to AST to balance current needs and future opportunities. For more on the AST Senior Review, see http://www.nsf.gov/mps/ast/ast_senior_review.jsp.

(The Answers Are) Out There



An artist's conception of the VertexRSI antenna (left foreground) and the AEM antenna (right foreground) superposed on a photo of the Atacama Large Millimeter Array (ALMA) site. When completed, ALMA will be the world's most sensitive and highest resolution millimeter-wavelength telescope, enabling researchers to explore fundamental questions of astronomy. ALMA also will play a central role in the education and training of U.S. astronomy and engineering students who are expected to account for at least 15 percent of ALMA's approximately 2,000 anticipated yearly users. *Credit: Courtesy of ALMA/ESO/NRAO/NAOJ*

National Optical Astronomy Observatory (NOAO) and National Solar Observatory (NSO)

The National Optical Astronomy Observatory and the National Solar Observatory operate telescopes and supporting instrumentation that enable research on some of the most compelling science questions in astronomy and solar physics. The facilities provide researchers with powerful and sophisticated tools to peer deep into space and back in time to investigate age-old questions and unexplained phenomena including the expansion of the universe, the formation and evolution of galaxies and individual stars, the evolution of planetary systems, and the generation, structure and dynamics of solar surface magnetic fields. The telescopes have been used in work leading to some of the most profound breakthroughs in astronomy and cosmology in recent years. For example, the NOAO 4-meter telescope in Chile was used in the remarkable 1998 discovery of the accelerating rate of the expansion of the universe, which led to the realization that the universe is permeated with a mysterious "dark energy." Understanding the nature of dark energy is one of the major questions in contemporary physics. NOAO operates the following facilities.

- **Kitt Peak National Observatory** (KPNO), located in the Quinlan Mountains near Tucson, Ariz., boasts a large collection of optical telescopes and some of the finest night skies in the world. In addition to the three telescopes that KPNO operates directly—the Mayall 4-meter, the Wisconsin-Indiana-Yale-NOAO (WIYN) 3.5 meter and the small 2.1-meter telescopes—the observatory hosts another 19 optical telescopes and two radio telescopes for various astronomy consortia.

This panorama of Kitt Peak National Observatory (KPNO) near Tucson, Ariz., shows telescopes and instrumentation operated by the National Optical Astronomy Observatory (NOAO) and the National Solar Observatory (NSO), including the triangular McMath-Pierce solar facility in the foreground and the WIYN 3.5-meter telescope on the far left. *Credit: NOAO/AURA/NSF*

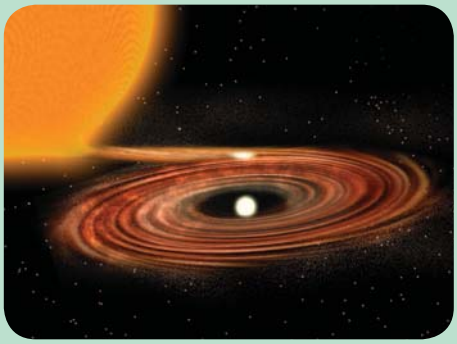
- **Cerro Tololo Interamerican Observatory** (CTIO) near La Serena, Chile, operates the 4-meter Blanco telescope and the 4-meter SOAR telescope, which is funded by NOAO, Brazil, Michigan State University and the University of North Carolina. Three smaller telescopes at CTIO are operated by a university consortium with a portion of telescope time available through NOAO.

- The **Gemini Science Center**, in Tucson, Ariz., coordinates access for U.S. astronomers to the twin optical/infrared 8-meter telescopes that comprise the **Gemini Observatory** (see next page).

NOAO also manages the U.S. astronomy community's involvement in the development of future infrastructure projects such as the Giant Segmented Mirror Telescope and the Large Synoptic Survey Telescope, both of which are high priority recommendations of the 2000 Decadal Survey conducted by the National Research Council's Astronomy and Astrophysics Survey Committee. Furthermore, NOAO administers the Telescope System Instrumentation Program (TSIP), funded by NSF, which supports improving instrumentation at private observatories in exchange for observing time for the general community.

Dusty Disks Revealed

Observations of an interacting binary star by a team of astronomers and educators suggest that the disks of hot gas that accumulate around a wide variety of astronomical objects— from white dwarf stars in energetic binary systems to supermassive black holes at the hearts of active galaxies—are likely to be much larger than previously believed. As part of a program called the Spitzer-NOAO Observing Program for Teachers and Students, Steve B. Howell of NOAO and a team of astronomers and educators used the 2.1-meter telescope and the WIYN 0.9-meter telescope, both located at Kitt Peak National Observatory, and NASA's Spitzer Space Telescope to image an interacting binary star (called WZ Sagittae) located in the constellation Sagitta. Interacting binary stars such as WZ Sagittae contain a white dwarf star (a compact star about the size of the Earth, but with a mass near that of the Sun) and a larger, but less massive and much cooler, companion star. The companion star has material ripped off its surface by the stronger gravity of the white dwarf. The material flows toward the white dwarf, forming an accretion disk surrounding the smaller star. The "standard accretion disk" model is a geometrically thin disk of gaseous material surrounding the white dwarf. Howell's team obtained optical observations that confirmed the standard view of the accretion disk size and temperature. However, mid-infrared observations were completely unexpected. They revealed that a larger, thicker disk of cool dusty material surrounds much of the gaseous accretion disk. This outer dust disk likely contains as much mass as a medium-sized asteroid. The newly discovered outer disk extends about 20 times the radius of the gaseous disk. The implications from such a discovery are far reaching, affecting not only the theoretical models, but also nearly all previous observations of systems containing accretion disks.



An artist's concept of the generally accepted model of an accretion disk in the binary star system WZ Sagittae. New data from Kitt Peak National Observatory and the Spitzer Space Telescope revealed a larger, thicker disk of cool, dusty material surrounding much of the gaseous accretion disk. An illustration of the new model can be viewed at http://www.noao.edu/image_gallery/html/im1044.html. *Credit: P. Marenfeld and NOAO/AURA/NSF*

The NSO operates facilities in Sunspot, N.M., and at KPNO. These facilities offer the world's largest collection of optical and infrared solar telescopes and auxiliary instrumentation for observation of the solar photosphere, chromosphere and corona, as well as a coordinated worldwide network of six telescopes specifically designed to study solar oscillations (Global Oscillations Network Group). Both NOAO and NSO are deeply involved in education and training of the next generation of astronomers and solar physicists. They offer research experiences for undergraduate students and afford use by graduate students to conduct research for their advanced degrees. Modern visitors' centers and Web sites featuring online image galleries and other outreach content contribute to promoting public understanding of and interest in astronomy. Each summer, for example, approximately 30 teachers are immersed in science at the NSO. The NOAO's Hands-On Optics program has engaged 17,000 middle-school students in activities with lenses, mirrors, lasers and mini-kaleidoscopes.

NOAO and NSO are managed and operated by the Association of Universities for Research in Astronomy, Inc. (AURA) under a cooperative agreement that runs through March 2009.

Gemini Observatory

The twin telescopes of the Gemini Observatory are helping astronomers explore important questions about the age and rate of expansion of the universe, its structure, the evolution of galaxies and the formation of stars and planetary systems. Gemini South is located at an almost 9,000-foot elevation on a mountain in the Chilean Andes called Cerro Pachon. The Frederick C. Gillett Gemini North Telescope is located on Hawaii's Mauna Kea, a long dormant volcano that rises almost 14,000 feet into the dry, stable air of the Pacific. Located on two of the best sites on Earth for observing the universe, the telescopes together can access the entire sky. The Gemini Observatory's international headquarters is in Hilo, Hawaii, at the University of Hawaii. Both of the Gemini telescopes have

been designed to take advantage of the latest technology and thermal controls to excel in a wide variety of optical and infrared capabilities. Gemini was built and is operated by a partnership of 7 countries—the U.S., United Kingdom, Canada, Chile, Australia, Brazil and Argentina. NOAO represents the U.S. astronomical community in the International Gemini Project. Enhanced operational and visitor support and a new generation of advanced instrumentation including the construction of the Gemini Planet Imager, a camera designed to directly detect planets orbiting nearby stars, are in the planning stages.

Advanced Technology Solar Telescope (ATST)–In Planning

The Advanced Technology Solar Telescope, now in planning, would provide unprecedented observations of solar plasma processes and magnetic fields, and enable a deepening understanding of the Earth's nearest star, the Sun. The facility would be built at the Haleakala High Altitude Observatory on the Hawaiian island of Maui and, if constructed, it would be the first new large U.S. solar telescope in 30 years. The ATST has the potential to become the world's flagship facility for ground-based solar physics observation. The 4-meter, off-axis Gregorian (all reflective) telescope with integrated adaptive

A rendering of the proposed Advanced Technology Solar Telescope (ATST) as it would appear with the existing facilities of the Haleakala High Altitude Observatories in Hawaii. *Credit: Tom Kekona, KC Environmental Inc.*

optics would have a field view of 3 arc minutes, an angular resolution of less than 0.03 acc seconds, and wavelength sensitivity that spans the entire visible and near-infrared regions of the electromagnetic spectrum. Its light grasp would be a factor of ten greater than the largest solar telescope in existence, and adaptive correction would yield an increase in angular resolution of a factor of three to seven over the best adaptively corrected systems currently available. The ATST is an international collaboration, involving 22 institutions from the U.S. and eight other countries. The project is managed by NSO. Continuation of design and future construction depends upon successful project design reviews, continued prioritization by NSF, NSB approval and the availability of federal funds.

National Astronomy and Ionosphere Center (NAIC)

The National Astronomy and Ionosphere Center, in operation since 1962 and the world's largest single-dish radio telescope, is used in radio astronomy, planetary radar and ionospheric physics. Radio astronomers and planetary scientists use the NAIC facility to study such diverse areas as interstellar gas, galactic structure formation and evolution, pulsars, and topics in solar system astronomy such as the physical properties of asteroids, planetary surfaces and moons. The center's principal observing facilities include a 305-meter fixed spherical radio/radar telescope. Made famous to non-astronomers in movies such as "Contact" and "Golden Eye," the dish is located near the town of Arecibo in western Puerto Rico. The facility has been used for ground-breaking research by many prominent scientists over the decades, including Nobel laureates Russell Hulse and Joseph Taylor. They studied the evolution of the orbits of binary neutron star systems, when one of the orbiting stars is a pulsar, to confirm the formulation of gravitational radiation put forth in Einstein's General Theory of Relativity. The facility provides users with a wide range of research instrumentation, including an L-Band Feed Array, essentially a seven-pixel camera that allows astronomers to collect data about seven times faster

than before. The NAIC, like other NSF facilities, places strong emphasis on education and outreach. It was one of NSF's first sites for the Research Experiences for Undergraduates (REU) program. NAIC sponsors a major outreach program in Puerto Rico with a modern visitors' center, a learning center and summer programs for K-12 teachers. The facility attracts approximately 120,000 visitors a year, including K-12 school groups from across Puerto Rico. NAIC is operated and managed for NSF by Cornell University under a cooperative agreement that runs through March 31, 2010.

The November 2006 report of the AST Senior Review committee recommended, among other things, that NSF reduce support for NAIC's base operating budget to $8 million over the next three years. Cornell and Arecibo staff are actively pursuing opportunities for partnerships with, and support from, others to maintain the observatory as a viable facility for scientific research, education and public outreach. A final decision about the NAIC's long-term future is expected by the time of NSF's FY 2011 budget.

National Radio Astronomy Observatory (NRAO)

The National Radio Astronomy Observatory designs, builds and operates state-of-the-art telescopes for studying the universe by means of radio waves. Scientists from around the world use these powerful tools to study the Sun, planets and other objects in our own solar system, as well as distant stars, galaxies and other mysterious objects many millions, or billions, of light-years away. NROA facilities include the following:

This map shows the locations of the 10 radio antennas of the Very Long Baseline Array (VLBA). The antennas function together as one instrument with very high resolution and sensitivity. *Credit: NRAO/AUI*

- Major radio telescopes located in Green Bank, W.Va.—the Green Bank Interferometer, Green Bank 140-ft Telescope and the Robert C. Byrd Green Bank Telescope (GBT). The GBT is the world's largest, fully steerable radio telescope. Its surface measures 100 by 110 meters—roughly two acres. The telescope can rotate 360 degrees on a track that is 210 feet in diameter, yet level to within a few thousandths of an inch, and capable of bearing 16 million pounds of moving weight.

- The **Very Large Array (VLA)** features 27 operating antennae in a "Y" pattern spread out through the plains of San Augustin, N.M., and arranged in one of four configurations that are changed every few months. In their closest configuration, the antennas cover about 0.6 miles (1 kilometer), while in the largest configuration, they span up to 22 miles (36 kilometers) across and are able to hone in on the fine details of astronomical objects. At its highest frequency, the VLA has a resolution of .04 arc seconds. Through the Expanded VLA (EVLA) project, NSF is refurbishing and updating the telescope's receivers to allow increased data sensitivity, more efficient transmission of data, and fine-tuned estimates of how emissions vary with frequency. The EVLA project's planned completion date is 2011.

- The **Very Long Baseline Array (VLBA)** consisting of 10 radio antennas at locations ranging from St. Croix in the Virgin Islands to Mauna Kea in Hawaii. Observation data are recorded on digital tape at each antenna site. At the Socorro, N.M., operations center, the data on the tapes are correlated and then delivered to the scientists. The AST Senior Review has recommended a reduction in support for the VLBA beginning in FY 2011.

NRAO is also the North American implementing organization for the international Atacama Large Millimeter Array (ALMA) project (see next page). Associated Universities, Inc. (AUI) operates NROA under a cooperative agreement with NSF.

Interstellar Chemistry Gets More Complex

An artist's concept showing how scientists believe negatively charged octatetraynyl formed in space. Astronomers searching archival data from the Robert C. Byrd Green Bank Telescope found the molecule, a chain of eight carbon atoms and one hydrogen atom, in the envelope of gas around an old, evolved star and in a cloud of molecular gas. *Credit: Bill Saxton, NRAO/AUI/NSF*

Astronomers using data from the GBT have found the largest negatively charged molecule yet seen in space. The discovery was the third negatively charged molecule, called an anion, found in less than a year, and it could force a drastic revision of theoretical models of interstellar chemistry, according to astronomers. Two teams of scientists found negatively charged octatetraynyl--a chain of eight carbon atoms and one hydrogen atom--in the envelope of gas around an old, evolved star and in a cold, dark cloud of molecular gas. In both cases, the molecule had an extra electron, giving it a negative charge. Anthony Remijan of NRAO and his colleagues found the octatetraynyl anions in the envelope of an evolved giant star (called IRC +10 216) about 550 light-years from Earth, in the constellation Leo. They found radio waves emitted at specific frequencies characteristic of the charged molecule by searching archival data from the GBT. Another team from the Harvard-Smithsonian Center for Astrophysics found the same characteristic emission when they observed a cold cloud of molecular gas (called TMC-1) in the constellation Taurus. These observations also were done with the GBT. In both cases, earlier laboratory experiments by the Harvard-Smithsonian team showed which radio frequencies actually are emitted by the molecule, and thus told the astronomers what to look for. The discovery could lead to new insights into the formation of amino acids and other compounds in regions of space that spawn stars and planets.

Atacama Large Millimeter Array (ALMA)

The Atacama Large Millimeter Array is a giant international observatory under construction in the 5,000-meter high Atacama Desert in northern Chile. It will be the world's most sensitive and highest resolution millimeter-wavelength telescope, providing astronomers with an unprecedented ability to explore the universe as seen at wavelengths from 3 millimeters to 0.4 millimeters. The high sensitivity and resolution in this range of the spectrum will allow researchers to test novel theories about the origins of stars and planetary systems, the nature of early galaxies and the evolution of the universe. When completed, ALMA will comprise an array of 50 high precision 12-meter antennas, plus 16 additional antennas in a component array, that work together as one telescope. With its adjustable configurations, ALMA will provide researchers with a "zoom lens" to focus deep in space. ALMA construction is carried out through a partnership between North America, Europe and Japan. The North American side, consisting of the U.S. and Canada, is led by AUI through NRAO.

South Pole Telescope (SPT)

The South Pole Telescope is a 10-meter telescope designed to study phenomena such as the formation and evolution of the early universe and the formation and evolution of solar systems like our own. It was first assembled in Kilgore, Texas, then taken apart and shipped to New Zealand, and then flown from there to the South Pole where it was reassembled. Telescope construction is funded primarily by NSF, with additional support from the Kavli Foundation of Oxnard, Calif., and the Gordon and Betty Moore Foundation of San Francisco. A major milestone for the project, SPT's first light—the scientific term for the time when a telescope becomes operational—occurred in February 2007.

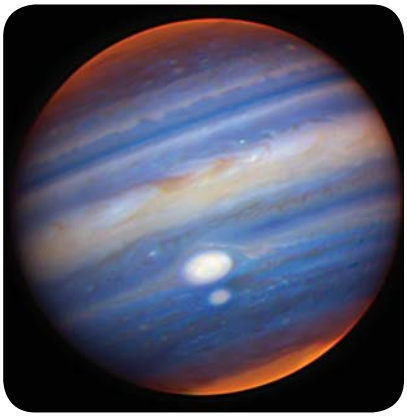
The South Pole Telescope (left) is located in the "Dark Sector" at Amundsen-Scott South Pole Station. The Dark Sector is an area devoid of light and radio interference. *Credit: Calee Allen, National Science Foundation*

Martin A. Pomerantz Observatory (MAPO)

The Martin A. Pomerantz Observatory, one of the facilities provided by the U.S. Antarctic Program, houses equipment that scientists use to store and analyze observations from the astronomical instruments around the South Pole.

Center for Adaptive Optics (CfAO)

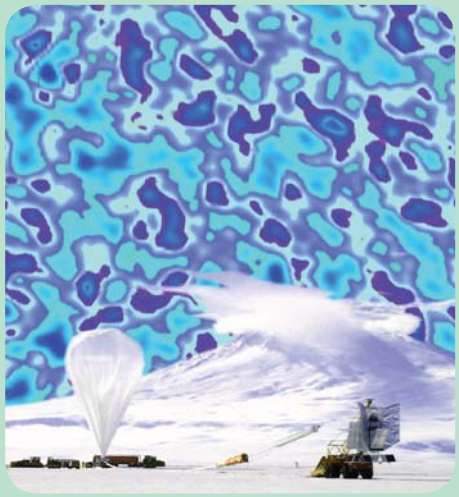
Researchers at the Center for Adaptive Optics, one of NSF's STCs, have developed technologies that enable telescopes to obtain clear, sharp images of space. Telescopes at the W.M. Keck, Gemini and other observatories are now equipped with sophisticated adaptive optics technology so they can overcome the turbulence in the Earth's atmosphere that causes images of stars and planets to appear fuzzy. The Keck Observatory was used by University of California, Los Angeles astronomer Andrea Ghez in her research to estimate the mass of a black hole at the center of the Milky Way galaxy. Adaptive optics have another application that, at first glance, appears very different from astronomy. Researchers at CfAO are studying the capabilities for adaptive optics to correct people's vision and enhance imaging of the retina in the diagnosis and treatment of eye diseases. The center's industrial partners, such as Bausch & Lomb, would facilitate the transfer of research results into marketable products, such as drugs for glaucoma and age-related macular degeneration.



This color composite image of Jupiter and its two "red" spots was obtained in near-infrared light using Gemini North's adaptive optics which correct, in real-time, for most of the distortions caused by turbulence in Earth's atmosphere. In the near-infrared, the red spots appear white. *Credit: Gemini Observatory*

Seeing the Universe in Infancy

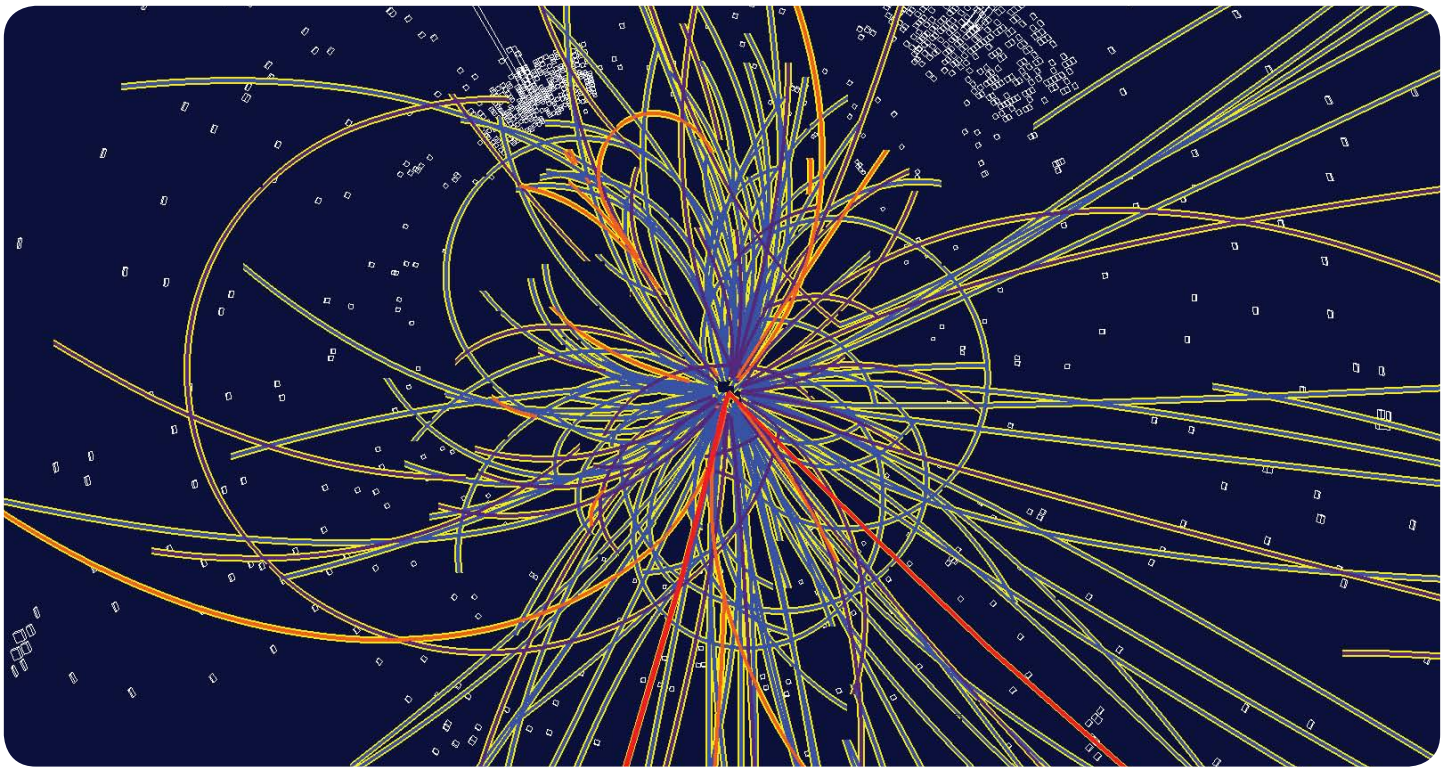
An international team of cosmologists supported in part by NSF produced the first detailed images of the universe in its infancy. The work brought into sharp focus the faint glow of microwave radiation, called the Cosmic Microwave Background (CMB), that filled the embryonic universe soon after the Big Bang. The information was assembled from measurements of the subtle temperature differences in the CMB radiation. The BOOMERANG (Balloon Observations of Millimetric Extragalactic Radiation and Geomagnetics) project captured the data using an extremely sensitive telescope suspended from a balloon that circumnavigated Antarctica in 1998. The atmospheric circulation over the continent allows balloons that are released near McMurdo Station, NSF's logistics hub in Antarctica, to circle the continent and return to be retrieved almost at the point of launch. Andrew Lange of the California Institute of Technology shared the 2006 Balkan Prize for Astronomy and Astrophysics with his BOOMERANG co-investigator, Paolo de Bernardis of Italy, in recognition of their contributions to cosmology. For more information, see the NSF news release at http://www.nsf.gov/news/news_summ.jsp?cntn_id=103063



A composite image showing the sky over Antarctica's Mt. Erebus, overlaid with images of the early universe as seen by the BOOMERANG experiment to indicate the size fluctuations in the Cosmic Microwave Background (CMB) that would appear if a 35-millimeter camera were sensitive to microwave light. The color map of the CMB images has been changed here to aesthetically match the rest of the picture. *Credit: Boomerang Team*

A research infrastructure that offers advanced capabilities and cutting-edge tools is necessary to transform the frontiers of research and deepen our knowledge of the physical world. NSF's Directorate for Mathematical and Physical Sciences supports state-of-the-art facilities and instrumentation that give researchers new powers to observe and analyze phenomena of great scientific interest, and, hopefully, unlock secrets of matter, energy, time and space, opening new windows on the universe.

Universal Laws and Order



Simulation of a detection of the Higgs boson in the Compact Muon Solenoid (CMS) experiment, one of two detectors built by NSF and the Department of Energy for the Large Hadron Collider. Over the next decade, the LHC will, among other things, enable a search for the Higgs particle, the existence and properties of which would provide a deeper understanding of the origin of mass of known elementary particles. *Credit: CERN*

Laser Interferometer Gravitational-Wave Observatory (LIGO)

The Laser Interferometer Gravitational-Wave Observatory is the most sensitive gravitational wave detector built to-date. Gravitational waves are ripples in the fabric of space-time, produced by rare cataclysmic events emanating from supernovae, pulsars and neutron star collisions occurring as far away as 50 million light years, and black hole mergers occurring at still greater ranges throughout the universe. Though Albert Einstein predicted the existence of gravitational waves in his 1918 general theory of relativity, their existence has never been directly observed. The observatory consists of three Michelson interferometers located at Hanford, Wash., and Livingston, La.—locations approximately 3,000 kilometers apart. The separation between the two locations ensures that the very small signals induced by gravitational waves in the LIGO apparatus can be distinguished from local sources of random noise that may affect one site, but not both simultaneously.

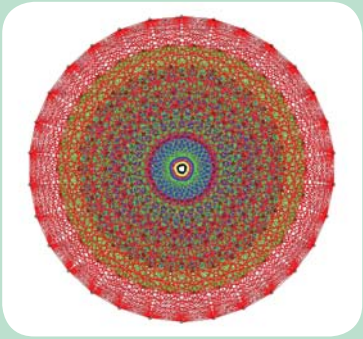
Aerial view of the Laser Interferometer Gravitational-Wave Observatory (LIGO) site at Livingston, La., looking south along one of its two interferometer arms. LIGO consists of three interferometers at two locations—the other location is Hanford, Wash.—that are approximately 3,000 kilometers apart. *Credit: LIGO Laboratory, California Institute of Technology*

Advanced Laser Interferometer Gravitational Wave Observatory (AdvLIGO)

The Advanced Laser Interferometer Gravitational Wave Observatory is a planned upgrade that will improve by a factor of 10 the sensitivity of LIGO. Since the volume of space that the instrument can examine varies as the cube of the sensitivity, AdvLIGO would look at a volume of space 1,000 times larger. As a result, a few hours of AdvLIGO observation time would equal one year of LIGO observations—greatly enhancing the chances of directly observing gravitational waves. The upgrade also comes with a change in the bandwidth of high sensitivity and the ability to tune the instrument for specific astrophysical sources. The upgrade is expected to help maintain U.S. leadership in this area of fundamental physics and keep pace with competing instruments abroad, which are also receiving upgrades. AdvLIGO is completing pre-construction planning activities. If the project moves forward, AdvLIGO could be expected to begin full operations in 2015.

A Calculation the Size of Manhattan

An international team of researchers studying the properties of nature's most important groups of symmetries has mapped E8, an extraordinarily complex object described by a numerical matrix of more than 400,000 rows and columns. The four-year effort involved eighteen researchers who planned and executed the computation using powerful computers and programming techniques. The magnitude of the calculation is staggering: the answer, if written out in tiny print, would cover an area the size of Manhattan. For comparison, the human genome, which contains all the genetic information of a cell, is less than a gigabyte in size. The result of the E8 calculation, which contains all the information about E8 and its representations, is 60 gigabytes in size. The final phase of calculations was performed on the NSF-funded supercomputer of the SAGE (System for Algebra and Geometry Experimentation) project, directed by William Stein at the University of Washington. The collaborative effort to map E8 is part of a larger project, sponsored by NSF through the American Institute of Mathematics, that is known as the Atlas of Lie Groups and Representations. Its goal is to map out all of the Lie groups—a collection of symmetries that permits smooth transitions from one motion to another, such as cones, spheres and their higher-dimensional counterparts. E8, an object of interest for applications in physics and mathematics, is the largest of the exceptional Lie groups. For more information, see the NSF news release at http://www.nsf.gov/news/news_summ.jsp?cntn_id=108482.



The E8 root system consists of 240 vectors in an eight-dimensional space. Those vectors are the vertices (corners) of an eight-dimensional object called the Gosset polytope 421. In the 1960s, Peter McMullen drew by hand a two-dimensional representation of the Gosset polytope 421. The image above was computer generated by John Stembridge, based on McMullen's drawing. *Credit: John Stembridge, University of Michigan*

Large Hadron Collider (LHC)

The Large Hadron Collider, an international project at the European Organization for Nuclear Research (CERN) Laboratory in Geneva, Switzerland, will be the world's premier facility for research in elementary particle physics. The high-energy accelerator will send beams of protons around a 27-kilometer (km) long, underground ring to smash them into other protons circulating from the other direction. The collisions will create brief showers of very exotic materials that physicists will examine as they seek out new types of matter. Detectors stationed around the ring will produce some 15 trillion gigabytes of data each year. The LHC will enable a search for the Higgs particle, the existence and properties of which will provide a deeper understanding of the origin of mass of known elementary particles. The facility will also enable a search for particles predicted by a powerful theoretical framework, known as supersymmetry, which could provide clues to how the four known forces evolved from different aspects of the same unified force in the early universe. Physicists expect the LHC experiments to help answer fundamental questions, including what is dark energy, do undiscovered dimensions of space exist and what is dark matter. NSF's contribution to the LHC includes support for the construction, maintenance and operation of two detectors: A Toroidal LHC ApparatuS (ATLAS) and the Compact Muon Solenoid (CMS). DOE is collaborating with NSF on support for the detectors. ATLAS and CMS are designed to characterize the different reaction products produced in the very high-energy proton-proton collisions that will occur in interaction regions where the two counter-circulating beams collide. In June 2008, NSF and DOE announced that the U.S. contribution to the LHC was completed on budget and ahead of schedule. On Sept. 10, 2008, the first beam of protons was sent around the particle accelerator's 27-kilometer underground ring. After further tests of the beams and acceleration systems, the beams will be brought into collision. Data-taking is expected to begin when beam performance stabilizes.

IceCube Neutrino Observatory

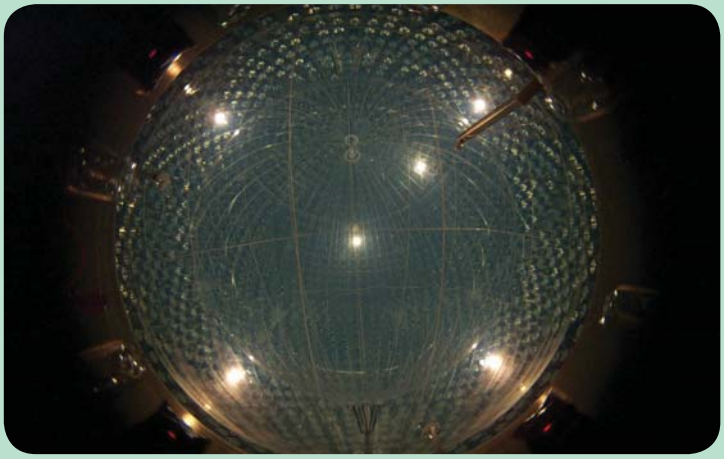
The IceCube Neutrino Observatory, under construction deep in the clear ice at the South Pole, will be the world's first high-energy neutrino observatory. The South Pole is a strikingly inhospitable place to build and operate a telescope. But ice also happens to be an excellent medium for observing neutrinos—nearly massless particles created by exotic deep-space events such as supernovae (the death explosions of large stars)—as they pass through the Earth. One cubic kilometer of ice is being instrumented with photomultiplier (PM) tubes to detect charged reaction products from high-energy neutrino interactions in

A view of the signal cables from strings of Digital Optical Modules (DOMs) extending down into the ice. The IceCube Neutrino Observatory, under construction in the highly transparent ice beneath the surface of the South Pole, will be composed of 70 strings of DOMs and 140 surface cosmic ray air detector modules. *Credit: Kathie L. Olsen, National Science Foundation*

the ice within or near the fiducial volume (the sensitive volume for detection). An array of Digital Optical Modules (DOMs), each containing a PM and associated electronics, will be positioned uniformly from 1.45 to 2.45 kilometers beneath the surface of the South Pole ice cap in highly transparent, bubble-free ice. IceCube will be comprised of 70 strings of DOMs and 140 surface cosmic ray air shower detector molecules upon completion. Astrophysicists from the University of Wisconsin are leading the construction project. IceCube is an international partnership with construction co-funding from Belgium, Germany and Sweden, as well as the U.S.

First Real-time Detection of Low-energy Neutrinos Streaming From the Sun's Core

An international team of researchers has detected elusive, low-energy solar neutrinos—subatomic particles produced in the core of the Sun—and measured in real-time the rate the particles hit the Earth. The researchers also obtained fresh evidence that neutrinos oscillate (transform from one state to another) before arriving on Earth, adding weight to current theories about the nature of neutrinos and the inner workings of the Sun and other stars. The team of more than 100 researchers, including NSF-supported investigators at Princeton University and Virginia Tech, have operated the so-called Borexino experiment in one of the deepest laboratories in the world, the Gran Sasso Laboratory of the Istituto Nazionale di Fisica Nucleare (INFN), the Italian National Institute of Nuclear Physics, near the town of L'Aquila, Italy. The 18-meter (59-foot) diameter Borexino detector lies more than a kilometer (almost a mile) underground at a depth that blocks out cosmic rays and other radiation sources that could create additional background signals. These are the first results from the Borexino experiment. It has been under construction since the late 1990s, with the support of INFN as the lead agency, and NSF in the U.S., and institutions in Germany, France and Russia. As it moves into a precision measurement phase, the Borexino detector will enable further probes that produce new knowledge about the properties of neutrinos and the Sun. For more information, see the NSF news release at http://www.nsf.gov/news/news_summ.jsp?cntn_id=109893.



The fully-assembled Borexino detector is visible from multiple cameras embedded in the structure. In the image above, the view of the interior of the sphere is distorted by the camera lens. *Credit: INFN*

National Superconducting Cyclotron Laboratory (NSCL)

The National Superconducting Cyclotron Laboratory is the leading rare isotope research facility in the U.S. Located on the campus of Michigan State University, the national user facility operates two superconducting cyclotrons–K500 was the world's first cyclotron to use superconducting magnets and K1200 is the highest-energy continuous beam accelerator in the nation. Through the Coupled Cyclotron Facility (CCF), the two cyclotrons make even rarer isotopes. Heavy ions are accelerated by the K500 and then injected into the K1200, enabling the production of rare unstable isotopes at much higher intensities. The research conducted by NCSL scientists is important to understanding stellar processes. Michigan State operates the facility under a cooperative agreement with NSF that was renewed in FY 2007 and runs through FY 2011.

This superconducting magnet was developed by researchers at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University to withstand the high radiation environment required for isotope research. *Credit: Chen-yu Gung, MIT Plasma Science and Fusion Cente*

Cornell Electron-positron Storage Ring (CESR)

The Cornell Electron-positron Storage Ring is an electron-positron collider that provides important knowledge of the properties of the b-quark. The facility has a circumference of 768 meters, and is located 12 meters below a parking lot and an athletic field on the Cornell University campus. It is capable of producing collisions between electrons and their anti-particles, positrons, with center-of-mass energies between 9 and 12 GeV. When an electron and positron collide and annihilate, the flash of energy results in the creation of new matter, sometimes exotic and unfamiliar. The products of these collisions are studied with a large and complex detection apparatus, called the CLEO detector.

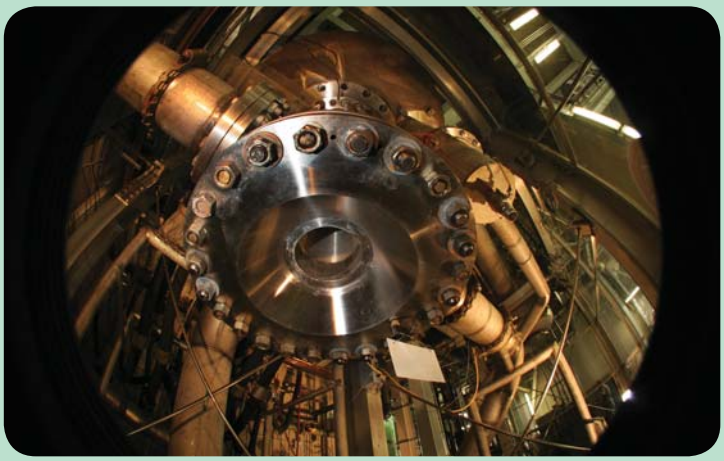
Use of the CESR as a facility for particle physics will conclude with final phase-out over the 2008 and 2009 fiscal years. With the closeout of the particle physics program at the CESR, physicists at Cornell are ramping up their participation in the research program of the Compact Muon Solenoid (CMS) experiment, one of two major detectors at the LHC (see page 64).

National High Magnetic Field Laboratory (NHMFL)

The National High Magnetic Field Laboratory develops and operates state-of-the-art, high-magnetic-field facilities and is among the preeminent facilities in the world for researchers and engineers studying superconductivity and other materials research. In operation since 1994 and the only facility of its kind in the U.S., the NHMFL seeks to provide the highest magnetic fields for scientific research. It holds numerous records—including the current Guinness World Record for highest magnetic field for a continuous field magnet of 45 tesla—which is about one million times the Earth's magnetic field. The record-setting measure provides researchers with a unique scale of magnetic energy to create novel states of matter and probe deeper into electronic and magnetic materials. High magnetic fields are crucial to fundamental research advances in a broad range of disciplines including biology, biochemistry, bioengineering, chemistry, engineering, geochemistry, materials science, medicine and physics. In cooperation with industry, the NHMFL also advances magnet and magnet materials technology. The NHMFL is operated by Florida State University, the University of Florida and Los Alamos National Laboratory.

Getting Warmer: High Magnetic Field Researchers Make Surprising Quantum Physics Discovery

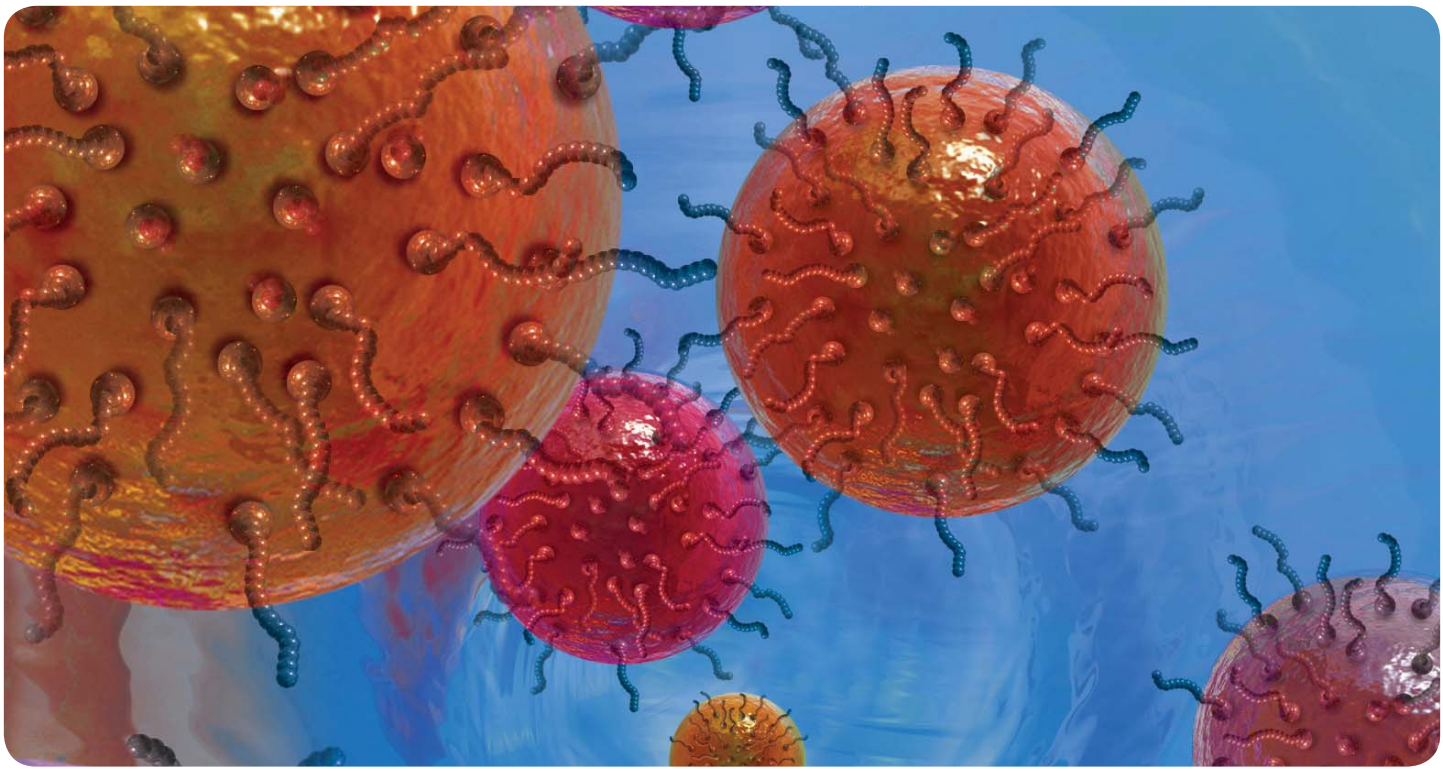
An international team of scientists working with the highest magnetic fields at Florida's NHMFL and in the Netherlands recently observed the quantum Hall effect–a much studied phenomenon of the quantum world–at room temperature. The quantum Hall effect is the basis for the international electrical resistance standard used to characterize even everyday materials that conduct electricity. Before the surprising discovery, the general view was that the quantum Hall effect was observable only at temperatures close to absolute zero (minus 459 degrees Fahrenheit; minus 273 degrees Celsius). The scientists at the NHMFL in the U.S. and at the High Field Magnet Laboratory in the Netherlands put graphene, a recently developed form of carbon made of a single atomic sheet of atoms about as strong as diamond, in very high magnetic fields, and observed the surprising result. The work could lead to a new generation of ultra-small electrical devices. For more information, see the NSF News From the Field story at http://www.nsf.gov/news/news_summ.jsp?cntn_id=110213.



The National High Magnetic Field Laboratory's (NHMFL) 45 tesla hybrid magnet (shown from below) is the strongest magnet of its kind in the world. It holds numerous records including a Guinness World Record. Weighing 35 tons and requiring 400 liters of chilled water per second to keep it cool, the 45 tesla hybrid magnet provides researchers with a unique scale of magnetic energy to create novel states of matter and probe deeper into electronic and magnetic materials. *Credit: Florida State University*

The potential of successfully utilizing our knowledge of various states and properties of matter is only beginning to be realized. NSF's investments in equipment, facilities and centers allow researchers to advance our understanding of materials, and enable scientists to create new, smart materials that are designed for particular uses. Nanotechnology is just one of the promising areas of materials science that is yielding new knowledge. Someday, the ability to manipulate matter at the nanoscale could revolutionize the design and manufacture of most products. The impact of nanotechnology products is projected to exceed $1 trillion worldwide by 2015. NSF-supported research infrastructure is playing a crucial role in preparing the U.S. for leadership in this brave new nanotechnology world. Another area of frontier research is the study of superconducting materials. Supported primarily by NSF's Directorate for Engineering and Directorate for Mathematical and Physical Sciences, research infrastructure in these and related areas enable scientists and engineers to advance our knowledge of the material world.

Big Ideas, Small Packages



The discovery of unexpected magnetic interactions between nanoparticles of rust is leading to a revolutionary, low-cost technology for cleaning arsenic from drinking water. Researchers from the Center for Biological and Environmental Nanotechnology (CBEN) at Rice University described the purification technique in the journal *Science*. CBEN is one of NSF's Nanoscale Science and Engineering Centers, where research at the scale of one nanometer (one billionth of a meter) is leading to breakthroughs in such critical fields as advanced computing, communications, materials development and medicine. *Credit: CBEN/Rice University*

Nanoscale Science and Engineering Centers (NSEC)

Nanotechnology, which addresses technology on the smallest of scales, is projected to be one of the largest drivers of technological innovation for at least the next decade and beyond. This potential was recognized in the National Nanotechnology Initiative and more recently in the American Competitiveness Initiative, particularly in the burgeoning area of nanomanufacturing. Research at the nanoscale through NSF-funded Nanoscale Science and Engineering Centers aims to advance the development of the ultrasmall technology that will transform electronics, materials, medicine, environmental science and many other fields. Each center has a long-term vision for research. Together they provide coherence and a long-term outlook to U.S. nanotechnology research and education; they also address the social and ethical implications of such research. Support is provided for education and outreach programs from K-12 to the graduate level, and is designed to develop a highly skilled workforce, advance precollege training, and further public understanding of nanoscale science and engineering. The centers have strong partnerships with industry, national laboratories and international centers of excellence, which puts in place the necessary elements to bring discoveries in the laboratory to real-world, marketable innovations and technologies. The NSECs currently supported by NSF are:

- Affordable Nanoengineering of Polymer Biomedical Devices - Ohio State University
- Integrated and Scalable Nanomanufacturing - University of California, Los Angeles
- Directed Assembly of Nanostructures - Rensselaer Polytechnic Institute
- Electronic Transport in Molecular Nanostructures - Columbia University
- High Rate Nanomanufacturing - Northeastern University, University of New Hampshire, University of Massachusetts-Lowell
- Integrated Nanomechanical Systems - University of California, Berkeley, California Institute of Technology, Stanford University, University of California, Merced
- Integrated Nanopatterning and Detection Technologies - Northwestern University
- Molecular Function at the Nano/Bio Interface - University of Pennsylvania
- Nanotechnology in Society Network: Center at ASU - Arizona State University
- Nanotechnology in Society Network: Center at UCSB - University of California, Santa Barbara
- Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems - University of Illinois at Urbana-Champaign
- Nanoscale Systems in Information Technologies - Cornell University
- Nanoscience in Biological and Environmental Engineering - Rice University
- National Nanomanufacturing Network: Center for Hierarchical Manufacturing - University of Massachusetts Amherst
- Probing the Nanoscale - Stanford University, IBM
- Science of Nanoscale Systems and their Device Applications - Harvard University
- Templated Synthesis and Assembly at the Nanoscale - University of Wisconsin-Madison

NSEC researchers are making discoveries that advance knowledge in wide-ranging fields of science. Two examples:

- A team of researchers at the NSEC for Integrated Nanopatterning and Detection Technologies at Northwestern University have developed an experimental procedure that has detected miniscule amounts of proteins known as ADDLs in fluid samples from around the brain and spinal cord. The proteins have been linked in other studies to Alzheimer's disease. The procedure, announced in 2005, uses the team's novel bio-bar-code (BCA) amplification technology as a extremely sensitive and highly selective biosensing system. BCA is about one million times more sensitive than standard enzyme-linked immunoassays, according to the researchers. If proven successful in further clinical studies, the procedure could become the first tool for early diagnosis of Alzheimer's and the first test to conclusively identify the disease in living patients.

- Researchers associated with the Center for Nanotechnology in Society at Arizona State University surveyed a national random sample of American households and more than 360 leading nanoscale science and engineering researchers in the U.S., and they found differences between the public's and scientists' perceptions about the risks and benefits of nanotechnology. Often with emerging technologies, researchers perceive higher benefits while the public senses higher risks. The survey found that the researchers perceived higher benefits from nanotechnology than the public across most categories, especially in the areas of treating diseases, a cleaner environment and solving energy problems. The public perceived greater risks than the researchers in such areas as loss of privacy, use of nanotechnology by terrorists and a loss of jobs. But surprisingly, the researchers perceived higher risks from nanotechnology than the public in the categories of health and environment.

World's Smallest Radio

Harnessing the electrical and mechanical properties of the carbon nanotube, a team of researchers crafted a working radio from a single carbon fiber. Fixed between two electrodes, the vibrating tube successfully performed the four critical roles of a radio—antenna, tunable filter, amplifier and demodulator—to tune in a radio signal generated in the room and play it back through an attached speaker. Functional across a bandwidth widely used for commercial radio, the tiny device could have applications far beyond novelty, from radio-controlled devices that could flow in the human bloodstream to highly efficient, miniscule, cell phone devices. The device was developed by researchers at the Center of Integrated Nanomechanical Systems at the University of California, Berkeley and the Lawrence Berkeley National Laboratory. The center is one of NSF's NSECs. For more information, see the NSF news release at http://www.nsf.gov/news/news_summ.jsp?cntn_id=110566.

This image, taken by a transmission electron microscope, shows a single carbon nanotube protruding from an electrode. The nanotube is less than a micron long and only 10 nanometers wide, or 10,000 times thinner than the width of a single human hair. The radio waves, added for visual effect, are not part of the original microscope image. Credit: Zettl Research Group, Lawrence Berkeley National Laboratory and University of California at Berkeley

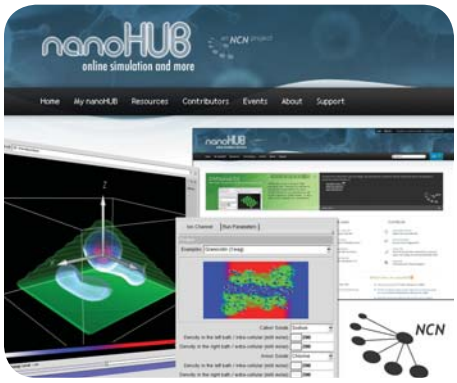
National Nanotechnology Infrastructure Network (NNIN)

The National Nanotechnology Infrastructure Network is an integrated partnership of thirteen user facilities, supported by NSF, that provide unparalleled opportunities for nanoscience and nanotechnology research. The network provides extensive support in nanoscale fabrication, synthesis, characterization, modeling, design, computation and hands-on training in an open environment, available to all qualified users. NNIN partners are:

- Center for Nanoscale Systems - Harvard University
- Center for Nanotechnology - Nanotech User Facility - University of Washington
- Cornell Nanoscale Facility - Cornell University
- Howard Nanoscale Science and Engineering Facility - Howard University
- Michigan Nanofabrication Facility - University of Michigan
- Microelectronics Research Center - University of Texas-Austin
- Microelectronics Research Lab - Georgia Tech
- Minnesota Nanotechnology Cluster - University of Minnesota
- Nanoscience @UNM - University of New Mexico
- Nanotech - University of California, Santa Barbara
- Penn State Nanofabrication Facility - Penn State University
- Stanford Nanofabrication Facility - Stanford University

Network for Computational Nanotechnology (NCN)

The Network for Computational Nanotechnology is a multi-university initiative that was launched in September 2002 to create a unique, Web-based infrastructure to serve researchers, educators and students. The NCN Web site, www.nanohub.org, is a "science gateway" that hosts collaborative tools and delivers unique educational resources such as online courses, learning modules, lectures and seminars on nanotechnology. The institutions involved in NCN are Purdue University, Northwestern University, Morgan State University, Stanford University, University of Florida, University of Illinois and the University of Texas at El Paso.



The Network for Computational Nanotechnology (NCN) Web site is a "science gateway" that hosts collaborative tools and delivers unique educational resources. Pictured at right are the nanoHUB home page and several nanoHUB applications including the bioMOCA tool and quantum dot simulation results. The nanoHub enables researchers to use the simulations on their personal computers with an ordinary Web browser. *Credit: Mark Lundstrom, Director, Network for Computational Nanotechnology, Purdue University*

The NCN is making it possible for more researchers to conduct nanoscale research from remote locations. Researchers at Purdue University are operating a virtual environment of Web-based simulation tools, believed to be the first of their kind, that enable scientists and engineers to remotely interpret raw data collected with powerful microscopes. Since the virtual environment for dynamic atomic force microscopy, or VEDA, went online in 2007, more than 300 researchers from around the world have used it to learn about the magnetic, electrical and physical properties of materials. The tools are provided through the nanoHub, a unique cyberinfrastructure provided by the NCN. The nanoHub uses NSF's TeraGrid high-speed fiber optic network. The VEDA virtual environment was described in a cover story in the June 2008 issue of the journal *Review of Scientific Instruments*. For more information, see the NSF news item at http://www.nsf.gov/news/news_summ.jsp?cntn_id=111957.

Centers for Chemical Innovation (CCI)

The Centers for Chemical Innovation are designed to support research on strategic, transformative "big questions" in basic chemical research. Appropriate research problems for the centers (originally known as Chemical Bonding Centers) are high-risk but potentially high-impact and will attract broad scientific and public interest. Among the grand challenges of interest to center researchers are emulating or even surpassing the efficiency of photosynthesis to capture the Sun's energy; learning how molecules combine to become living things; activating strong bonds as a means to store and use chemical energy and to lower energy costs in chemical processing; and designing self-assembling, complex structures with useful functions. The CCI program is a two-phase program. Phase I centers receive significant resources to develop the scientific, educational, innovation and management aspects of a CCI before requesting Phase II funding. NSF is currently supporting the following CCIs:

Phase II

- Center for Enabling New Transformations Through Catalysis - University of Washington
- Powering the Planet - California Institute of Technology (2008 award)

Phase I

- Center for Molecular Cybernetics - Columbia University
- Chemistry at the Space-Time Limit - University of California, Irvine
- Orchestrating Proton Transport Through Supramolecular Alignment of Functionalities - University of Massachusetts Amherst
- The Origins Chemical Inventory and Early Metabolism Project - Georgia Tech
- Center for Green Materials Chemistry – Oregon State University (2008 award)
- Center for Molecular Interfacing – Cornell University (2008 award)
- Center for Chemistry of the Universe – University of Virginia (2008 award)

New Technique for Extracting Oxygen From Water

Using a simple and inexpensive technique, researchers at the Massachusetts Institute of Technology announced a way to pull pure oxygen from water using relatively small amounts of electricity and common chemicals. Daniel Nocera, the Henry Dreyfus Professor of Energy at the Massachusetts Institute of Technology, and Matthew Kanan, a postdoctoral fellow in Nocera's lab, developed the process using a new catalyst that produces oxygen gas from water. Another catalyst produces valuable hydrogen gas. The oxygen and hydrogen could be recombined inside a fuel cell, creating carbon-free electricity, day or night. The technology could remove the biggest barrier to large-scale use of solar energy—the need to store solar energy for use when the Sun isn't shining. Nocera is a member of the Powering the Planet center's partnership between the California Institute of Technology, the Massachusetts Institute of Technology and several other institutions. In his role as a co-investigator with the center, Nocera has been pursuing sustainable energy technology through a broader effort to learn from, and apply, the lessons of photosynthesis and other natural processes. For more information, see the NSF news release at http://www.nsf.gov/news/news_summ.jsp?cntn_id=111975.

Massachusetts Institute of Technology chemist Daniel Nocera and his postdoctoral student Matthew Kanan discovered this new, efficient catalyst that produces oxygen gas from water. Nocera is a member of Powering the Planet, one of NSF's Centers for Chemical Innovation (CCI). *Credit: MIT/NSF*

Materials Research Science and Engineering Centers (MRSECs)

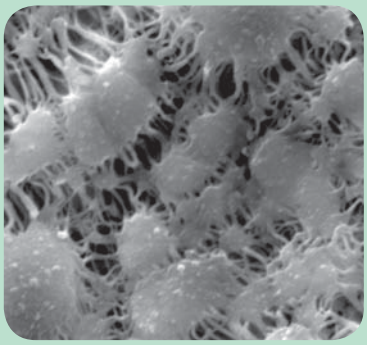
Materials Research Science and Engineering Centers address fundamental materials research problems of intellectual and strategic importance that are critical for American competitiveness and the development of future technologies. MRSECs also support shared experimental facilities, place strong emphasis on the integration of research and education at all levels, and provide seed support to stimulate emerging areas of materials research. They support cutting-edge materials research in areas such as electronic and photonic materials, polymers, biomimetic and biomolecular materials, magnetic and ferroelectric materials, nanoscale materials, structural materials, and organic systems and colloids. MRSECs have strong links to industry and other sectors, enabling the development of marketable technologies that depend on new classes of materials and the discovery, control and innovative exploitation of materials phenomena. The following MRSECs are supported by NSF:

- Center for Nanostructured Materials - Columbia University
- Center on Polymer Interfaces and Macromolecular Assemblies - Stanford University
- Response-Driven Polymeric Films Center - University of Southern Mississippi
- MRSEC - University of Alabama Tuscaloosa
- MRSEC - University of Pennsylvania
- Cornell Center for Materials Research - Cornell University
- MRSEC at UCSB - University of California, Santa Barbara
- Carnegie Mellon University MRSEC – Carnegie Mellon University
- The University of Maryland MRSEC - University of Maryland College Park
- MRSEC - Johns Hopkins University
- MRSEC for Research on Interface Structures and Phenomena - Yale University
- Multifunctional Nanoscale Material Structures - Northwestern University
- MRSEC on Nanostructured Interfaces - University of Wisconsin-Madison

- Center for Semiconductor Physics in Nanostructures - University of Oklahoma Norman Campus
- Center for the Science and Engineering of Materials - California Institute of Technology
- Genetically Engineered Materials Science and Engineering Center - University of Washington
- Micro- and Nano- Mechanics of Materials - Brown University
- MIT MRSEC - Massachusetts Institute of Technology
- Princeton Center for Complex Materials - Princeton University
- University of Minnesota MRSEC - University of Minnesota-Twin Cities
- MRSEC - University of Chicago
- Semantophoretic Assemblies - New York University (2008 award)
- The Georgia Tech Laboratory for New Electronic Materials - Georgia Tech (2008 award)
- MRSEC: Center for Nanoscale Science - Penn State University
- Center for Emergent Materials - Ohio State University (2008 award)
- MRSEC - Harvard University
- Constraints and Frustration in Nano-Structured and Bio-Molecular Materials - Brandeis University (2008 award)
- Quantum and Spin Phenomena in Nanomagnetic Structures - University of Nebraska-Lincoln
- MRSEC on Polymers - University of Massachusetts Amherst
- Renewable Energy MRSEC - Colorado School of Mines (2008 award)
- Soft Materials Research Center - University of Colorado at Boulder

Penicillin-coated Polymer for Medical Devices to Ward Off Staph Infections

Imagine the advantage of having antibiotics built into objects that are inserted into the body during medical procedures instead of having to give patients antibiotics to ward off infections. That could be the reality one day. Researchers at MRSEC at the University of Southern Mississippi chemically attached penicillin to expanded polytetrafluoroethylene (PTFE) to produce an antibacterial surface that kills Staphylococcus aureus, the most common cause of staph infections. Expanded PTFE is a highly porous polymer commonly used in waterproof fabrics such as Gore-Tex. It is also extensively used in medical devices and implants. The research was published in the Feb. 12, 2007, issue of *Biomacromolecules*. Since then, the research team has been working on expanding their tool box by attaching an array of drugs to expanded PTFE, for example to control blood clotting, and other antibiotics to surfaces for control of an array of bacteria. For more information, see the NSF discovery story at http://www.nsf.gov/discoveries/disc_summ.jsp?cntn_id=110645&org=NSF.



Polymer science professor Marek Urban and his team of researchers at the University of Southern Mississippi have developed a new process to coat surfaces with antibiotics. Surgical instruments coated with antibiotics could potentially save thousands of lives and reduce the number of patients who contract infections following medical procedures. This scanning electron microscope image shows a polymer surface prior to its coating with penicillin. Credit: Marek W. Urban, The University of Southern Mississippi

Nanobiotechnology Center (NBTC)

The Nanobiotechnology Center, an NSF STC led by Cornell University, brings together life scientists, physical scientists and engineers to apply the tools and processes of nano/microfabrication to build devices for biomedical and biological research. Center researchers have developed a new kind of nanoparticle, called Cornell dots or "CU dots." Consisting of fluorescent dye molecules surrounded by a protective silica shell, the particles are small—about 25 nanometers in diameter—but could have a large impact in biological imaging. CU dots are brighter than single fluorescent dye molecules and there are other advantages over current technology as well. Cornell University has licensed the CU dot technology to a start-up company that hopes to commercialize it for biological imaging applications. Another of the center's teams has created "nanobarcodes"— multicolor fluorescent tags made out of synthetic DNA that attach to target species. Under ultraviolet light, the tags produce a combination of colors that is unique to the target species. The method can be used to rapidly identify genes, pathogens, drugs and other chemicals.

Center for Environmentally Responsible Solvents and Processes (CERSP)

Researchers at NSF's STC for Environmentally Responsible Solvents and Processes (CERSP) in North Carolina are developing innovative "green" manufacturing methods. The work involves technology using liquid and supercritical carbon dioxide (CO_2) as a cleaning agent and reaction medium. The technology would eliminate millions of tons of wastewater and airborne emissions created by conventional processes. The new technology is already being used in a new chain of dry-cleaning stores called "Hangers," where liquid CO_2 replaces the volatile organic solvent perchloroethylene, a known contaminant of groundwater. In addition, DuPont has adopted the technology in a new $40 million Teflon manufacturing facility, which unlike plants using the conventional water-based process, does not use a pollutant known as C8. Joseph DeSimone, center director and professor of chemistry at the University of North Carolina at Chapel Hill and professor of chemical engineering at North Carolina State University, was awarded the 2008 Lemelson-MIT prize. The award recognizes outstanding inventors, encourages sustainable solutions to real-world problems and seeks to inspire new generations of inventors.

On a smaller scale, an MRI award to a team of researchers at the University of Virginia enabled the development of a new technique for identification of chemical agents. The technique dramatically reduces the time required for studying chemical structures in gas phase. The "Chirped Pulse Fourier Transform Microwave" measures a broader range of microwave frequencies than existing spectrometers, and allows users to select the desired sensitivity when obtaining measurements. The new microwave has a number of potential applications in chemical analysis including breath analysis and detection of chemical warfare agents.

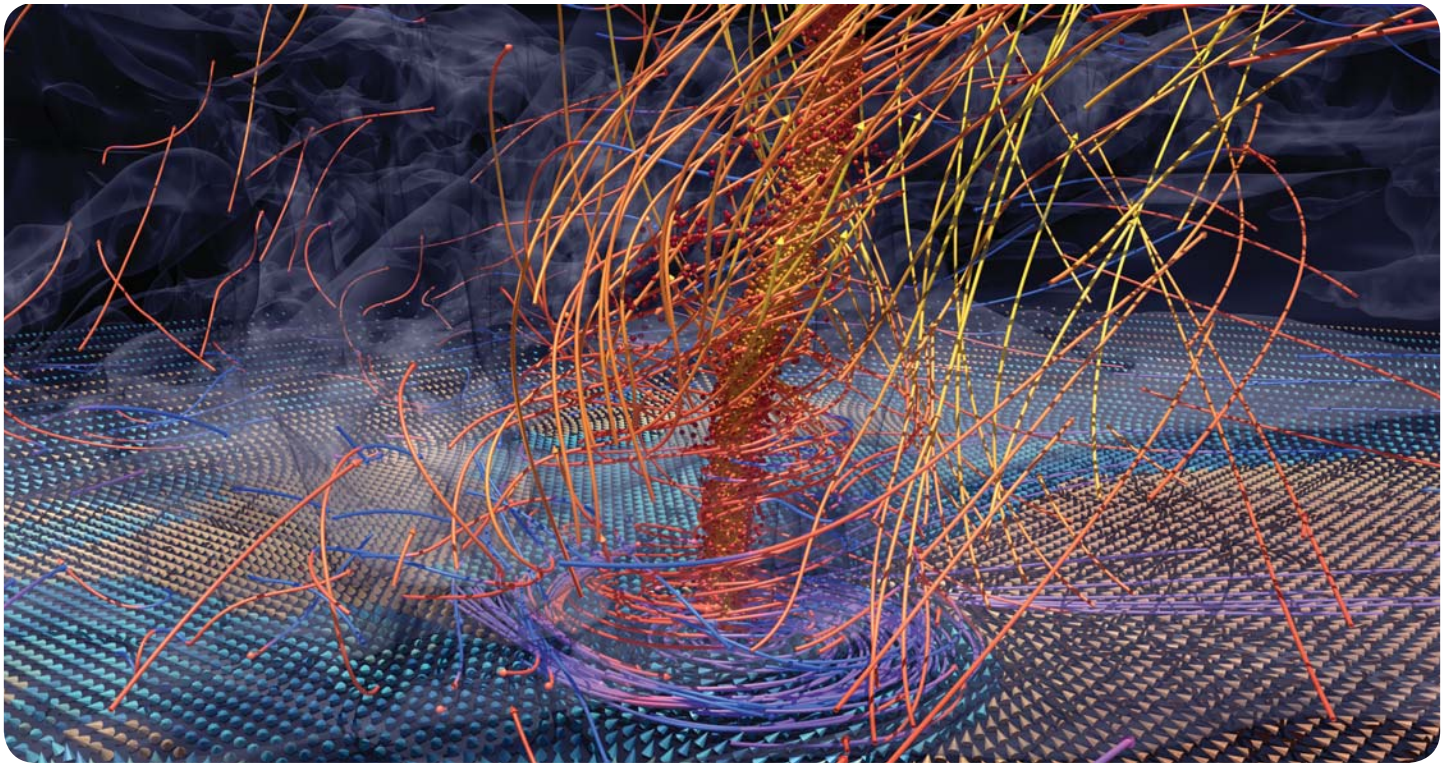
NSF is unique—the only federal agency with a mandate to support U.S. fundamental research and education across all fields of science and engineering. Enhancing the nation's research infrastructure and collaborative environments is one critical component of this mandate.

This document provides an overview of the various types of programs and mechanisms by which NSF achieves excellence in supporting the national science and engineering research infrastructure. It includes descriptions of many current and planned instruments, facilities and centers, with evidence of the frontier research they enable. Where appropriate, the story of transition from research to the market place and examples of excellence in educational programs and public outreach are also provided. Our continued support for cutting-edge instrumentation, unique national facilities, shared cyberinfrastructure and centers—along with the scientists, engineers, teachers and students who use them—will be essential to enabling the discoveries, innovation and learning that will help the U.S. meet critical national needs.

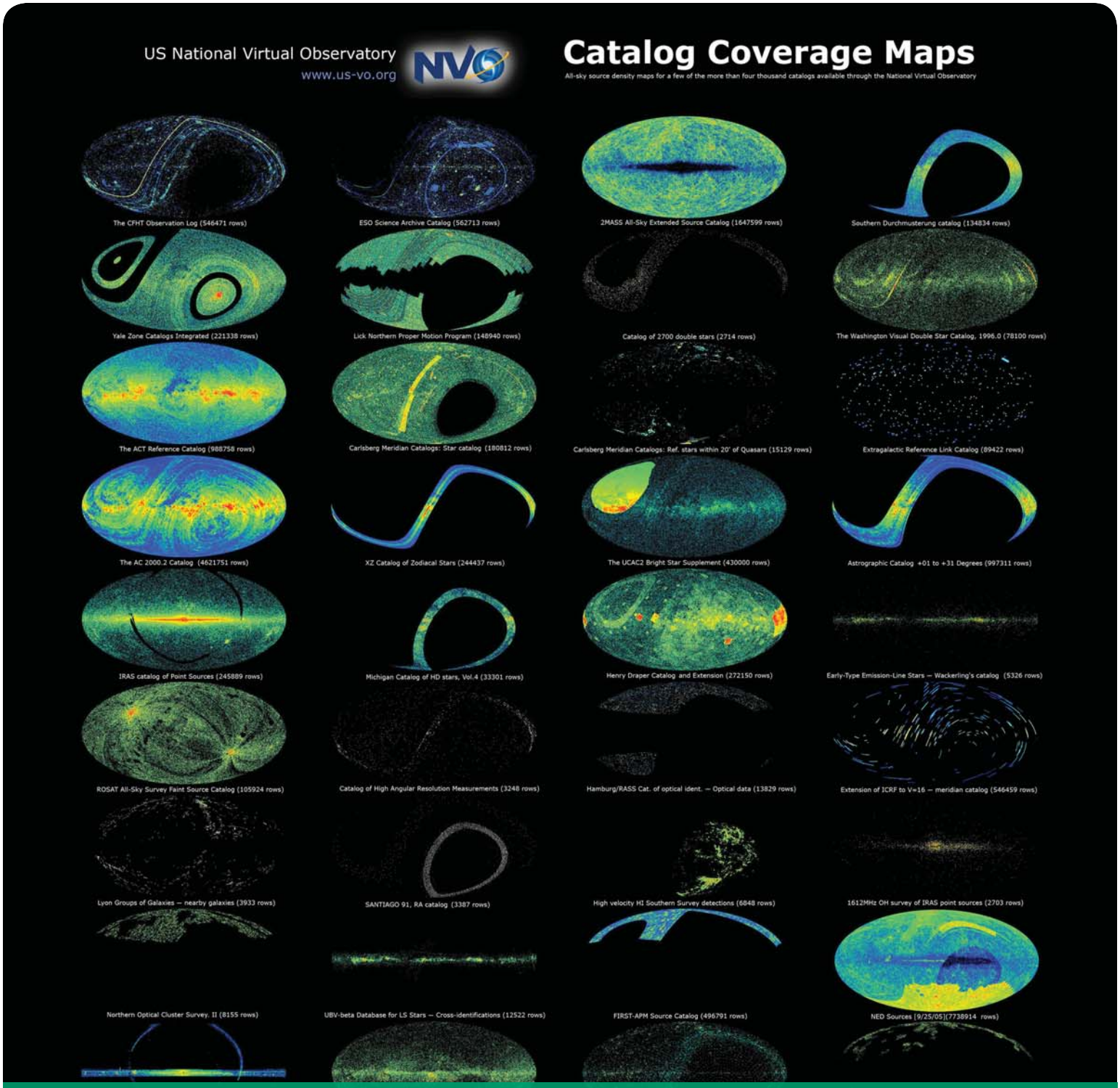
A world class research infrastructure enables frontier discovery and innovation, trains future generations of scientists and engineers, prepares the workforce needed to keep the 21st century knowledge economy growing, and ensures that the U.S. science and engineering enterprise is a global leader.

To learn more about NSF-supported research infrastructure, visit our Web site at http://www.nsf.gov.

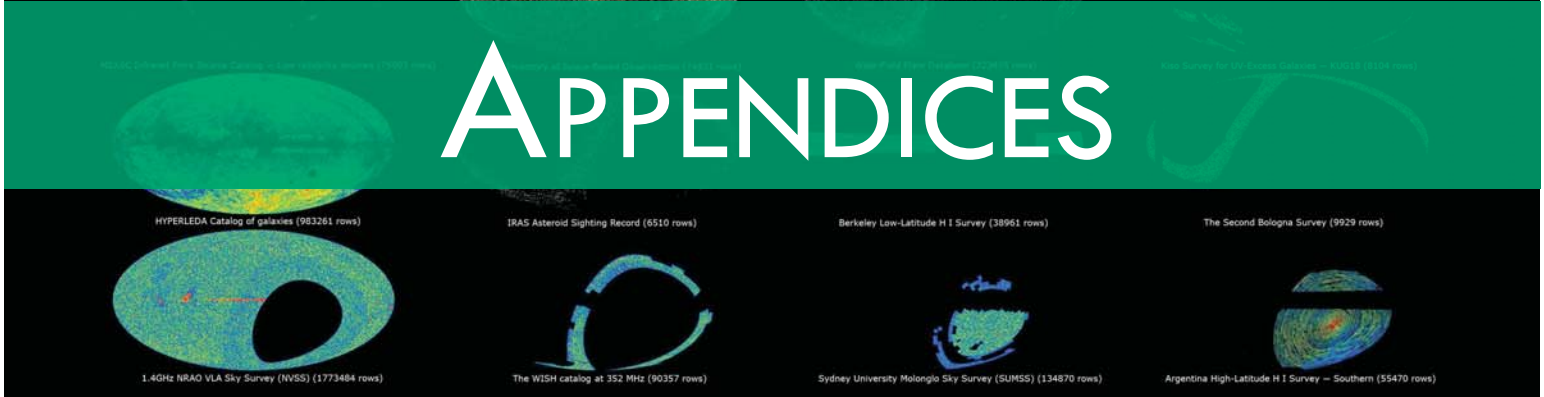
Conclusion



This visualization, created in 2004 from data generated by a tornado simulation calculated on the computing cluster of the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign, shows the tornado by spheres colored according to pressure. Orange and blue tubes represent the rising and falling airflow around the tornado. NCSA's Blue Waters facility will be able to detail even more complex simulations. *Credit: Bob Wilhelmson, NCSA and the University of Illinois at Urbana-Champaign; Lou Wicker, National Oceanic and Atmospheric Administration's National Severe Storms Laboratory; Matt Gilmore and Lee Cronce, University of Illinois atmospheric science department. Visualization by Donna Cox, Robert Patterson, Stuart Levy, Matt Hall and Alex Betts, NCSA*



APPENDICES



The National Virtual Observatory's Sky Statistics Survey allows astronomers to get a fast inventory of all astronomical objects from various catalogs. The U.S.-based Virtual Observatory project is collaborating with the International Virtual Observatory Alliance to make it possible for researchers to access astronomical data from ground- and space-based telescopes worldwide. The U.S.-based virtual observatory project is supported by NSF. *Credit: National Virtual Observatory and California Institute of Technology (http://us-vo.org/)*

The following list of instruments, facilities, shared cyberinfrastructure and centers provides an expanded view of NSF's investments in the nation's research infrastructure. Although comprehensive, this is not a complete list of all NSF-supported instruments, facilities, shared cyberinfrastructure and centers. But it is representative of the extensive range of investments we make. The agency is continually providing awards for new and innovative research tools that advance the frontiers of science and engineering research and education.

APPENDIX I: Expanded List of NSF-supported Instruments, Facilities, Shared Cyberinfrastructure and Centers

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
AIRCRAFT	**High-performance Instrumented Airborne Platform for Environmental Research (HIAPER)** A modified Gulfstream V jet equipped with advanced instrumentation for environmental research. For more information, see http://www.nsf.gov/news/news_summ.jsp?cntn_id=106708 .	Operated by NCAR
	Aircraft Specially Instrumented as Lower Atmospheric Observing Facilities NSF supports the following: • C-130Q, a versatile and capable research platform that carries a wide variety of scientific payloads, and L-188C, operated by NCAR/Earth Observing Laboratory. • KA B200T, a specially instrumented Raytheon King Air 200T (twin turbo-prop) designed and used for atmospheric research, managed by the University of Wyoming. • A T-28 instrumented research aircraft owned by the Institute of Atmospheric Sciences at the South Dakota School of Mines and Technology. For more information, see http://www.nsf.gov/geo/atm/ulafos/laof/.	NCAR, University of Wyoming and South Dakota School of Mines and Technology
VESSELS	**Academic Research Fleet** The Academic Research Fleet consists of 23 vessels in UNOLS. NSF owns seven of the research ships (listed below). For more information, see: http://www.unols.org/	
	R/V Marcus Langseth A 235-foot research vessel that can accommodate 35 researchers and a crew of 20. For more information, see: http://www.ldeo.columbia.edu/res/fac/oma/langseth/index.html	Operated by Lamont-Doherty Earth Observatory of Columbia University
	R/V Wecoma A 185-foot research vessel that can accommodate 18 researchers and a crew of 13. For more information, see http://www.shipops.oregonstate.edu/ops/wecoma/	Operated by Oregon State University's College of Oceanic and Atmospheric Sciences

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	R/V Endeavor A 185-foot ship that can accommodate 18 scientists (including a marine technician) and a crew of 12. For more information, see http://techserv.gso.uri.edu/	Operated by University of Rhode Island's Graduate School of Oceanography
	R/V Oceanus A 177-foot ship that can accommodate 19 researchers and a crew of 12. For more information, see: http://www.whoi.edu/page.do?pid=8158	Operated by Woods Hole Oceanographic Institution
	R/V Point Sur A 135-foot ship that can accommodate 13 researchers and technicians and a crew of 8. For day cruises, it has a capacity of 40 researchers. For more information, see http://marineops.mlml.calstate.edu/ptsur.html	Operated by Moss Landing Marine Laboratories for the San Jose State University Foundation
	R/V Cape Hatteras A 135-foot ship that can accommodate 14 scientists (including a marine technician) and a crew of 10. For more information, see http://www.nicholas.duke.edu/marinelab/facilities/hatteras/research.html	Operated by the Duke University/ University of North Carolina Oceanographic Consortium
	R/V Clifford A. Barnes A 66-foot ship that can accommodate six scientists and a two-person crew. For more information, see http://www.ocean.washington.edu/2004/services/vessels/cab/cab.html	Operated by the University of Washington's School of Oceanography
	Alaska Region Research Vessel (ARRV) -- *Proposed* A 242-foot ship designed to operate in seasonal sea ice and open regions near Alaska. The project is approaching final design review with ship construction expected to get underway in early 2010. For more information, see http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0749590	Construction and operations to be managed by the University of Alaska, Fairbanks
	Integrated Ocean Drilling Program The Integrated Ocean Drilling Program is an international marine research program that explores Earth's history and structure as recorded in seafloor sediments and rocks. Japan and the U.S. are each providing a drillship. For more information, see http://www.iodp.org/	Led by NSF and MEXT of Japan

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Scientific Ocean Drilling Vessel The U.S.-provided Scientific Ocean Drilling Vessel is undergoing an extensive refitting and is scheduled to begin IODP operations in early 2009. For more information, see http://www.oceanleadership.org/	IODP
	Sentry A one-of-a-kind unmanned submersible vehicle (also called autonomous underwater vehicle or AUV) that can operate in rugged undersea environments without being tethered to a ship. Sentry's first research mission came in July-August 2008 when it mapped a section of the seafloor off the coast of Oregon and Washington. Sentry was built by Woods Hole Oceanographic Institution with funding largely from NSF. For more information, see http://www.nsf.gov/news/news_summ.jsp?cntn_id=112037	Woods Hole Oceanographic Institution
TELESCOPES, OBSERVATORIES		
	Gemini Observatory Twin 8-meter optical/infrared telescopes. Gemini South is located on a mountain in the Chilean Andes called Cerro Pachon, and the Frederick C. Gillett Gemini North Telescope is located on Hawaii's Mauna Kea, a long dormant volcano. For more information, see http://www.gemini.edu/public/	Built and operated by a partnership of seven countries: the U.S., United Kingdom, Canada, Chile, Australia, Brazil and Argentina
	National Astronomy and Ionosphere Center The National Astronomy and Ionosphere Center's principal observing facilities are located near the town of Arecibo in Puerto Rico and include a 305-meter, fixed spherical radio/radar telescope, the world's largest single radio wavelength reflector. For more information, see http://www.naic.edu/	Operated by Cornell University
	National Optical Astronomy Observatory (NOAO) Operating facilities, telescopes and supporting instrumentation (listed on following page). For more information, see http://www.noao.edu/	Operated by the Association of Universities for Research in Astronomy, Inc. (AURA)

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Kitt Peak National Observatory (KPNO) Near Tucson, Ariz. For more information, see http://www.noao.edu/kpno/	NOAO
	Cerro Tololo Interamerican Observatory (CTIO) Near La Serena, Chile. For more information, see http://www.ctio.noao.edu/	NOAO
	Gemini Science Center Located in Tucson. The center coordinates access for U.S. astronomers to the twin Gemini 8-meter telescopes. For more information, see http://www.noao.edu/usgp/	NOAO
	National Solar Observatory Operates the solar facilities listed below. For more information, see http://www.nso.edu/general/facilities.html	Operated by the Association of Universities for Research in Astronomy, Inc. (AURA)
	Dunn Solar Telescope Located on Sacramento Peak near Sunspot, N.M., the 76-centimeter telescope is the premier facility for high-resolution solar physics.	NSO
	McMath-Pierce Solar Telescope Located on Kitt Peak in Arizona, at an altitude of 2,096 meters, it is currently the largest unobstructed-aperture optical telescope in the world, with a diameter of 1.5 meters.	NSO
	Advanced Technology Solar Telescope (ATST) – *In Planning* A solar telescope facility to be built at the Haleakala High Altitude Observatory on the Hawaiian island of Maui.	NSO

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Global Oscillation Network Group GONG) GONG studies the internal structure and dynamics of the Sun by means of helioseismology--the measurement of acoustic waves that penetrate throughout the solar interior--using a six-station, world-circling network that provides nearly continuous observations of the Sun's "five-minute oscillations".	NSO
	Evans Solar Facility Located at Sacramento Peak, and consisting of two main telescopes: a 16-inch coronagraph and a 12-inch coelostat telescope. They are used to conduct observations of the Sun for both local staff and visiting scientists worldwide.	NSO
	Hilltop Dome Facility Located at Sacramento Peak, and housing an octagonal spar that allows several instruments to be operated simultaneously.	NSO
	Kitt Peak Vacuum Telescope (KPVT) Used to make daily maps of solar magnetic and Doppler fields, and intensity maps in several solar spectral lines.	NSO
	National Radio Astronomy Observatory (NRAO) Provides state-of-the-art radio telescope facilities (listed below) for use by the scientific community. For more information, see http://www.nrao.edu/	Operated by Associated Universities, Inc. (AUI)
	Green Bank Operating major radio telescopes at Green Bank, W.Va., including the Robert C. Byrd Green Bank Telescope (GBT), the most technically advanced, single dish radio telescope in the world. With a 100-meter by 110-meter dish, the telescope is also one of the largest moving structures on land. The GBT is a leader in the scientific study of pulsars, dense neutron stars that serve as laboratories in which astronomers study the physics of extreme states of matter and enormous magnetic fields. Other instruments include the Green Bank Interferometer.	NRAO

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Very Large Array (VLA) Located near Socorro, N.M., and consisting of 27, 230-ton, 25-meter diameter dish antennas that together comprise a single radio telescope system. The VLA has made key observations of black holes and protoplanetary disks around young stars that may be signs of planet formation.	NRAO
	Expanded VLA Project (EVLA) A project to refurbish and update the VLA's receivers. By 2012, new state-of-the-art electronics and software will have completely transformed the VLA into the EVLA, a research tool with more than ten times the VLA's sensitivity.	NRAO
	Very Long Baseline Array (VLBA) Consists of 10, 240-ton, 25-meter diameter dish antennas spread across the Western Hemisphere, from Hawaii to St. Croix, Virgin Islands. These ten antennas work together to produce the VLBA's sharp radio "vision."	NRAO
	Atacama Large Millimeter Array (ALMA) The giant international observatory under construction in the 5,000-meter high Atacama Desert in northern Chile. It will include at least 66 radio telescopes and open a new window on one of astronomy's last frontiers – the millimeter and sub-millimeter wavelength.	NRAO is the North American implementing organization for the international group
	Laser Interferometer Gravitational-Wave Observatory (LIGO) The most sensitive gravitational wave detector built to-date, LIGO consists of three Michelson interferometers located at Hanford, Wash., and Livingston, La. For more information, see http://www.ligo.caltech.edu/	Operated by the California Institute of Technology and Massachusetts Institute of Technology
	Advanced Laser Interferometer Gravitational Wave Observatory (AdvLIGO) The project will improve by a factor of 10 the sensitivity of the Laser Interferometer Gravitational-Wave Observatory (LIGO).	California Institute of Technology and the Massachusetts Institute of Technology
	Pierre Auger Cosmic Ray Observatory Located in western Argentina, the international Pierre Auger Observatory was developed to provide a window on the universe's highest energy cosmic rays. NSF, DOE and the Grainger Foundation are the U.S. funding agencies. For more information, see: http://www.auger.org/observatory/	Universities Research Association (URA) is the sponsoring organization for U.S. participants

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	IceCube Neutrino Observatory The world's first high-energy neutrino observatory is under construction deep in the clear ice at the South Pole. For more information, see http://icecube.wisc.edu/	Under construction, led by University of Wisconsin (for U.S.) IceCube is a multi-national, multi-institutional project
	South Pole Telescope (SPT) A 10-meter telescope to study phenomena such as the formation and evolution of the early universe and the formation and evolution of solar systems like our own. For more information, see http://pole.uchicago.edu/	SPT Collaboration (University of Chicago, University of California, Berkeley, University of Illinois at Urbana-Champaign, Case Western Reserve University, Jet Propulsion Laboratory, Harvard-Smithsonian Center for Astrophysics, McGill University, University of Colorado at Boulder, and University of California, Davis)
HIGH ENERGY PHYSICS FACILITIES	**Cornell Electron Storage Ring (CESR)** An electron-positron collider with a circumference of 768 meters that provides important knowledge of the properties of the b-quark. For more information, see http://www.lns.cornell.edu/public/lab-info/cesr.html	Cornell University (phasing out)
	National Superconducting Cyclotron Laboratory (NSCL) A world leader in rare isotope research and nuclear science education operating two superconducting cyclotrons. For more information, see http://www.nscl.msu.edu/	Michigan State University
	Large Hadron Collider (LHC) The high-energy accelerator located at CERN in Geneva, Switzerland, will be the world's premier facility for research in elementary particle physics. NSF, with the DOE, supports the construction, maintenance and operation of two detectors: A Toroidal LHC ApparatuS (ATLAS) and the Compact Muon Solenoid (CMS). For more information, see: http://public.web.cern.ch/public/en/LHC/LHC-en.html	U.S. LHC Collaboration
GEOSCIENCE AND ECOLOGICAL OBSERVATORIES	**EarthScope** An integrated facility for observing Earth's systems, made up of USArray, the Plate Boundary Observatory, and the San Andreas Fault Observatory at Depth (SAFOD). For more information, see http://www.earthscope.org/	Constructed, operated and maintained as a collaborative effort with the University NAVSTAR Consortium, Inc. (UNAVCO), IRIS, and Stanford University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	National Ecological Observatory Network (NEON) -- *Proposed* Planned as a cutting edge, regional-to-continental scale research platform consisting of geographically distributed infrastructure for ecological research that is networked via state-of-the-art communications technology. For more information, see http://www.neoninc.org/	Construction and operations plan under development
	Ocean Observatories Initiative (OOI) -- *Proposed* Preconstruction planning underway to develop an integrated observatory network that will provide the oceanographic research and education communities with continuous, interactive access to the ocean. For more information, see http://www.oceanleadership.org/ocean_observing	OOI Project Team
	Incorporated Research Institutes for Seismology (IRIS) A university research consortium dedicated to exploring the Earth's interior through the collection and distribution of seismographic data. For more information, see http://www.iris.edu/hq/	IRIS Consortium
	National Center for Atmospheric Research (NCAR) A focal point for research in the field of atmospheric sciences, making available to university and other scientists world-class supercomputing services, research aircraft, airborne and portable ground-based radar systems, and atmospheric sounding and other surface sensing systems. For more information, see http://www.ncar.ucar.edu/	Managed by UCAR under a cooperative agreement with NSF
	Critical Zone Observatories (CZO) Field sites operating at the watershed scale to significantly advance understanding of the integration and coupling of Earth surface processes as mediated by the presence and flux of fresh water. For more information, see http://www.czen.org/	CZEN.org
	Consortium for Materials Properties Research in Earth Science (COMPRES) COMPRES scientists seek to develop an understanding of the phenomena, processes and state of the Earth by studying the spectrum of materials (rocks, minerals, fluids, vapors, volatile rich zones, dry sintered regions, molten iron and solid iron alloys) that comprise the Earth. For more information, see http://www.compres.stonybrook.edu/	State University of New York at Stony Brook

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	GeoSoilEnviroCARS (GSECARS) A synchrotron-based research facility at the Advanced Photon Source in Argonne, Ill., dedicated to state-of-the-art research on earth materials and open to the entire scientific community.	University of Chicago
	Purdue Rare Isotope Measurement Laboratory (PRIME Lab) A dedicated research and service facility for accelerator mass spectrometry (AMS). AMS is an ultra-sensitive analytical technique for measuring low levels of long-lived radionuclides and rare trace elements. PRIME Lab is funded by NSF, NASA, NIH and the Indiana 21st Century Research and Technology Fund.	Purdue University
	NSF-University of Arizona Accelerator Mass Spectrometry (AMS) Laboratory Primarily used to provide radiocarbon measurements. For more information, see http://www.physics.arizona.edu/physics2006/research.php?page=accelerator_mass	University of Arizona
	Institute for Rock Magnetism A national multi-user facility whose core mission is to serve the greater geomagnetic community by providing free-of-charge access to state-of-the-art facilities and technical expertise. For more information, see http://www.irm.umn.edu/IRM/Home.html	University of Minnesota
	University of Texas High-Resolution X-ray Computed Tomography Facility Located at the University of Texas at Austin, this shared, multi-user facility offers researchers access to a completely nondestructive technique for visualizing features in the interior of opaque solid objects, and for obtaining digital information on their 3D geometries and properties. For more information, see http://www.ctlab.geo.utexas.edu/	University of Texas at Austin
	UCLA SIMS Laboratory UCLA SIMS (secondary ion mass spectrometry) laboratory for *in situ* microscale isotopic analyses of geologic materials. The ion microprobe has become one of the most potent tools for isotope geochemistry and cosmochemistry due to the instrument's ability to reveal isotopic and elemental heterogeneity at the micro-scale. For more information, see http://sims.ess.ucla.edu/nsf_facility/index.php	University of California, Los Angeles

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	National Center for Airborne Laser Mapping National Center for Airborne Laser Mapping supports the use of airborne laser mapping technology in the scientific community.	Operated jointly by the Department of Civil & Coastal Engineering, College of Engineering, University of Florida and the Department of Earth and Planetary Science, University of California, Berkeley
	Amino Acid Geochronology Laboratory The laboratory is dedicated to estimating the ages of Quaternary deposits by analyzing the extent of racemization in amino acids preserved within carbonate fossils.	Northern Arizona University
	Drilling, Observation, and Sampling of the Earth's Continental Crust, Inc. A not-for-profit corporation whose mission is to provide leadership and technical support in subsurface sampling and monitoring.	
	Arizona LaserChron Center A multi-user facility that generates uranium-thorium-lead geochronologic information by Laser Ablation-ICP Mass Spectrometry.	University of Arizona
	Arizona State University SIMS Laboratories A multi-user facility for conducting research in the general fields of quantitative secondary ion mass spectrometry.	Arizona State University
	University of Wisconsin SIMS Lab A national facility enabling *in situ* analysis of stable isotope ratios at the scale of 1 to 10 micrometers.	University of Wisconsin
RADAR FACILITIES AND INSTRUMENTATION	**Advanced Modular Incoherent Scatter Radar (AMISR)** A solid-state, phased array incoherent scatter radar for measuring basic properties of the upper atmosphere and ionosphere with unprecedented versatility and power. AMISR systems are deployed at Poker Flat, Alaska, and Resolute Bay, Canada. For more information, see http://isr.sri.com/iono/amisr/	SRI International

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Millstone Hill Incoherent Scatter Radar Facility A facility for studying the Earth's upper atmosphere and ionosphere, it features a fully steerable, 46-meter antenna and 67-meter fixed zenith pointing dish. For more information, see http://www.haystack.mit.edu/obs/mhr/index.html	Massachusetts Institute of Technology
	Sondrestrom Radar Facility Located north of the Arctic Circle and 100 kilometers inland from the west coast of Greenland, the instruments are used to study upper atmospheric physics. For more information, see http://isr.sri.com/	SRI International, in cooperation with Denmark's Meteorological Institute
	Arecibo Observatory The 305-meter telescope is used as an incoherent scatter radar to measure with extremely high accuracy the basic properties of the ionosphere, including electron density and temperature, ion temperature, and plasma drift velocity. For more information, see http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0630533	Cornell University
	Jicamarca Radio Observatory Large, incoherent scatter radar facility for studying the Earth's upper atmosphere. For more information, see http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0432565	Cornell University
	Super Dual Auroral Radar Network (SuperDARN) An international network of radars—currently 9 in the northern hemisphere and 6 in the southern hemisphere--for studying the Earth's upper atmosphere, ionosphere, and connection into space. For more information, see http://superdarn.jhuapl.edu/	Johns Hopkins University Applied Physics Laboratory
	Atmosphere Surface Turbulent Exchange Research Facility (ASTER) A micrometerology facility with fast-response sensors for multi-site measurements of surface momentum, heat, water vapor fluxes, and surface energy balances. ATD/Surface and Sounding Systems Facility (SSSF) operates (1) ASTER consisting of a base station and several tower-based sensor arrays.	NCAR Atmospheric Technology Division (ATD)
	Cross-chain Loran Atmospheric Sounding System (CLASS) Balloon sounding system that supports Loran-C and Omega navigational winds and includes surface meteorological measurements. ATD/SSSF operates (5) trailer-based and (1) van-based mobile CLASS.	NCAR/ATD

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Integrated Sounding System (ISS) A container-based multi-platform system that combines a balloon-borne Radiosonde Navaid (Loran or Omega) Sounding System, an enhanced surface observing station, a 915-MHz Doppler clear-air Wind Profiling Radar, a Radio Acoustic Sounding System (RASS) and communication, data processing and display infrastructure. ATD/SSSF operates (4) ISS.	NCAR/ATD
	Portable Automated Mesonet (PAM III and Flux PAM) A network of remote surface meteorology stations. ATD/SSSF operates (3) PAM III stations, all with flux measurement capability.	NCAR/ATD
	S-POL Radar A highly-portable, S-band dual-polarization Doppler radar with improved signal processing and polarization capabilities.	NCAR/ATD
	CHILL Radar An 11-centimeter wavelength Doppler system with dual polarization capability.	Colorado State University
	P3Dora Radar (ELDORA) An airborne X-Band Doppler radar that produces dual-Doppler data from vertical scans of two fixed-plate antennas with fore and aft orientations. It is installed on the Naval Research Laboratory P-3 (NRL P-3) aircraft.	NCAR/ATD
NETWORKS, OTHER FACILITIES	**George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES)** NEES is a shared national network of 15 experimental facilities, collaborative tools, a centralized data repository, and earthquake simulation software, all linked by the ultra-high-speed connections of NEESgrid. For more information, see http://www.nsf.gov/news/special_reports/nees/index.jsp and http://www.nees.org/	
	Large-Scale Structural Lab One of the NEES program's seven large-scale testing facilities, Cornell University's Large Displacement Facility can test the structural integrity of underground pipelines as well as surface level structures. For more information, see http://nees.cornell.edu/index.htm	Cornell University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Large-Scale Structural Lab One of the NEES program's seven large-scale testing facilities, Lehigh University specializes in fast hybrid testing that combines real-time physical experiments with computer-based simulation for evaluating the earthquake performance of structural components and systems. For more information, see http://www.nees.lehigh.edu/	Lehigh University
	Tsunami Wave Basin Oregon State University's Tsunami Research Facility is the world's largest facility for studying the effects of large waves. It provides testing capabilities and experimental data to tsunami researchers around the world. For more information, see http://nees.orst.edu/	Oregon State University
	Geotechnical Centrifuge Lab The NEES Program has two geotechnical centrifuge facilities. The centrifuge machine at Rensselaer Polytechnic Institute is an Acutronic Model 665-1 constructed to Rensselaer's specifications. It has an in-flight platform radius of 3.0m and can test a payload of 1 ton at 100g (or 0.5 ton at 200g). For more information, see http://www.nees.rpi.edu/	Rensselaer Polytechnic Institute
	Shake Table and Large-Scale Structural Lab One of three NEES equipment sites equipped with shake tables, the University at Buffalo has two relocatable shake tables that may be moved up to 200 feet apart. Researchers explore the use of real-time dynamic hybrid testing, where shake table tests of structural components are combined in real-time with computer simulations of the remainder of the structure. This provides a more complete picture of how earthquakes would affect large structures, such as buildings and bridges, without the need to physically test the entire structure. For more information, see http://nees.buffalo.edu/	University at Buffalo
	Large-Scale Structural Lab One of the NEES program's seven large-scale testing facilities, the University of California, Berkeley designed its Reconfigurable Reaction Wall-Based Earthquake Simulation Facility to support the development of a new generation of hybrid testing methods that smoothly integrate physical testing with simulations. For more information, see http://nees.berkeley.edu/	University of California, Berkeley

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	Geotechnical Centrifuge Lab The NEES Program has two geotechnical centrifuge facilities. The centerpiece of the University of California, Davis equipment site is a 9-m, 80 g centrifuge that can spin and shake models of soil layers and soil-structure systems. For more information, see http://cgm.engineering.ucdavis.edu/index.php	University of California, Davis
	Mobile Field Testing Equipment The NEES program has three equipment sites providing field and mobile facilities. The University of California, Los Angeles' mobile lab can conduct testing on full-scale structural and foundation systems. For more information, see http://nees.ucla.edu/	University of California, Los Angeles
	Shake Table Lab One of three NEES equipment sites equipped with shake tables, the University of California, San Diego boasts the largest outdoor shake table in the U.S. For more information, see http://nees.ucsd.edu/	University of California, San Diego
	Instrumented Field Sites The NEES program has three equipment sites providing field and mobile facilities. The University of California, Santa Barbara, in partnership with the University of Southern California and Brigham Young University, has established a permanent field-testing site in the seismically active area of Garner Valley. For more information, see http://nees.ucsb.edu/	University of California, Santa Barbara
	Large-Scale Structural Lab One of the NEES program's seven large-scale testing facilities, the University of Colorado at Boulder specializes in fast hybrid testing that combines real-time physical experiments with computer-based simulation for evaluating the earthquake performance of structural components and systems. For more information, see http://nees.colorado.edu/	University of Colorado at Boulder
	Large-Scale Structural Lab One of the NEES program's seven large-scale testing facilities, the University of Illinois at Urbana-Champaign has created a physical-analytical simulation environment whereby multi-axial full-scale models can be subjected to complex testing conditions, representing earthquake ground motion. For more information, see http://nees.uiuc.edu/	University of Illinois at Urbana-Champaign

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	Large-Scale Structural Lab One of the NEES program's seven large-scale testing facilities, the University of Minnesota facility supports multi-axial subassemblage testing, which can be used to investigate the effects of earthquakes, high winds and other extreme events on structures several stories tall. Structures up to 29 feet tall can be placed on a testing platform and subjected to heavy loads by hydraulic arms that mimic the conditions of extreme events. The arms can simulate vertical forces of 1.32 million pounds and horizontal forces of 800,000 pounds. For more information, see http://nees.umn.edu/	University of Minnesota
	Shake Table Lab One of three NEES equipment sites equipped with shake tables, the University of Nevada at Reno has three bi-axial shake tables, which can function in unison or independently. For more information, see http://nees.unr.edu/	University of Nevada, Reno
	Mobile Field Testing Equipment The NEES program has three equipment sites providing field and mobile facilities. The University of Texas, Austin has three mobile, large-scale shakers with diverse force and frequency capabilities. For more information, see http://nees.utexas.edu/Home.shtml	University of Texas at Austin
OTHER RESEARCH INFRASTRUCTURE	**National High Magnetic Field Laboratory (NHMFL)** The only facility of its kind in the U.S., it develops and operates state-of-the-art, high-magnetic-field facilities and is among the preeminent facilities in the world for researchers and engineers studying superconductivity and other materials research. For more information, see http://www.magnet.fsu.edu/	Florida State University, University of Florida, Los Alamos National Laboratory
	National Nanotechnology Infrastructure Network (NNIN) The National Nanotechnology Infrastructure Network is an integrated partnership of thirteen user facilities (listed on next page), providing unparalleled opportunities for nanoscience and nanotechnology research. For more information, see http://www.nnin.org/nnin_about.html	

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	Cornell Nanoscale Facility The facility enables researchers from universities and companies across the country to access state-of-the-art fabrication and characterization tools, and learn to use them with the help of a knowledgeable technical staff. For more information, see http://www.nnin.org/nnin_cornell.html	Cornell University
	Stanford Nanofabrication Facility The facility is a state-of-the-art, shared-equipment, open use resource. This laboratory serves academic, industrial and governmental researchers. For more information, see http://www.nnin.org/nnin_stanford.html	Stanford University
	Microelectronics Research Lab The facility emphasizes the application of nanofabrication to bioengineering and biomedicine. For more information, see http://www.nnin.org/nnin_georgiatech.html	Georgia Tech
	Center for Nanotechnology - Nanotech User Facility The facility's objectives are educating the nanotechnology workforce of tomorrow and providing access to nanoscale tools with an emphasis on the applications of nanotechnology in biology and life sciences. For more information, see http://www.nnin.org/nnin_washington.html	University of Washington
	Michigan Nanofabrication Facility The facility is one of the leading centers worldwide on MEMS and microsystems. It provides facilities and processes for the integration of silicon integrated circuits and MEMS with nanotechnology, with applications in biology, medical systems, chemistry and environmental monitoring. For more information, see http://www.nnin.org/nnin_michigan.html	University of Michigan
	Minnesota Nanotechnology Cluster The node includes three partners--the Nanofabrication Center hosting a full suite of processing tools for building micro and nano devices; the Characterization Facility offering a wide suite of electron beam, ion beam, x-ray, optical and proximal probe tools; and the Particle Technology Lab that has a wide variety of instrumentation. For more information, see http://www.nnin.org/nnin_minnesota.html	University of Minnesota

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	Penn State Nanofabrication Facility The facility enables advanced interdisciplinary academic and industrial research and development in the semiconductor electronic and optoelectronic, micro- and nanoelectromechanical systems, materials, biological and pharmaceutical fields. For more information, see http://www.nnin.org/nnin_psu.html	Penn State University
	Nanotech The facility's strengths include leading expertise in compound semiconductors, photonics, quantum structures and expertise with non-standard materials and fabrication processes. For more information, see http://www.nnin.org/nnin_ucsb.html	University of California, Santa Barbara
	Microelectronics Research Center The facility provides opportunities to perform research in novel materials of interest to the integrated circuits industry, optoelectronics and nanophotonics, novel electronic devices and nano-structures, and interconnects and packaging. For more information, see http://www.nnin.org/nnin_texas.html	University of Texas-Austin
	Nanoscience @UNM The facility, distributed across three locations of the UNM, provides rapid access for academia and industry to high technology cleanroom, advanced lithography, and characterization equipment as well as to quantum nanostructure growth facilities. For more information, see http://www.nnin.org/nnin_newmexico.html	University of New Mexico
	Center for Nanoscale Systems The facility emphasizes the areas of 1) soft lithography and the assembly of nanoparticle and molecular electronics; 2) theoretical simulations of electron states and transport in nanoscale systems; and 3) the establishment of core computational resources to assist users in the understanding and visualization of new device structures. For more information, see http://www.nnin.org/nnin_harvard.html	Harvard University
	Howard Nanoscale Science and Engineering Facility The facility emphasizes general microfabrication, electronics and materials, characterization science and nonfiltration. For more information, see http://www.nnin.org/nnin_howard.html	Howard University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
ARCTIC AND ANTARCTIC EQUIPMENT, FACILITIES AND LOGISTICS	**United States Antarctic Program (USAP)** The United States Antarctic Program supports scientific research in Antarctica and the Southern Ocean. The USAP carries forward the nation's goals of supporting the Antarctic Treaty, fostering cooperative research with other nations, protecting the Antarctic environment, and developing measures to ensure only equitable and wise use of resources. The program has three year-round research stations (listed below). For more information, see http://www.nsf.gov/od/opp/antarct/usap.jsp	
	Amundsen-Scott South Pole Station The new station at the South Pole, the third since 1956, was dedicated in January 2008. The elevated station is larger and much more sophisticated than any previous structure built at the Pole--a reflection of the logistical support needed for the ever-increasing range and diversity of the research taking place there. For more information, see http://www.nsf.gov/news/special_reports/livingsouthpole/index.jsp	USAP
	McMurdo Station Located on the Ross Sea, Antarctica's largest station serves as a "gateway" to Antarctica for U.S. scientific field teams as well as the hub for most of the U.S. scientific activity. During the austral summer, the population of scientists and support personnel at McMurdo often exceeds 1,000 people. For more information, see http://www.nsf.gov/od/opp/support/mcmurdo.jsp	USAP
	Palmer Station Located on Anvers Island in the Antarctic Peninsula region, the station is the only U.S. Antarctic station north of the Antarctic Circle. More than 40 people can occupy Palmer in the summer. Wintering population is about 10, although Palmer does not have a long period of winter isolation as do McMurdo and South Pole. For more information, see http://www.nsf.gov/od/opp/support/palmerst.jsp	USAP
	R/V Nathaniel B. Palmer One of two research ships with icebreaking capability operated by the USAP to support research throughout the Southern Ocean region, particularly in the Ross Sea near McMurdo Station. A first-rate platform for global change studies, including biological, oceanographic, geological and geophysical components, the ship can operate safely year-round in Antarctic waters that often are stormy or covered with sea ice. For more information, see http://www.nsf.gov/od/opp/support/nathpalm.jsp	USAP (chartered, owned and operated by Louisiana-based Edison Chouest Offshore)

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	R/V Laurence M. Gould An ice-strengthened, multi-disciplinary research platform, the *Gould* is designed for year-round polar operations and can accomodate 26 research scientists for missions up to 75 days long. Its primary mission is to support research in the Antarctic Peninsula region and to resupply and transport researchers and staff between Palmer Station and South American ports. The ship began its service in Antarctica in January 1998. For more information, see http://www.nsf.gov/od/opp/support/gould.jsp	USAP (chartered, owned and operated by Louisiana-based Edison Chouest Offshore)
	Other Antarctic Logistical Support An array of aircraft, including C-17 jet aircraft, ski-equipped Hercules (LC-130s) and ski-equipped Twin Otters, are used to ferry personnel and cargo between both gateways (Christchurch, New Zealand, and Punta Arenas, Chile) and the appropriate destinations in Antarctica. Helicopters provide support to field parties traveling to and back from field camps and research sites. The main helicopter operating area is in the McMurdo Dry Valleys, although helicopters are used at large field camps in remote areas of Antarctica. For more information, see http://www.nsf.gov/od/opp/ail/index.jsp	USAP
	U.S. National Ice Core Laboratory A laboratory dedicated to providing colleagues with a premier facility for examining, sampling, and analyzing ice cores from some of the most remote places on Earth.	NSF and USGS
	U.S. Polar Rock Repository at the Byrd Polar Research Center at Ohio State University Houses and makes available for research rock samples from Antarctica, the Arctic, southern South America and South Africa.	Ohio State University
	Antarctic Marine Geology Research Facility at Florida State University A national repository for geological materials collected in and around Antarctica.	Florida State University
	Paleobotany Collection of Kansas University Houses more than 7,000 specimens of Antarctic fossil plants from throughout the Transantarctic Mountains.	Kansas University

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	Arctic Logistical Support The Arctic Research Support and Logistics (RSL) program assists the field component of research projects in the Arctic. The program's Arctic logistics contractor CH2M HILL Polar Services (formerly known as VECO Polar Resources) provides logistics support to NSF-funded researchers. The Arctic RSL program also funds base support of the Arctic Research Consortium of the United States, Toolik Field Station, the Barrow Arctic Science Consortium, procurement and maintenance of instrumentation on the USCGC *Healy* (see below), and the development of a digital elevation model of the Kuparuk Watershed in northern Alaska.	
	U.S. Coast Guard Cutter (USCG) *Healy* An icebreaker designed to support scientific research. It has been used in a number of research cruises, mostly in the Arctic Ocean region. The ship is able to accommodate 35-50 scientists and is equipped with more than 5,000 square feet of science lab and support space. The *Healy*'s first science cruise was in 2001, as part of the Arctic Mid-ocean Ridge Expedition (AMORE).	**USCG**
SHARED CYBERINFRA-STRUCTURE (Including Computer Systems, Grid Networking, Data Bases, and Data Analysis and Storage Systems)	**TeraGrid** The Extensible Terascale Facility (commonly known as the TeraGrid) is the world's most powerful distributed cyberinfrastructure for open scientific research, supporting more than 1,000 projects and 4,000 researchers all across the U.S. For more information, see http://www.teragrid.org/	Eleven partners – Indiana University, Louisiana Optical Network Initiative, NCAR, University of Illinois NCSA, NICS, Oak Ridge National Laboratory, PSC, Purdue University, SDSC, Texas Advanced Computing Center and University of Chicago/Argonne National Laboratory
	Ranger The new high performance computing system provides the first petascale platform for the U.S. university research community, with peak performance of one-half petaflop per second. Ranger is specifically designed to provide unprecedented power to meet very large science and engineering computational requirements, and is currently supporting some 150 research projects, ranging from earthquake simulation and advanced biology to nanoelectronics and particle physics. For more information, see http://www.tacc.utexas.edu/research/users/features/ranger.php	Texas Advanced Computing Center at the University of Texas at Austin
	NICS Kraken The new near-petascale system's computing capability will significantly expand the capacity of the TeraGrid and enable investigators to pursue breakthrough science and engineering research in a wide range of computationally demanding areas. For more information, see http://www.nics.tennessee.edu/computing-resources/kraken	Led by the University of Tennessee at Knoxville in collaboration with the Oak Ridge National Laboratory

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	Blue Waters Project Blue Waters is being designed to be the world's most powerful "petascale" system for science and engineering research, capable of making arithmetic calculations at a sustained rate in excess of 1,000-trillion operations per second. For more information, see http://www.ncsa.uiuc.edu/BlueWaters/	NCSA at the University of Illinois at Urbana-Champaign will acquire and deploy the system, which will be operated by NCSA its partners in the Great Lakes Consortium for Petascale Computing
	Protein Data Bank The Protein Data Bank ensures open access to the worldwide collection of deposits of more than 50,000 molecular structures, as well as tools and resources for studying them. For more information, see http://www.rcsb.org/pdb/home/home.do	Operated by the Research Collaboratory for Structural Biology (RCSB), a partnership between Rutgers, the State University of New Jersey, and the University of California, San Diego.
	iPlant Collaborative The iPlant Collaborative seeks to take collaboration to a new level, bringing together researchers in every area of plant science—from molecular and cellular biologists to those working at the ecosystem and global levels—as well as computer scientists, information scientists, engineers, mathematicians and social scientists and enabling specialists from different fields to work together more effectively than ever before. For more information, see http://www.nsf.gov/news/news_summ.jsp?cntn_id=111048 and http://iplantcollaborative.org/	University of Arizona (lead), Cold Spring Harbor Laboratory, Arizona State University, the University of North Carolina at Wilmington and Purdue University
	National Science Digital Library (NSDL) The National Science Digital Library (NSDL) is the nation's online library for education and research in science, technology, engineering and mathematics. For more information, see http://nsdl.org/	
	Digital Library for Earth System Education (DLESE) The Digital Library for Earth System Education (DLESE) offers the nation's most extensive collection of digital learning resources for geoscience education. Based at NCAR in Boulder, Colo., DLESE allows scientists, educators and students around the world to access geosciences information. For more information, see http://www.dlese.org/library/index.jsp	
	Data Intensive Science University Network (DISUN) The Data Intensive Science University Network is a distributed cyberinfrastructure for applications requiring data-intensive distributed computing technology. For more information, see http://www.disun.org/	California Institute of Technology, University of California, San Diego, University of California, Los Angeles, University of Florida and University of Wisconsin-Madison

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	Global Ring Network for Advanced Applications Development (GLORIAD) The Global Ring Network for Advanced Applications Development is a high-speed (10-gigabit-per-second) optical network around the entire northern hemisphere. For more information, see http://www.gloriad.org/gloriad/index.html	Joint Institute for Computational Science of the University of Tennessee and Oak Ridge National Laboratory
	Grid Physics Network (GriPhyN) The Grid Physics Network is a collaboration of experimental physicists and information technology researchers to implement the first petabyte-scale computational environments for data intensive science in the 21st century. For more information, see http://www.griphyn.org/index.html	University of Florida
	Collaborative Center for Internet Epidemiology and Defenses (CCIED) The Collaborative Center for Internet Epidemiology and Defenses is an NSF-supported joint effort between researchers at the University of California, San Diego, and the International Computer Science Institute's Center for Internet Research to address critical challenges posed by large-scale Internet-based pathogens, such as worms and viruses. For more information, see http://www.ccied.org/.	University of California, San Diego
	Cooperative Association for Internet Data Analysis (CAIDA) The Cooperative Association for Internet Data Analysis was established to foster engineering and technical collaborations among Internet providers, vendors and user groups. For more information, see http://www.caida.org/home/.	University of California, San Diego
	Cluster Exploratory (CluE) A new Cluster Exploratory initiative will provide NSF-funded researchers with access to software and services running on a Google-IBM data cluster to explore innovative research ideas in data-intensive computing. For more information, see http://www.nsf.gov/cise/clue/index.jsp	

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CENTER PROGRAMS	**National Institute for Mathematical and Biological Synthesis (NIMBioS)** The National Institute for Mathematical and Biological Synthesis is a new NSF-funded center established to foster research and education at the interface of the mathematical and biological sciences.	University of Tennessee-Knoxville
	Centers for Analysis and Synthesis	
	National Center for Ecological Analysis and Synthesis (NCEAS) The National Center for Ecological Analysis and Synthesis is focused on the development and testing of important ecological ideas and theories using existing data to help people see the "big picture" when it comes to Earth's systems.	University of California, Santa Barbara
	National Evolutionary Synthesis Center (NESCent) The National Evolutionary Synthesis Center enables collaborative biological research efforts, with the central goal of fostering greater conceptual synthesis in biological evolution by bringing together researchers and educators, existing data and information technology resources.	Duke University, North Carolina State University, University of North Carolina
	Engineering Research Centers (ERCs) The Engineering Research Centers program brings knowledge of industrial practices and needs to universities and other research institutions, and speeds the translation of their research into useful products and processes. The Gen-3 ERCs, starting with the Class of 2008, have been designed to build on the well-developed understanding laid down by the two previous generations, with several new dimensions designed to speed the innovation process and prepare engineering graduates who are innovative, creative, and understand how to function in a global economy where engineering talent is broadly distributed throughout the world. NSF supports the following ERCs:	

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	Biomimetic Microelectronic Systems	University of Southern California
	Biorenewable Chemicals (Gen-3, *2008 award*)	Iowa State University
	Collaborative Adaptive Sensing of the Atmosphere	University of Massachusetts Amherst
	Compact and Efficient Fluid Power	University of Minnesota
	Extreme Ultraviolet Science and Technology	Colorado State University
	Future Renewable Electric Energy Delivery and Management Systems (Gen-3, *2008 award*)	North Carolina State University
	Integrated Access Networks (Gen-3, *2008 award*)	University of Arizona
	Mid-Infrared Technology for Health and the Environment	Princeton University
	Quality of Life Technology	Carnegie Mellon University/ University of Pittsburgh
	Revolutionizing Metallic Biomaterials (Gen-3, *2008 award*)	North Carolina Agricultural and Technical State University
	Smart Lighting (Gen-3, *2008 award*)	Rensselaer Polytechnic Institute
	Structured Organic Composites	Rutgers University
	Subsurface Sensing and Imaging Systems	Northeastern University
	Synthetic Biology	University of California, Berkeley
	Wireless Integrated MicroSystems	University of Michigan

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Nanoscale Science and Engineering Centers (NSECs) The Nanoscale Science and Engineering Centers bring together researchers with diverse expertise, in partnership with industry, government laboratories, and/or partners from other sectors, to address complex, interdisciplinary challenges in nanoscale science and engineering, and integrate research with education both internally and through a variety of partnership activities. The following centers are supported:	
	Affordable Nanoengineering of Polymer Biomedical Devices	Ohio State University
	Integrated and Scalable Nanomanufacturing	University of California, Los Angeles
	Directed Assembly of Nanostructures	Rensselaer Polytechnic Institute
	Electronic Transport in Molecular Nanostructures	Columbia University
	High Rate Nanomanufacturing	Northeastern University, University of New Hampshire, University of Massachusetts-Lowell
	Integrated Nanomechanical Systems	University of California, Berkeley, California Institute of Technology, Stanford University, University of California, Merced
	Integrated Nanopatterning and Detection Technologies	Northwestern University
	Molecular Function at the Nano/Bio Interface	University of Pennsylvania
	Nanotechnology in Society Network: Center at ASU	Arizona State University
	Nanotechnology in Society Network: Center at UCSB	University of California, Santa Barbara

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems	University of Illinois at Urbana-Champaign
	Nanoscale Systems in Information Technologies	Cornell University
	Nanoscience in Biological and Environmental Engineering	Rice University
	National Nanomanufacturing Network: Center for Hierarchical Manufacturing	University of Massachusetts Amherst
	Probing the Nanoscale	Stanford University, IBM
	Science of Nanoscale Systems and their Device Applications	Harvard University
	Templated Synthesis and Assembly at the Nanoscale	University of Wisconsin-Madison
	Centers for the Environmental Implications of Nanotechnology (CEIN) The Centers for the Environmental Implications of Nanotechnology will explore how nanomaterials interact with the environment and with living systems, and will translate this knowledge into risk assessment and mitigation strategies useful in the development of nanotechnology. NSF is partnering with EPA to sponsor the centers. For more information, see the NSF news release at http://www.nsf.gov/news/news_summ.jsp?cntn_id=112234	
	Center for Environmental Implications of Nanotechnology	Duke University
	CEIN: Predictive Toxicology Assessment and Safe Implementation of Nanotechnology in the Environment	University of California, Los Angeles

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Industry/University Cooperative Research Centers (I/UCRC) The Industry/University Cooperative Research Centers program develops long-term partnerships among industry, academia and government. The centers focus on research in crucial areas of interest to both industry and university researchers such as advanced electronics, advanced manufacturing, advanced materials, biotechnology, civil infrastructure systems, information-communication-computing systems, energy and environment, fabrication and processing technology, health and safety, and system design and simulation. The following centers are supported:	
	Center for Advanced Vehicle Electronics	Auburn University
	Center for Telecommunications - Connection One: Communication Circuits and Systems Research	Arizona State University (lead), University of Arizona, University of Hawaii, Rensselaer Polytechnic Institute, Ohio State University
	Compact, High-Performance Cooling Technologies Research Center	Purdue University
	Center for Intelligent Maintenance Systems	University of Cincinnati (lead), University of Michigan at Ann Arbor, University of Missouri-Rolla
	Center for Lasers and Plasmas for Advanced Manufacturing	University of Virginia (lead), University of Michigan at Ann Arbor, Southern Methodist University
	Center for Precision Forming	Ohio State University (lead), Virginia Commonwealth University
	Smart Vehicle Concepts Center	Ohio State University (lead), Texas A&M
	Center for Dielectric Studies	Penn State University
	Ceramic and Composite Materials Center	Rutgers University, University of New Mexico, Penn State University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Biomolecular Interaction Technologies Center	University of New Hampshire
	Center for Biocatalysis and Bioprocessing of Macromolecules	Polytechnic University
	Center for Advanced Forestry	North Carolina State University (lead), Purdue University, Oregon State University, Virginia Tech
	Center for Repair of Buildings and Bridges with Composites	University of Miami (lead), North Carolina State University
	Cyber Protection	Iowa State University (lead), Stony Brook
	Center for Experimental Research in Computer Systems	Georgia Institute of Technology (lead), Ohio State University
	Center for High-Performance Reconfigurable Computing	University of Florida (lead), George Washington University, Brigham Young University, Virginia Tech
	Wireless Internet Center for Advanced Technology	Polytechnic University (lead), Auburn University, University of Virginia, Virginia Polytechnic Institute and State University
	Water Quality Center	University of Arizona at Tucson (lead), Arizona State University at Tempe
	Center for Fuel Cells	University of South Carolina
	Berkeley Sensor and Actuator Center	University of California, Berkeley (lead), University of California, Davis
	Center for Friction Stir Processing	South Dakota School of Mines and Technology (lead), University of South Carolina, Brigham Young University, Missouri University of Science and Technology, Wichita State University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Membrane Applied Science and Technology Center	University of Colorado at Boulder
	Safety Security Rescue Research Center	University of Minnesota (lead), University of Pennsylvania
	Center for Identification Technology Research	West Virginia University (lead), University of Arizona
	Minimally Invasive Medical Technologies Center	University of Minnesota (lead), University of Cincinnati
	Center for Child Injury Prevention Studies	Children's Hospital of Philadelphia, University of Pennsylvania
	Center for Computational Materials Design	Penn State University, Georgia Tech
	Center for e-Design	Virginia Polytechnic Institute (lead), University of Pittsburgh, University of Massachusetts, University of Central Florida
	Center for Engineering Logistics and Distribution	University of Arkansas, University of Oklahoma, University of Louisville, Oklahoma State University, Lehigh University, Texas Tech University, Clemson University, Virginia Tech, University of Missouri, Arizona State University
	Center for Advanced Cutting Tools (2008 award)	Michigan State University
	Center for Advanced Sustainable Iron and Steel (2008 award)	Michigan State University (lead), University of Utah
	Center for Advanced Space Technologies Research and Engineering Center (2008 award)	University of Florida (lead), North Carolina State University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Center for Bioenergy Research and Development (2008 award)	South Dakota School of Mines and Technology (lead), South Dakota State, North Carolina State University, University of Hawaii, State University of New York, Kansas State University
	Center for Health Organization and Transformation (2008 award)	Texas A&M (lead), Georgia Tech
	Center for Surfactant and Particulate (2008 award)	University of Florida (lead), Columbia University
	Silicon Solar (2008 award)	North Carolina State University (lead), Georgia Tech
	Center for Autonomic Computing (2008 award)	University of Florida (lead), Rutgers University, University of Arizona
	Center for Advanced Knowledge Abatement (2008 award)	Florida International University
	Centers for Chemical Innovation (CCI, formerly Chemical Bonding Centers) The Centers for Chemical Innovation are designed to support research on strategic, transformative "big questions" in basic chemical research. Appropriate research problems for the centers are high-risk but potentially high-impact and will attract broad scientific and public interest. Supported centers are:	
	Center for Enabling New Transformation Through Catalysis – Phase II	University of Washington
	Powering the Planet – Phase II (2008 award)	California Institute of Technology
	Center for Molecular Cybernetics – Phase I	Columbia University
	Chemistry at the Space-Time Limit – Phase I	University of California, Irvine

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Orchestrating Proton Transport Through Supramolecular Alignment of Functionalities – Phase I	University of Massachusetts Amherst
	The Origins Chemical Inventory and Early Metabolism Project – Phase I	Georgia Tech
	Center for Green Materials Chemistry – Phase I (2008 award)	Oregon State University
	Center for Molecular Interfacing – Phase I (2008 award)	Cornell University
	Center for Chemistry of the Universe – Phase I (2008 award)	University of Virginia
	Materials Research Science and Engineering Centers (MRSECs) The Materials Research Science and Engineering Centers address fundamental materials research problems of intellectual and strategic importance that are critical for American competitiveness and the development of future technologies. NSF supports the following centers:	
	Center for Nanostructured Materials	Columbia University
	Center on Polymer Interfaces and Macromolecular Assemblies	Stanford University
	Response-Driven Polymeric Films Center	University of Southern Mississippi
	MRSEC	University of Alabama Tuscaloosa
	MRSEC	University of Pennsylvania

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Cornell Center for Materials Research	Cornell University
	MRSEC at UCSB	University of California, Santa Barbara
	Carnegie Mellon University MRSEC	Carnegie Mellon University
	The University of Maryland MRSEC	University of Maryland College Park
	MRSEC	Johns Hopkins University
	MRSEC for Research on Interface Structures and Phenomena	Yale University
	Multifunctional Nanoscale Material Structures	Northwestern University
	MRSEC on Nanostructured Interfaces	University of Wisconsin-Madison
	Center for Semiconductor Physics in Nanostructures	University of Oklahoma Norman Campus
	Center for the Science and Engineering of Materials	California Institute of Technology
	Genetically Engineered Materials Science and Engineering Center	University of Washington
	Micro- and Nano- Mechanics of Materials	Brown University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	MIT MRSEC	Massachusetts Institute of Technology
	Princeton Center for Complex Materials	Princeton University
	University of Minnesota MRSEC	University of Minnesota-Twin Cities
	MRSEC	University of Chicago
	Semantophoretic Assemblies (2008 award)	New York University
	The Georgia Tech Laboratory for New Electronic Materials (2008 award)	Georgia Tech
	Center for Nanoscale Science	Penn State University
	Center for Emergent Materials (2008 award)	Ohio State University
	MRSEC	Harvard University
	Constraints and Frustration in Nano-Structured and Bio-Molecular Materials (2008 award)	Brandeis University
	Quantum and Spin Phenomena in Nanomagnetic Structures	University of Nebraska-Lincoln
	MRSEC on Polymers	University of Massachusetts Amherst

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Renewable Energy MRSEC (2008 award)	Colorado School of Mines
	Soft Materials Research Center	University of Colorado at Boulder
	Physics Frontiers Centers (PFCs) The Physics Frontiers Centers program supports university-based centers and institutes where the collective efforts of a larger group of individuals can enable transformational advances in the most promising research areas. The centers are:	
	FOCUS: Frontiers in Optical Coherent and Ultrafast Science	University of Michigan-Ann Arbor
	Center for the Study of the Origin and Structure of Matter	Hampton University
	Center for Theoretical Biological Physics	University of California, San Diego
	Center for Ultracold Atoms	Massachusetts Institute of Technology
	JILA AMO Physics Frontier Center	JILA, an institute jointly operated by the University of Colorado and the National Institute for Standards and Technology
	Physics Frontier Center of the Kavli Institute for Cosmological Physics	University of Chicago
	Physics Frontier Center: Joint Institute for Nuclear Astrophysics (JINA)	University of Notre Dame
	Physics Frontier Center: Center for the Physics of Living Cells	University of Illinois at Urbana-Champaign
	Physics Frontiers Center at the Joint Quantum Institute	University of Maryland-College Park

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas (2008 award)	University of Wisconsin-Madison
	Science and Technology Centers (STCs): Integrative Partnerships The Science and Technology Centers: Integrative Partnerships program supports innovative, potentially transformative, complex research and education projects that require large-scale, long-term awards. STCs conduct world-class research through partnerships among academic institutions, national laboratories, industrial organizations, and/or other public/private entities, and via international collaborations, as appropriate. The centers are:	
	Center for Adaptive Optics	University of California, Santa Cruz
	Center of Advanced Materials for the Purification of Water with Systems	University of Illinois
	Center for Behavioral Neuroscience	Georgia State Partners: Clark Atlanta University and Emory University, Georgia Tech, Morehouse College, Morehouse School of Medicine, and Spelman College
	Center for Biophotonics Science and Technology	University of California, Davis
	Center for Remote Sensing of Ice Sheets	University of Kansas
	Center for Coastal Margin Observation and Prediction	Oregon Health and Science University
	National Center for Earth-Surface Dynamics	University of Minnesota
	Center for Embedded Networked Sensing	University of California, Los Angeles
	Center for Environmentally Responsible Solvents and Processes	University of North Carolina

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Center for Integrated Space Weather Modeling	Boston University
	Center for Layered Polymeric Systems	Case Western Reserve University
	Center on Materials and Devices for Information Technology Research	University of Washington
	Center for Microbial Oceanography: Research and Education	University of Hawaii
	Center for Multi-Scale Modeling of Atmospheric Processes	Colorado State University
	Nanobiotechnology Center	Cornell University
	Center for Sustainability of Semi-Arid Hydrology and Riparian Areas	University of Arizona
	Team for Research in Ubiquitous Secure Technology	University of California, Berkeley
	Science of Learning Centers (SLCs) The Science of Learning Centers are built around a unifying research focus on the science of learning. The centers incorporate diverse, multidisciplinary environments involving appropriate partnerships with academia, industry, international partners, all levels of education, and other public and private entities. NSF supports the following:	
	Center for Learning in Education, Science and Technology	Boston University
	Pittsburgh Science of Learning Center - Studying Robust Learning	Carnegie Mellon University
	LIFE Center-Learning in Formal and Informal Environments	University of Washington

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Spatial Intelligence and Learning Center	Temple University
	Temporal Dynamics of Learning Center	University of California, San Diego
	Visual Language and Visual Learning	Gallaudet University
	Centers of Research Excellence in Science and Technology (CREST) The Centers of Research Excellence in Science and Technology make resources available to enhance the research capabilities of minority-serving institutions through the establishment of centers that effectively integrate education and research. The centers are:	
	Center for Forest Ecosystems Assessment	Alabama A&M University
	Center for Nanobiotechnology Research	Alabama State University
	Center for Environmental Analysis	California State University, Los Angeles
	Center for Functional Nanoscale Materials	Clark Atlanta University
	Center for Exploitation of Nanostructures in Sensors and Energy Systems (Phase II center funded in FY 2008)	CUNY City College
	Center for Research and Education in Optical Sciences and Applications	Delaware State University
	Center for Physics and Chemistry of Materials	Fisk University
	Center for Astronomy	Florida A&M University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Center for Information Processing (Phase II center funded in FY 2008)	Florida International University
	Center for Laser Science	Hampton University
	Center for Nanomaterials (Phase II center funded in FY 2008)	Howard University
	Interdisciplinary Nanotoxicity Center (2008 award)	Jackson State University
	Center for Excellence in Bioinformatics and Computational Biology	New Mexico State University
	Center for Photonic Materials Research	Norfolk State University
	Center for Advanced Materials	North Carolina A&T State University
	Computational Center for Fundamental and Applied Science (2008 award)	North Carolina Central University
	Coastal Ecology/Engineering	Texas A&M University, Kingsville
	Nanomaterials	Tuskegee University
	Tropical Ecology (2008 award)	University of Hawaii at Hilo
	Tropical Ecology	University of Puerto Rico - Rio Piedras

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Nanotechnology (2008 award)	University of Puerto Rico - Mayaguez
	Center for Gravitational Wave Astronomy	University of Texas Brownsville
	Cyber-ShARE - Center for the Sharing of Cyber-Resource to Advance Science and Education	University of Texas El Paso
	Historically Black Colleges and Universities Research Infrastructure for Science and Engineering (HBCU-RISE) The Historically Black Colleges and Universities Research Infrastructure for Science and Engineering (HBCU-RISE) program helps to strengthen the science and engineering research and education capabilities of minority-serving institutions that offer doctoral degrees in science and engineering disciplines. The centers are:	
	Research and Education in Advanced Computing	Clark Atlanta University
	Neuroscience	Delaware State University
	Estuary Ecology	Florida A&M University
	Optics and Photonics	Hampton University
	Computational Chemistry	Jackson State University
	Materials Science and Engineering	Norfolk State University
	Advanced Signal Systems	Prairie View A&M University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Environmental Toxicology	Southern University
	Infrastructure Composite	Southern University
	Decision Systems	Tennessee State University
	Endocrine Disruptors	Texas Southern University
	Material Science and Engineering (2008 award)	Tuskegee University
	Long-Term Ecological Research (LTER) The Long-Term Ecological Research project sites represent Earth's major ecosystems, including deserts, grasslands, forests, tundra, urban areas, agricultural systems, freshwater lakes, coastal estuaries and salt marshes, coral reefs and coastal ocean zones. Research conducted at the LTER sites is contributing to our understanding of climate change, biodiversity, human's impact on the environment and other major ecological challenges. The following are NSF's LTER sites:	
	Andrews (Forest) LTER, Oregon	Oregon State University
	Arctic LTER, Alaska	Marine Biological Laboratory (Woods Hole)
	Baltimore Ecosystem Study, Maryland	Institute of Ecosystem Studies
	Bonanza Creek LTER, Alaska	University of Alaska-Fairbanks
	California Current Ecosystem	Scripps Institution of Oceanography-University of California, San Diego

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Cedar Creek Ecosystem Science Reserve, Minnesota	University of Minnesota-Twin Cities
	Central Arizona - Phoenix Urban LTER	Arizona State University
	Coweeta LTER	University of Georgia
	Florida Coastal Everglades LTER	Florida International University
	Georgia Coastal Ecosystems LTER	University of Georgia
	Harvard Forest LTER, Massachusetts	Harvard University
	Hubbard Brook LTER, New Hampshire	Cornell University
	Jornada Basin LTER, New Mexico	New Mexico State University, Duke University
	Kellogg Biological Station LTER, Michigan	Michigan State University
	Konza Prairie LTER, Kansas	Kansas State University
	Luquillo LTER, Puerto Rico	University of Puerto Rico-Rio Piedras
	McMurdo Dry Valleys LTER, Antarctica	Ohio State University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Moorea Coral Reef LTER, French Polynesia	University of California, Santa Barbara
	Niwot Ridge LTER, Colorado	University of Colorado-Boulder
	North Temperate Lakes LTER, Wisconsin	University of Wisconsin-Madison
	Palmer Station LTER, Antarctica	University of California, Santa Barbara, College of William and Mary
	Plum Island Ecosystem LTER, Massachusetts	Marine Biological Laboratory (Woods Hole)
	Santa Barbara Coastal LTER, California	University of California, Santa Barbara
	Sevilleta LTER, New Mexico	University of New Mexico
	Shortgrass Steppe, Colorado	Colorado State University
	Virginia Coast Reserve LTER	University of Virginia
MAJOR RESEARCH INSTRUMENTATION – FY 2007 Awards	Major Research Instrumentation (MRI) NSF's Major Research Instrumentation program supports the acquisition and development of mid-range instrumentation for research and training in U.S. institutions of higher education, research museums and non-profit research organizations. The awards below, all made in FY 2007, are representative of the types of instrumentation funded. For more information, see: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5260	
	Acquisition of Microwave Measurement Facilities for RF/MMIC Research	University of Texas Brownsville

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Development of a Multi-Channel Receiver for the Realization of Multi-Mission Capabilities at the National Weather Radar Testbed	University of Oklahoma Norman Campus
	Acquisition of a Femtosecond Fluorescence Upconversion System	South Dakota State University
	Acquisition of a Scanning Electron Microscope with *In Situ* Capabilities	University of Pennsylvania
	Acquisition of a 64 Channel Geodesic EEG System	Illinois Wesleyan University
	Acquisition of Trace Metal Analysis Instrumentation	Northern Michigan University
	Acquisition of Hydrodynamic Equipment and a Laser Grain Size Analyzer to Investigate the Lake Erie Seiche and Its Impact on Sedimentation in the Buffalo River	State University of New York College at Buffalo
	Development of a Cooled Sapphire Oscillator Frequency Standard for VLBI	Northeast Radio Observatory Corp
	Acquisition of a Single-Crystal X-Ray Diffractometer	Eastern Illinois University
	Acquisition of a Stimulated Emission Depletion (STED) Microscope for Nanoscopic Resolution of Biological Samples	University of California, Los Angeles
	Acquisition of an EM PACT2 High Pressure Freezer	House Ear Institute
	Acquisition of 15 High-rate GPS Units for Developing a Broadband Earthquake Observation System in Puerto Rico and the U.S. Virgin Islands	University of Puerto Rico Mayaguez
	Acquisition of Marine Geophysical Instrumentation Suite for Seafloor Mapping and Bottom Boundary Layer Analysis	Coastal Carolina University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Acquisition of a Circular Dichroism Spectropolarimeter with Stopped-Flow Detection for Undergraduate Research	Trinity University
	Development of a Silicon Detector for Synchrotron Based X-Ray Spectroscopy, X-Ray Holography and Materials Education	New Jersey Institute of Technology
	Acquisition of Modern Analytical X-Ray Diffraction Instrumentation	University of Alaska Fairbanks Campus
	Acquisition of a Phosphorimager for Research in Marine Functional Genomics	Mount Desert Island Biological Laboratory
	Acquisition of COPAS Instrumentation for Research and Teaching Enhancement in Kansas Universities	University of Kansas Center for Research Inc.
	Acquisition of a Fast-Pulse-Laser for a Local Electrode Atom Probe	University of Alabama Tuscaloosa
	Development of Ring-Ribbon Resonator Biosensor Instrument	Polytechnic University of New York
	Acquisition of a High-Performance Parallel Computer	Oakland University
	Development of a Superconducting Magnet Coil and a 201 MHz RF Cavity for Testing Muon Ionization Cooling Techniques	University of Mississippi
	Acquisition of a High-Performance Computing Cluster for Astrophysics	Princeton University
	Acquisition of a Nanoflow Hybrid Triple Quadrupole/Linear Trap Mass Spectrometer System for Three Diverse Institutions	University of Colorado at Denver
	Acquisition of 400 MHz NMRs for Research and Education	Illinois State University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Development of a Parallel Imager for Southern Cosmology Observations: Time Evolution of Dark Energy	Smithsonian Institution Astrophysical Observatory
	Development of the Next Generation Submillimeter Grating Spectrometer	Cornell University
	Acquisition of a High-Resolution Microcomputed Tomography System in Support of Research in the Biology and Chemistry Departments	University of Scranton
	Acquisition of System for the Integration of Raman Scattering, Luminescence and Scanning Electron Microscopies	Drexel University
	Acquisition of an 800 MHz NMR Spectrometer	University of California, Davis
	Development of a Compact Echelle Spectrograph for Aeronomical Research (CESAR)	SRI International
	Development of an Imaging Nonlinear Optical Ellipsometer	Purdue University
	Acquisition of Broadband Seismic Stations for Polar Regions	Incorporated Research Institutions for Seismology
	Acquisition of an X-Ray Micro-Computed Tomography System for Evaluating Crack Evolution and Failure Characterization of Engineering Materials	University of Michigan Ann Arbor
	Acquisition of Processing and Testing Equipment for the Integration of Materials Science and Engineering Research at the University of Puerto Rico at Mayaguez	University of Puerto Rico Mayaguez
	Acquisition of Integrated Instrumentation to Facilitate Correlative Light and Electron Microscopy of Cellular Systems	Brandeis University
	Acquisition of an EPR Spectrometer	Utah State University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Development of Advanced Ultra-low Temperature System for Exploration of Quantum Mechanics at the Macroscale	Cornell University
	Acquisition of a Genetic Analyzer for Research, Research Training, and Education	Indiana University
	Development of a Refractive Gradiometer Probe for Oceanic Microstructure	Woods Hole Oceanographic Institution
	Acquisition of an Automated Assembly System and RFID Equipment for Research and Education in Advanced Manufacturing	University of Texas at San Antonio
	Acquisition of a Tabletop Scanning Electron Microscope for Undergraduate Research and Training in Materials Chemistry and Geological Science and STEM Activities in Grades 7-12	CUNY Queensborough Community College
	Development of Open-access Photonic Networked Sensors (PHOTONS) for Security, Industrial and Environmental Applications	William Marsh Rice University
	Acquisition of Surface-Enhanced Confocal Raman-AFM	Rensselaer Polytechnic Institute
	Acquisition of Particle Counter and Sizer	Marywood University
	Acquisition of a multi-wavelength femtosecond laser facility	University of New Mexico
	Acquisition of Geophysics Survey Instruments for Archaeological Geophysics Research and Training	Ithaca College
	Acquisition of an x-ray photoelectron spectrometer for research and education in inorganic, nanoparticulate, and biological materials	Vanderbilt University
	Acquisition of an X-Band Electron Paramagnetic Resonance Spectrometer System	California State University-Fullerton

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Real Time Ocean Observations	Humboldt State University
	Acquisition of an XPS system for Interdisciplinary Research and Education	Boise State University
	Development and Acquisition of Oceanographic Instrumentation to Enhance the Arctic Ocean Observing Network for the 2007-2009 International Polar Year Period and Beyond	Woods Hole Oceanographic Institution
	Acquisition of a Thermo-Hydroforming Stamping Press for Research and Education in Forming of Multifunctional Nanocomposite and Biocomposite Polymer Structures	Michigan State University
	Acquisition of a High Performance Computing System for Undergraduate Geoscience Research	Angelo State University
	Acquisition of a High Performance Computing System for Undergraduate Geoscience Research	Augusta State University
	Acquisition of an Atomic Force Microscope and Surface Profilometer for Surface Analysis Facility	Syracuse University
	Acquisition of a Confocal Laser Scanning Microscope for Research and Training in the Natural Sciences	California State University-Long Beach
	Collaborative Research: Development of the Detector Package for the Super HMS in Hall C at JLab	College of William and Mary
	Development of a Phase-coherent Laser System for Attosecond Science and Precision Spectroscopy	Texas A&M
	Acquisition of a Spectropolarimeter for Research and Education	University of Memphis
	Acquisition of a Monochromated, Aberration-Corrected, Ultra High Resolution Transmission Electron Microscope for the University of Michigan's Electron Microbeam Analysis Laboratory	University of Michigan Ann Arbor

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Acquisition of Instrumentation for Organic Molecular Research	Yale University
	Acquisition of a 40-core Linux cluster for oceanographic research at Earth and Space Research	Earth and Space Research
	Acquisition of a Field Emission Environmental Scanning Electron Microscope to Enhance Research and Teaching at Oklahoma State University	Oklahoma State University
	Acquisition of a Kodak Image Station 4000MM Pro for the Visualization and Quantification of Proteins, DNA and RNA	St. Cloud State University
	Development of Infrastructure for Integrated Sensing, Modeling, and Manipulation with Robotic and Human-Machine Systems	Johns Hopkins University
	Acquisition of a 400 MHz Nuclear Magnetic Resonance Spectrometer for Research on Organic Materials and Student Training	Hampton University
	Acquisition of a 3-D Scanning Laser Vibrometer	University of Massachusetts Lowell
	Collaborative Research: Development of the Detector Package for the Super HMS in Hall C at JLab	James Madison University
	Acquisition of Computationally Intensive Research in High Energy Physics	College of William and Mary
	Acquisition of a Molecular Imaging System to Continue Faculty-Student Research in an Interdisciplinary Biomolecular Science Program	Saint Olaf College
	Acquisition and Development of Atomic Force Microscopy Technologies for Biophysical Studies	University of Miami School of Medicine
	Acquisition of a Gas Chromatograph/Mass Spectrometer for Research and Research Training	Oak Crest Institute of Science

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Development of a frequency-comb nearfield infrared spectrometer	University of California, San Diego
	Acquisition of High Brilliance X-ray Optical Components for the ChemMatCARS Synchrotron X-ray Resource at the Advanced Photon Source	Northern Illinois University
	Acquisition of gas chromatographic instrumentation for research and advanced training in the analysis of new and emerging chemicals of concern and legacy pollutants	State University of New York College at Fredonia
	Acquisition of an NMR Spectrometer to Maintain Active Undergraduate Education and Research Programs	Hobart and William Smith Colleges
	Acquisition of a Dual Beam Focused Ion Beam System as a Regional Resource for Collaborative Research and Education in Missouri	University of Missouri-Rolla
	Acquisition of Fluorescence Microscopy System for Live Cell Biological Analysis and Chemical Analysis of Synthetic Materials in Research and Teaching	Fairleigh Dickinson University
	Acquisition of a Terrestrial Laser Scanning System for Polar Research	UNAVCO, Inc.
	Acquisition of a Low Pressure Chemical Vapor Deposition System for Applications in Micro/Nano Technology	University of Louisville
	Acquisition of an Atomic Force Microscope to Enhance Interdisciplinary Materials Research	Bucknell University
	Manufacturing of Nanocrystaline Silicon Materials	University of Rochester
	Acquisition of a Laser Scanning Confocal Microscope for Research and Training in Biology and Physics	Wake Forest University
	Development of a Hybrid Scanning Fluorescence and Sum Frequency Spectroscopy Imaging Microscope	University of Maine

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Acquisition of Mass Spectrometers and Related Equipment to Create the ISU Interdisciplinary Lab for Elemental and Isotopic Analysis (ILEIA)	Idaho State University
	Acquisition of a Rapid Compression Machine for Chemical Kinetic Studies on Biofuels	Rowan University
	Acquisition of a Rapid Compression Machine for Chemical Kinetic Studies on Biofuels	Colorado State University
	Acquisition of Unique, High-Power Instrumentation for Future Distribution Systems Test and Evaluation	University of Arkansas
	Acquisition of an Inductively Coupled Plasma Etch System	University of Cincinnati
	Acquisition of a Confocal Raman/AFM Hybrid System	University of Texas at El Paso
	Acquisition of an Ultracentrifuge for Research and Undergraduate Teaching	State University of New York College at Oswego
	Acquisition of a High Performance Computing Cluster Dedicated to the Energy Sciences	Colorado School of Mines
	Acquisition of Multi-Modal Sensor Arrays for Rainforest Research	Organization for Tropical Studies Inc
	Acquisition of a Pulsed EPR Spectrometer for Miami University	Miami University
	Acquisition of the Second Phase of the Grid Laboratory of Wisconsin (GLOW-II)	University of Wisconsin-Madison
	Development of a New Paradigm for Apertureless Near-field Scanning Optical Microscope	University of California, Davis

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Acquisition of an Ar Ion Laser for Photonic Bandgap Materials Research and Education	University of Texas - Pan American
	Acquisition of a Laser-Ablation System for High Resolution, Micro-Scale Analyses of Environmental Materials	State University of New York College of Environmental Science and Forestry
	Evolutionary Development of an Advanced Distributed Testbed	University of Utah
	Acquisition of Equipment to Simulate Collapse of Engineered Systems under Extreme Loads	University of Washington
	Acquisition of Instrumentation Supporting Quantitative Spectral and Image Analysis	Western Washington University
	Development of the Active Temperature Ozone and Moisture Microwave Spectrometer (ATOMMS) cm and mm-wave Occultation Instrument	University of Arizona
	Acquisition of Particle Image Velocimetry System for Study of Bluff Body Wakes and Shock-Accelerated Flows	University of Texas Brownsville
	Acquisition of a Test-bed for Next Generation Cognitive Radio Wireless Networks	San Diego State University Foundation
	Acquisition of an X-Ray scattering system for polymer and nanomaterials research and education	CUNY College of Staten Island
	Acquisition of Mobile Facility for Providing High-Resolution Input to Hydrologic Observatories	University of Iowa
	Acquisition of a Powder X-ray Diffractometer for Materials Chemistry Research and Education	University of South Dakota Main Campus
	Acquisition of Off-Axis Integrated-Cavity Output Spectroscopy Instruments for Ecological Research and Training	Northern Arizona University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Acquisition of a Powder X-Ray Diffractometer for Multidisciplinary/Multi-institutional Research and Training	Lawrence University
	Acquisition of a Confocal Live Cell Imaging System	University of Connecticut
	Acquisition of a Distributed Computing Cluster for Multidisciplinary Research, Research Training, and Education	Austin Peay State University
	Acquisition of a Physical Properties Measurement System	Indiana University of Pennsylvania
	Acquisition of Equipment to Support Research and Education in Ecosystem Science and Resource Management	Paul Smith's College of Arts and Sciences
	Acquisition of a Live-Cell Confocal Imaging Microscope	University of Georgia Research Foundation Inc
	Acquisition of Equipment to Establish a Cognitive Sensorium and Visualization Facility	University of California, Merced
	Development of a Confocal Instrument for Spatially Resolved Luminescence Measurements in Geologic and Archaeological Dating and Radiation Dosimetry	Oklahoma State University
	Acquisition of an X-ray Diffraction Instrument for Interdisciplinary and Collaborative Research and Education in an Undergraduate Setting	Whitman College
	Acquisition of Computing Equipment to Enhance Computational Science Research	Kean University
	Acquisition of an Integrated Atmospheric Chemistry Mobile Laboratory	Washington State University
	Acquisition of a Thin Film Deposition System - Supporting Nanoscience and Nanotechnology Research and Education	Portland State University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Acquisition of Signal Analysis Equipment for High Frequency Electrical and Optical Research	Lafayette College
	Acquisition of Instrumentation for Aqueous Biogeochemistry Investigations	Smith College
	Acquisition of Multicollector Thermal Ionization Mass Spectrometer (MC-TIMS) for Earth, Environmental, and Cross-disciplinary Research	Northwestern University
	Acquisition of a Full-Wave Interferometric Digital Radio System For Space Research and University Education	Inter American University of Puerto Rico San Juan
	Acquisition of a Mass Spectrometer to Enhance Undergraduate Research and Student Research Training	Winthrop University
	Acquisition of Instrumentation for a Biofuels Research Laboratory	University of Massachusetts Amherst
	Acquisition of a Material Testing System for Research and Educational Training in Static and Dynamic Characterization of Advanced Structural Nanocomposites	Tuskegee University
	Acquisition of instruments for biogeochemical analyses of carbon, nitrogen and phosphorus	Western Washington University
	Acquisition of an Atomic Force Microscope for Research and Education in Cellular and Molecular Biophysics	Johns Hopkins University
	Acquisition of 40Ar/39Ar Facilities at NM Tech	New Mexico Institute of Mining and Technology
	Acquisition of Eight-Channel Receiver System and RF Coils for Functional Neuroimaging	New York University
	Development of a System for Thin Film Deposition of Highly Ordered Organic Materials	University of Vermont & State Agricultural College

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Acquisition of chlorine based reactive ion etcher	Brigham Young University
	Acquisition of an LTQ Mass Spectrometer	Oklahoma State University
	Acquisition of Hydroacoustic and Associated Instrumentation for Fisheries Research	State University of New York College at Oneonta
	Development of Enhanced T-Probe for Aircraft Measurement of Mixed Phase Ice-Water Cloud	University of Nevada Desert Research Institute
	Acquisition of Biogeochemical Analytical Instrumentation for Enhanced Interdisciplinary Research and Training	Arkansas State University Main Campus
	Acquisition of an Advanced Driving Simulator for Safety Research and Education	Arizona State University
	Acquisition of a Magnetic Resonance Imaging System for UCSB Brain Imaging Center	University of California, Santa Barbara
	Acquisition of a Confocal Laser Scanning Microscope for Research and Training in Biology and Biochemistry	Florida Institute of Technology
	Acquisition of a Variable-pressure Scanning Electron Microscope for Interdisciplinary Teaching and Research	University of Minnesota Duluth
	Acquisition of Analytical Instrumentation for a State-of-the-Art Proteomic Facility	William Marsh Rice University
	Instrument Development of Microfluidic-Based Flow-Injection Capillary Electrophoresis with Fiber-Optics Detection	California State Los Angeles University Auxiliary Services Inc.
	Development of Simultaneous Single Molecule Fluorescence and Atomic Force Microscopy	University of Pennsylvania

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Acquisition of Terascale Data Analytic Platforms for Research in the Combinatorial and Graph Sciences Consortium	Howard University
	MRI-RUI: Acquisition of a SQUID Magnetometer for Materials Science Research and Education	Missouri State University
	Development of New Instrumentation to Measure Upper Extremity Motion for Research and Teaching in Rehabilitation Science, Bioengineering and Robotics	George Mason University
	Acquisition of Instrumentation for Creation of a Regional Undergraduate Biophysical Chemistry Research Cluster	University of Richmond
	Development of Unmanned Vehicle Systems as Research Platform for Autonomous Intelligence	The University Corporation, Northridge
	Acquisition of a High-Resolution Scanning Electron Microscope for an Interdisciplinary, Multi-User Facility Serving Life, Physical, and Materials Sciences	University of Wisconsin-Milwaukee
	Acquisition of an Inductively Coupled Plasma Etch System for Optoelectronic and Microelectronic Research and Training	Norfolk State University
	Acquisition of a Flow Cytometer for Multiparametric Analysis of Environmental, Microbial and Aquatic Samples	University of California, Merced
	Acquisition of a Real Time Digital Simulator for Power and Energy Systems Research and Education	Tennessee Technological University
	Acquisition of a high-efficiency scintillation detector for photon detection with rare isotopes	Michigan State University
	Acquisition of Equipment to Establish an Information Assurance Infrastructure for Research and Education	Dakota State University
	Acquisition of a 500 MHz Solid State NMR Spectrometer for Research and Research Training at Pacific Lutheran University and the South Puget Sound Area	Pacific Lutheran University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Acquisition of a high-field NMR spectrometer	University of the Pacific
	Acquisition of PolarGrid: Cyberinfrastructure for Polar Science	Indiana University
	Acquisition of an Atomic Force Microscope for Fundamental Nanotribology Research	Luther College
	Acquisition of a Laser Microdissection Instrument	Mississippi State University
	Acquisition of Large Shared-Memory Computing for the Center for Computational Sciences	Duquesne University
	Acquisition of Drilling Rig and Accessories for *In Situ* Investigations of Slurry Trench Cutoff Walls	Bucknell University
	Acquisition of a CCD-based Single Crystal X-Ray Diffractometer	University of California, Irvine
	Acquisition of an Atomic Force Microscope System to Further Research and Educational Goals	University of the Sciences in Philadelphia
	Acquisition of a Scanning XPS Microprobe	Case Western Reserve University
	Acquisition of a Stereographic Projection System to Support Multidisciplinary Scientific Visualization	Florida State University
	Acquisition of an Experimental Platform for Wireless Multimedia Networking	Polytechnic University of New York
	Acquisition of a Laser Capture Microscope System for Research and Education at Clemson University	Clemson University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Isotope Ratio Mass Spectrometers for Environmental Research	University of Utah
	Acquisition of an Isothermal Titration Calorimeter and a Differential Scanning Calorimeter	San Jose State University Foundation
	High-Speed imaging facility to assess ultra-rapid biological movements	Williams College
	The Core Genomics Laboratory for Teaching and Research in Biotechnology	Villanova University
	Acquisition of Equipment to Upgrade the Pittsburgh Experimental Economics Laboratory	University of Pittsburgh
	Acquisition of a High Resolution Analytical Transmission Electron Microscope for the Miami University Electron Microscope Facility	Miami University
	Acquisition of a Laser Micromanipulation, Dissection and Catapulting System	University of Hawaii
	Acquisition of a State-of-the-Art X-ray Diffractometer for Research, Education and Training	Louisiana Tech University
	Acquisition of inductively coupled plasma etcher to support research and teaching in micro and nanodevices	Montana State University
	Acquisition of a High Performance Cluster for the University of Maine Scientific Grid Portal	University of Maine
	Acquisition of a Near-Field Optical Microscope with Spectroscopic Capabilities	University of Oregon Eugene
	Development of microwave quasi-optical instrumentation for control and detection of polar molecules	Yale University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Acquisition of a Liquid Chromatograph Electron Spray Ionization Mass Spectrometer	Virginia Polytechnic Institute and State University
	Focused Ion Beam System for Nano Fabrication and Nano Machining of Materials	University of New Mexico
	Acquisition of Infrastructure to Enhance Research in Computer Science and Engineering in HPC in Puerto Rico	Polytechnic University of Puerto Rico
	Acquisition of a Large-Stroke, Piston-Type Wavemaker for Coastal Hazards Research and Education	Oregon State University
	Acquisition of a Primary Cluster for the SIO COMPAS Shared Computer Facility	University of California, San Diego Scripps Inst of Oceanography
	Development of a Mobile Fe-Resonance/Rayleigh/Mie Doppler Lidar	University of Colorado at Boulder
	Collaborative Research: Development of the Detector Package for the Super HMS in Hall C at JLab	Hampton University
	Acquisition of Tandem Mass Spectrometry Instrumentation for Integrated Studies of Emerging Contaminants in Water	University of Arizona
	Acquisition of Mobile Spatial Data Acquisition and Processing Technologies to Support Cross-Disciplinary Research and Student Training	Indiana University of Pennsylvania Research Institute
	Acquisition of Aerodyne High-Resolution, Time-of-Flight Aerosol Mass Spectrometer	Washington University
	Development of a Sonic IR Research Instrument for Nondestructive Testing	Rowan University
	Development of an Integrated Ion Scattering and Vibrational Spectroscopy Facility for Quantitative Analysis of Hydrogen for Research and Education	Rutgers University New Brunswick

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Acquisition of Improved Optics and New Instrumentation for a Research and Instructional Observatory	Appalachian State University
	Acquisition of an FT-Raman Spectrometer for Interdisciplinary Art Materials Research and Education	The Art Institute of Chicago
	Acquisition of a 600 MHz Nuclear Magnetic Resonance Spectrometer	Oregon State University
	Acquisition of an advanced micro-Computed Tomography imaging facility	CUNY City College
	Acquisition of a Research-Dedicated fMRI Scanner at Stony Brook	State University of New York at Stony Brook
	Acquisition of an Advanced Computer Cluster for Computational Relativity and Gravitation	Rochester Institute of Technology
	Instrument Acquisition to Enable Time-Resolved Single-Molecule Fluorescence Measurements	Wheaton College
	Development of a Pulsed High Frequency Quasioptical Electron Spin Resonance Spectrometer	Northeastern University
	Acquisition of an X-Ray Diffractometer to Enhance Faculty and Undergraduate Collaborative Research	University of Minnesota Morris
	Acquisition of a Multi-Length Scale Ultra High-Resolution X-Ray Nanotomography Instrument	University of Illinois at Urbana-Champaign
	Acquisition of an Isotope-Ratio Mass Spectrometer Facility for East Georgia	Skidaway Institute of Oceanography
	Acquisition of a Mass Spectrometer System for Undergraduate Research at the University of St. Thomas and Associated Colleges of the Twin Cities	University of St. Thomas

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Acquisition of a Stereoscopic Molecular Tagging Velocimetry (sMTV)/ Molecular Tagging Thermometry (MTT) System	Clarkson University
	Acquisition of a Confocal Microscope	University of Maryland Baltimore County
	Acquisition of a spinning disk confocal microscope for rapid imaging of plant cellular processes	Samuel Roberts Noble Foundation, Inc.
	Acquisition of a Computational Cluster for Research and Training at the University of South Florida in Partnership with Eckerd College and the University of Tampa	University of South Florida
	Acquisition of an Environmental Scanning Electron Microscope for Visualization, Characterization and Manipulation of Nanoscale Systems	Carnegie Mellon University
	Acquisition of Major Instrumentation for Watershed Biogeochemistry Research	Vassar College
	Acquisition of a 3-Station Global Network of Automated Telescopes to Detect a Large Number of Nearby Transiting Extra-solar Planets	Smithsonian Institution Astrophysical Observatory
	An Ultra High Resolution Mass Spectrometer to Identify Novel Protein Sequences and Modifications from Extinct Organisms Such as Tyrannosaurus Rex	Beth Israel Deaconess Medical Center
	Development of an Autonomous Underwater Vehicle (AUV) for Benthic Research and Training	University of Puerto Rico Mayaguez
	Development of a High-Speed Confocal Microscope for 4D Live-Cell Imaging	University of California, Los Angeles
	Acquisition of a Supercomputing Cluster for Computational and Data-Intensive Applications in Science and Engineering	University of Arkansas
	Acquisition of Transmission Electron Microscope to Enhance Biology and Materials Sciences Research	Howard University

WHAT	NAME	LEAD OR PARTNERING INSTITUTION, ENTITY
	Collaborative Facility for Research on Aerogel Materials	Union College
	Acquisition of New Culture Chambers for the CCMP	Bigelow Laboratory for Ocean Sciences
	Acquisition of a High-throughput Genotyping Core	American Museum Natural History
	Acquisition of Instruments to Facilitate Molecular-Level Studies in Earth and Ocean Sciences	University of California, San Diego Scripps Institution of Oceanography
	Collaborative Research: Development of the Detector Package for the Super HMS in Hall C at JLab	North Carolina Agricultural & Technical State University
	Acquisition of a Scanning Electron Microscope for Undergraduate Research	Coe College
	Acquisition and Analysis of a Multi-Disciplinary Beowulf Cluster	Calvin College

Appendix II: Glossary of Acronyms

ACI	American Competitiveness Initiative
AdvLIGO	Advanced Laser Interferometer Gravitational Wave Observatory
ALMA	Atacama Large Millimeter Array
AMISR	Advanced Modular Incoherent Scatter Radar
AMORE	Arctic Mid-Ocean Ridge Expedition
AMS	Accelerator Mass Spectrometry
AON	Arctic Observing Network
ARRV	Alaska Region Research Vessel
AST	Division of Astronomical Sciences
ASTER	Atmosphere Surface Turbulent Exchange Research
ATLAS	A Toroidal LHC ApparatuS
ATST	Advanced Technology Solar Telescope
AUI	Associated Universities, Inc.
AURA	Association of Universities for Research in Astronomy, Inc.
AUV	Autonomous Underwater Vehicle
BCA	Bio-bar-code
BEA	Bureau of Economic Analysis
BES	Baltimore Ecosystem Study LTER
BIO	Directorate for Biological Sciences
BMES	Biomimetic Microelectronic Systems
BOOMERANG	Balloon Observations of Millimetric Extragalactic Radiation and Geomagnetics
BSAC	Berkeley Sensor and Actuator Center
CAIDA	Cooperative Association for Internet Data Analysis
CASA	Collaborative Adaptive Sensing of the Atmosphere
CCF	Coupled Cyclotron Facility
CCI	Center for Chemical Innovation
CCIED	Collaborative Center for Internet Epidemiology and Defenses
CEAS	Center for Analysis and Synthesis
CEIN	Center for the Environmental Implications of Nanotechnology
CENS	Center for Embedded Networked Sensing
CERN	European Organization for Nuclear Research
CERSP	Center for Environmentally Responsible Solvents and Processes
CESR	Cornell Electron Storage Ring
CfAO	Center for Adaptive Optics
CISE	Directorate for Computer and Information Science and Engineering
CISM	Center for Integrated Space Weather Modeling
CLASS	Cross-chain Loran Atmospheric Sounding System
CluE	Cluster Exploratory
CMB	Cosmic Microwave Background
CMMAP	Center for Multi-Scale Modeling of Atmospheric Processes
CMOP	Center for Coastal Margin Observation and Prediction
CRI	CISE Computing Research Infrastructure
CMS	Compact Muon Solenoid
COSMIC	Constellation Observing System for Meteorology Ionosphere and Climate
CO_2	Carbon dioxide
CREST	Center of Research Excellence in Science and Technology
CTD	Conductivity, Temperature and Depth
CTIO	Cerro Tololo Interamerican Observatory
CZEN	Critical Zone Exploration Network
CZO	Critical Zone Observatories
DARPA	Defense Advanced Research Projects Agency
DEB	Division of Environmental Biology
DHS	U.S. Department of Homeland Security

DLESE	Digital Library for Earth System Education
DISUN	Data Intensive Science University Network
DMS	Data Management System
DOE	U.S. Department of Energy
DOM	Digital Optical Module
ECO	Edison Chouest Offshore
EHR	Education and Human Resources
ELOKA	Exchange for Local Observations and Knowledge of the Arctic
ENG	Directorate for Engineering
EPA	U.S. Environmental Protection Agency
EPSCoR	Experimental Program to Stimulate Competitive Research
ERC	Engineering Research Center
ETS	Episodic Tremor and Slip
EVLA	Expanded Very Large Array
FFRDC	Federally Funded Research and Development Center
FY	Fiscal Year
GBT	Robert C. Byrd Green Bank Telescope
GDP	Gross Domestic Product
GEO	Directorate for Geosciences
GLC	Great Lakes Consortium for Petascale Computing
GLORIAD	Global Ring Network for Advanced Applications Development
GNET	GPS Network
GONG	Global Oscillation Network Group
GPS	Global Positioning System
GriPhyN	Grid Physics Network
GSN	Global Seismographic Network
GSS	General Social Survey
HBCU	Historically Black Colleges and Universities
HPWREN	High Performance Wireless Research and Education Network
I/UCRC	Industry/University Cooperative Research Center
IARPC	Interagency Arctic Research Policy Committee
INFN	Istituto Nazionale di Fisica Nucleare, the Italian National Institute of Nuclear Physics
IODP	Integrated Ocean Drilling Program
IPCC	Intergovernmental Panel on Climate Change
IPY	International Polar Year
IPYDIS	International Polar Year Data and Information Service
IRIS	Incorporated Research Institutions for Seismology
ISS	Integrated Sounding System
KPNO	Kitt Peak National Observatory
KREW	Kings River Experimental Watershed
LHC	Large Hadron Collider
LIGO	Laser Interferometer Gravitational-wave Observatory
LMG	R/V Laurence M. Gould
LTER	Long-Term Ecological Research
MAPO	Martin A. Pomerantz Observatory
MEMs	Micro-electromechanical system
MEXT	Ministry of Education, Culture, Sports, Science and Technology (Japan)
MPS	Directorate for Mathematical and Physical Sciences
MREFC	Major Research Equipment and Facilities Construction
MRI	Major Research Instrumentation
MRSEC	Materials Research Science and Engineering Center
NAIC	National Astronomy and Ionosphere Center
NASA	National Aeronautics and Space Administration
NBP	R/V Nathaniel B. Palmer

NBTC	Nanobiotechnology Center
NCAR	National Center for Atmospheric Research
NCEAS	National Center for Ecological Analysis and Synthesis
NCED	National Center for Earth-Surface Dynamics
NCI	National Cancer Institute
NCN	Network for Computational Nanotechnology
NCSA	National Center for Supercomputing Applications
NEES	George E. Brown, Jr. Network for Earthquake Engineering Simulation
NEON	National Ecological Observatory Network
NESCent	National Evolutionary Synthesis Center
NHMFL	National High Magnetic Field Laboratory
NICS	National Institute for Computational Sciences
NIDDK	National Institute of Diabetes and Digestive and Kidney Diseases
NIGMS	National Institute of General Medical Sciences
NINDS	National Institute of Neurological Disorders and Stroke
NLM	National Library of Medicine
NNIN	National Nanotechnology Infrastructure Network
NOAA	National Oceanic and Atmospheric Administration
NOAO	National Optical Astronomy Observatory
NORC	National Opinion Research Center
NRAO	National Radio Astronomy Observatory
NSB	National Science Board
NSCL	National Superconducting Cyclotron Laboratory
NSDL	National Science Digital Library
NSEC	Nanoscale Science and Engineering Center
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center
NSO	National Solar Observatory
NWS	National Weather Service
OCI	Office of Cyberinfrastructure
OIA	Office of Integrative Activities
OOI	Ocean Observatories Initiative
OPP	Office of Polar Programs
OSTP	Office of Science and Technology Policy
PACDEX	Pacific Dust Experiment
PAM	Portable Automated Mesonet
PASSCAL	Program for the Array Seismic Studies of the Continental Lithosphere
PBO	Plate Boundary Observatory
PDB	Protein Data Bank
PM	Photomultiplier
POLENET	Polar Earth Observatory Network
PSC	Pittsburgh Supercomputing Center
PSD	Post-traumatic stress disorder
PSID	Panel Study of Income Dynamics
PRIME	Purdue Rare Isotope Measurement
PTFE	Polytetrafluoroethylene
R&D	Research and Development
R&RA	Research and Related Activities
RASS	Radio Acoustic Sounding System
RB2C	Center for Repair of Buildings and Bridges with Composites
REU	Research Experiences for Undergraduates
RII	Research Infrastructure Improvement
RISE	Research Infrastructure for Science and Engineering
RSL	Research Support and Logistics

R/V	Research Vessel
SAFOD	San Andreas Fault Observatory at Depth
SAGE	System for Algebra and Geometry Experimentation
SAHRA	Center for Sustainability of Semi-Arid Hydrology and Riparian Areas
SBE	Directorate for Social, Behavioral and Economic Sciences
SBIR	Small Business Innovation Research
SCAR	Scientific Committee on Antarctic Research
SDSC	San Diego Supercomputer Center
SEM	Scanning Electron Microscope
SIMS	Secondary Ion Mass Spectrometry
SLC	Science of Learning Center
SODV	Scientific Ocean Drilling Vessel
SPSM	South Pole Station Modernization
SPT	South Pole Telescope
SRS	Division of Science Resources Statistics
SSSF	Surface and Sounding Systems Facility
STC	Science and Technology Center
STEM	Science, Technology, Engineering and Mathematics
STTR	Small Business Technology Transfer
SuperDARN	Super Dual Auroral Radar Network
TeraGrid	Extensible Terascale Facility
TRUST	Team for Research in Ubiquitous Secure Technology
TSIP	Telescope System Instrumentation Program
UCAR	University Corporation for Atmospheric Research
UNESCO	United Nations Education, Science and Culture Organization
UNOLS	University-National Oceanographic Laboratory System
USARC	U.S. Antarctic Resource Center
USAP	U.S. Antarctic Program
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VEDA	Virtual Environment for Dynamic Atomic Force Microscopy
VLA	Very Large Array
VLBA	Very Long Baseline Array
WAIS	West Antarctic Ice Sheet
WARPnet	Wireless Open-Access Research Platform for Networks
WaterCAMPWS	Center of Advanced Materials for the Purification of Water With Systems
WIYN	Wisconsin-Indiana-Yale-NOAO telescope

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