I. SOME NSF ACHIEVEMENTS

NOBEL PRIZES FOR 2002

Physics

Raymond Davis, Jr., of Brookhaven National Laboratory and the University of Pennsylvania was honored for his detection of solar neutrinos. Before Davis' early work in the 1960s, scientists had theorized that the fusion reactions in the sun should produce massless particles called neutrinos. At present it is believed there are three types of neutrinos. The number of neutrinos his experiment detected was significantly less than predicted. This result played a major role in development of the theory that neutrinos change from one type to another and that at least one type actually does have mass. Since 1985 Davis' work at the University of Pennsylvania and the operation of the Homestake neutrino detector have been supported by the National Science Foundation.

In 2001, Davis was also awarded the National Medal of Science administered by the National Science Foundation.

Davis shares this year's Nobel Prize in Physics with Riccardo Giacconi, of Associated Universities, Inc., and Masatoshi Koshiba of the University of Tokyo.

Chemistry

John B. Fenn of the Virginia Commonwealth University was awarded the Nobel Prize in Chemistry for his work developing mass-spectrometric analysis tools that allow scientists to "weigh" and identify large biological molecules. Conventional mass spectrometry techniques vaporize substances to identify individual molecules, but proteins are too fragile to survive such harsh methods. Fenn solved this problem by developing a technique to spray water droplets containing proteins into the mass spectrometer. As the water evaporates, the "stark-naked" protein molecules that are left behind can be analyzed. The technique now allows researchers to identify proteins rapidly and analyze hundreds of potential drugs and biological samples per day.

Fenn has received 13 research awards from the National Science Foundation since 1975, including funding for his prize-winning work on "electrospray ionization."

Fenn shares the chemistry prize with Koichi Tanaka of Shimadzu Corp. in Kyoto Japan and with Kurt Wüthrich of the Swiss Federal Institute of Technology (ETH), Zürich, Switzerland and The Scripps Research Institute, La Jolla, USA.

Economics

Daniel Kahneman of Princeton University was recognized for his groundbreaking work in behavioral economics. While traditional economic models treated consumers as purely rational decision-makers, Kahneman's experiments have shown that people's decisions are often biased and based on rules of thumb. Kahneman has helped explain consumer motivations and has influenced fields as diverse as advertising, the stock market and medical decision-making.

Vernon L. Smith of George Mason University was honored for founding the field experimental economics. Smith pioneered the use of controlled laboratory experiments to test predictions from economic theory. He was also the first to use controlled experiments. Smith's work has been used in designing markets for trading pollution rights, auctioning the broadband communication spectrum, deregulating electricity utilities, and allocating landing slots at airports.

NSF is currently supporting Kahneman's work and has supported Vernon Smith's work since it's very beginnings.

PEOPLE

Indicator P1. ***Development of well-prepared scientists, engineers or educators whose participation in NSF activities provides them with the capability to explore frontiers and challenges of the future***

National Medal of Science. Karen Uhlenbeck works on partial differential equations originally derived to describe things like electromagnetism, but now used to look at the shapes of space. She is well known for her work on gauge field theory and its applications to four manifolds.

In 2000, Uhlenbeck received the National Medal of Science as one of the founders of geometry based on analytical methods, as a leader in her field, and as a mentor for women and minorities in mathematics. Uhlenbeck founded the Mentoring Program for Women in Mathematics held at the Institute for Advanced Study in Princeton, New Jersey

Television show enhances science learning. *DragonflyTV* is a multimedia science experience for kids, educators, and families. In January 2002, a new weekly science magazine television show, *DragonflyTV,* was launched and is now seen by over 1,000,000 households nationwide. The show involves real kids doing real science and gives children and scientists a national forum where they share the excitement of scientific discovery. Does it translate to real science learning? A Multimedia Research evaluation says "yes." More than 90% of 5th graders and 87% of 6th graders said they understood the *DragonflyTV* investigations. In small-group discussions, these children were able to describe investigations in detail, and offer ideas for new investigations of their own. The series is accompanied by a hands-on, interactive Website[2], Teacher's Guides that reach over 40,000 classrooms, as well as community outreach to schools, Boys and Girls Clubs of America, and other youth organizations.

Indicator P2. Improved science and mathematics performance for U.S. K-12 students involved in NSF activities;

Mobile Chemistry Laboratory. The Mobile Chemistry Laboratory (MCL) is an outreach project of Virginia Tech to rural and disadvantaged high schools. It is a self-contained unit that carries chemical instrumentation, computers, chemical equipment, and modern lab space to high schools in Southwestern, Central Virginia, and inner city Richmond, all of which lack adequate laboratory facilities. The unit brings state-of-the-art chemical instrumentation to underserved schools. This outreach project provides a conduit for the exchange of ideas with a student population that would normally have little external scientific stimuli. Teachers are trained on the MCL curriculum in NSF and state-supported workshops. The effectiveness of the MCL program is gauged by the significant increase in the Chemistry Standards of Learning (SOL) Pass rates from 2000 (no MCL program) to 2001 (using the MCL). The average gain was 20 points for the 18 schools. The state average gain was only 8 points. The largest gains (school 1 and 2) were from inner-city schools in Richmond.

Early exposure to physics boosts student performance. What would happen if you introduced physics into the curriculum in 9th grade before chemistry and biology? *Active Physic*s, an innovative curriculum supported by the Instructional Materials Development program, is expanding the number of students taking physics and strengthening conceptual learning and inquiry skills using themes surrounding communication, home, medicine, predictions, sports, and transportation. Since published in 1998, more than 500,000 students have completed units and market potential expected to reach millions. A growing number of the 322 implementing districts already show gains in student performance using the *Stanford Achievement Test* (SAT-9). In addition, University of California (UC) faculty recently

[2] http://pbskids.org/dragonflytv/index.html

approved the curriculum as meeting the "d-laboratory science" requirement, finding that it provides a solid foundation for college-level work and a deeper conceptual understanding than is achieved through traditional approaches emphasizing number problems. The U.S. Department of Energy (DOE) has adopted the *Active Physics* model in content, design, and pedagogical format.

NSF-supported high school instructional materials improve student learning. *Contemporary Mathematics in Context (Core-Plus*)—a secondary mathematics curriculum emphasizing investigations of real-life contexts and applications of mathematical modeling—represents a four-year research, development, and evaluation effort. *Core-Plus* students are showing gains in achievement, as well as effective transition to university-level study. For example:

A University of Michigan study of over 200 *Core-Plus* students from a district of high socioeconomic status near Detroit scored higher in their first university mathematics course, on average, than students from a control school in a similar Detroit suburb. This pattern also held when comparing *Core-Plus* students to those who graduated from the same school before the curriculum was implemented. *Core-Plus* students were also as likely as peers to take advanced courses (e.g., Calculus II, Differential Equations) when entering the university.

In 1999-2000, released assessment items from the Third International Mathematics and Science Study (TIMSS) were administered at three sites to assess the curriculum's effectiveness. Core-Plus students had mean scores similar to students in the Netherlands, the top-scoring country in mathematics literacy; in advanced mathematics, Core-Plus students scored above the international average on probability, statistics, and transformation geometry. By the end of junior year, Core-Plus students performed considerably better in those areas than typical U.S. seniors enrolled in alternative pre-calculus, calculus and Advanced Placement (AP) calculus courses.

Indicator P3. Professional development of the STEM instructional workforce involved in NSF activities

Project links pre-service teacher preparation to inservice teacher enhancement. To address the need for more science and mathematics teachers, the Montana Systemic Teacher Excellence Preparation (STEP) project has connected state universities and colleges with Tribal Colleges and has combined distance education courses with onsite courses. In Years 3–5 of the project, investigators developed an "early career support program" that served 127 beginning teachers and continues to serve about 60 new teachers per year. To date, there is a 95% retention rate in the profession for teachers who participated in the program. In addition to providing professional development for new teachers, the Montana STEP project has established an M.S. in Science Education degree program, which is an interdisciplinary program involving both on campus and distance learning. It is the only inter-college program for science education in the United States with a 65% distance education component. To date, over 100 teachers have been admitted to the program, 42 have received graduate degrees, and 77 are currently enrolled.

An internship program in marine science for African American teachers. The Dauphin Island Sea Laboratory (DISL) is operated by the Alabama Marine Environmental Sciences Consortium. The faculty studies a variety of problems in oceanography and marine biology, and they provide advice to industry, government, and the public. DISL serves Alabama's research and instructional needs in the marine sciences. Students at all educational levels, including K-12 pupils, undergraduate and graduate students, teachers-in-training, elder hostel participants, and the general public, benefit from the programs offered at DISL. A recently constructed public building, The Estuarium, exhibits live organisms and recreates the estuarine and marine environments of Alabama. DISL is an NSF-Research Experiences for Undergraduate (REU) site, and the laboratory is developing a minority

internship program in marine science, the first of its kind in Alabama. In addition, this year the lab has developed a program to bring in African American teachers as interns for the summer to learn the material presented in the Discovery Hall displays, assist in teaching at each grade level, assist in the field-based programs and be mentors for the young students. These opportunities go beyond traditional methods of teaching and curriculum enhancement and will blaze a trail for minority teachers in marine science.

Highest discovery rate for novae found in this galaxy. The use of astronomy in Research Based Science Education at the National Optical Astronomy Observatories/National Solar Observatory (NOAO/NSO) brings teachers to NOAO for intensive workshops and also produces Web-based educational materials. A particularly successful and widely distributed program contains the imaging data from an NOAO telescope that is used by students to discover new novae in the Andromeda Galaxy. Astronomers, high school teachers and their students have discovered 73 novae in Andromeda. Novae are stellar outbursts that lead to a rapid brightening when mass is transferred between two stars in a binary system, causing the surface layers of one star to ignite explosively from the fusion of hydrogen nuclei. The novae in Andromeda were discovered by students using images from Kitt Peak National Observatory and collectively represent the highest discovery rate for novae found in this galaxy.

Indicator P4. Contributions to development of a diverse workforce through participation of underrepresented groups (women, underrepresented minorities, persons with disabilities) in NSF activities

Minority graduate education at Mountain States Alliance. The Minority Graduate Education at Mountain States Alliance (MGE@MSA) has enrolled 329 African American, American Indian, and Hispanic students in science, engineering, and mathematics (SEM) doctoral programs within the alliance. This represents an increase of 196.3% over the 111 enrolled during the baseline year. Designed by individual awardees of the Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring, MGE@MSA sponsored the first of a series of doctoral mentoring institutes. This institute provided 58 select doctoral faculty from ten regional universities with both an overview of successful mentoring practices and meaningful tools to empower them to address problems associated with recruiting, retaining, and graduating underrepresented minority science education and math (SEM) students at the Ph.D. level. After the first year of MGE@MSA, 43 SEM doctoral degrees were awarded to African Americans, American Indians, and Hispanics within its alliance. This represents a sharp increase (86.9%) over the 23 produced in the baseline year. The overall five year goal of MGE@MSA is to triple the number of underrepresented minority science, mathematics, and engineering doctorates to achieve an annual rate of 69 in the year 2004.

Indicator P5. Participation of NSF scientists and engineers in international studies, collaborations, or partnerships

Partnerships involving multiple organizations. Co-supported by NSF, the Centre National de Recherche Scientifique (CNRS), the French Ministry of Research, the Scientific Mission of the French Embassy, and several industrial sources, this program gives students training in an international environment via 12-week research immersion experiences at several universities across France. In a reciprocal exchange, French undergraduates live with domestic peers at Florida. Participants are encouraged to co-author publications and more than 40 peer-reviewed papers have been published. Since 1997, some 105 students have been recruited from 30 US states and Puerto Rico. Students participate in a mid-program science meeting and a post-program poster session at Florida. This multidisciplinary program recruits students of Chemistry, Chemical Engineering, Physics, Materials Science, and Biochemistry and gives them academic credit in the University of Florida

honors program and co-registration in French Universities.

Tissue Engineering. NSF-supported researchers have participated in WTEC (World Technology Division of the International Technology Research Institute[3]) studies on Tissue Engineering that was sponsored by NSF. Their study involved a comparative review of tissue engineering research and development activities in the United States, Japan, and Western Europe. It covers biomaterials, cells, biomolecules, non-medical applications, engineering design, informatics, and legal and regulatory issues associated with tissue engineering research and applications. The panel's conclusions are based on a literature review, a U.S. review workshop held at the National Institutes of Health (NIH) in June of 2000, and a series of site visits to leading tissue engineering research centers in Japan and Western Europe.

Indicator P6. Enhancement of undergraduate curricular, laboratory, or instructional infrastructure

Game theory and social interactions. A Virtual Collaboratory for Teaching and Research Game theory is one of the prime contenders for becoming the central theory in economics and related social sciences. Broadly speaking, a game is an interactive situation in which everyone's incentives depend on their own and others' actions. Games have been used to model a wide variety of environments, such as collective action problems, market pricing, auctions, committee voting, family decisions, organizational behavior, and contract law negotiations. The Nash equilibrium, which has been the central solution concept in game theory, is one of the most commonly used constructs in economics. Game theory is increasingly being applied in political science and management science. Its relevance in many non-market interactions, however, is limited by the extreme rationality assumptions that underlie standard solution concepts. Although game theory has been successfully applied in some settings (for example, the design of the Federal Communications Commission (FCC) spectrum auctions), the inclusion of behavioral elements and limited rationality is essential to ensure a major impact on the study of a wide array of social interactions. This project has brought together a group of social scientists that incorporate behavioral and cultural factors into the analysis of strategic interactions. Cross-cultural studies of non-economic motivations have been naturally supplemented with controlled experiments. To make experiments easily available, a portable wireless laboratory and web-based software to connect participants at different locations have been developed.

Strengthening undergraduate education. The project "Strengthening Undergraduate Education through Research in Radio Astronomy" is designed to combine the development of a small radio telescope with the development of educational materials and a Web-based environment to support the use of radio astronomy in undergraduate research. Twenty-three institutions have utilized the 37-meter telescope for educational activities; 165 students participated in the activities, 8 student theses were written based on undergraduate research experiences associated with the use of the telescope or Web-based materials, and 14 student projects were completed. In addition, faculty from 23 community colleges and small four-year colleges attended in an NSF Chautauqua course on "*Radio Astronomy in the Undergraduate Classroom.*" Two articles and a book chapter were either published or accepted for publication based on the work of the project.

Indicator P7. Awardee communication with the public in order to provide information about the process and benefits of NSF supported science and engineering activities

PBS series explores *"The Secret Life of the Brain."* In the past decade of the 1990's, science has deciphered more secrets of the human brain than in the previous 90 years combined. In 2002, the Public Broadcasting System (PBS) aired the five-part series, *The Secret Life of the Brain*, exploring the startling new map of our most complicated organ, contradicting much of what was previously believed, and holding out hope

[3] http://www.wtec.org

for dramatic advances in the areas of addiction, depression, learning disorders, Alzheimer's Disease, and schizophrenia. With support from the NSF, *The Brain* called on neuroscience's leading researchers to assist the public in understanding how research is practiced; the connection between pure and applied research; and how these methods impact their lives. The series explores stages of human development—infancy, childhood, adolescence, adulthood, and old age—from fundamental neural development and innovative medical treatments to behavioral therapies, new brain-based educational techniques, and the characteristics of the older brain that may form the basis of wisdom. Through the series, the public learns of significant departures from previous theories, e.g., that the brain develops throughout life, increasing and renewing its capacities from birth to death instead of remaining static after reaching early maturity.

The *Brain* received a 1.9 national rating that translates to approximately 2.0 million households and 2.4 million viewers per average broadcast. Approximately 15.4 million people viewed all or part of the total series. Educational outreach products include: (1) an award-winning book, *The Secret Life of the Brain* (2001), Richard Restak, M.D., Joseph Henry Press; (2) a Website[4], including multi-media, interactive areas that has been accessed by more than 609,500 users with 2,276,600 page views with an average hit time of 22-40 minutes; (3) teen and adult guides; and, (4) grants to PBS stations nationally for educational outreach and audience development.

Socio-linguistic variations in American Sign Language. Phase I of this NSF-supported research collected videotaped data from 207 American sign language users from sites throughout the United States. In Phase II, graduate research assistants employed data reduction to analyze systematic and patterned socio-linguistic variations (phonological, lexical, and syntactical) in American Sign Language, comparing it with spoken language. The results were disseminated through workshops, conference presentations and journal articles. The supplement supported videotape development and workshops to educate the public. Both workshop and conference presentations have brought increased understanding within the deaf community of the nature of human language, the nature of the structure of sign language, and how it compares to spoken language.

Arecibo Observatory Visitor and Education Facility (AOVEF). The National Astronomy and Ionosphere Center AOVEF overlooks the 305-meter radio telescope, and was funded entirely with non-Federal monies. This Center (opened in March 1997) contains a series of exhibits describing the science done at the Observatory. These heavily "hands-on" bilingual displays were funded by NSF and provide a unique resource for Puerto Rico's 650,000 K-12 students – with the exception of the Visitor Center there are no other science museums of any sort on the Island of Puerto Rico. The Arecibo AOVEF receives 120,000 visitors and 40,000 K-12 students each year, approximately triple the number that visited before the AOVEF was built.

IDEAS

Indicator I1. Discoveries that expand the frontiers of science, engineering or technology

Survival of plants during periods of drought. Plants must continually supply their leaves with water that is absorbed by the roots and transported to the leaves through the stem. The driving force for this comes from the evaporation of water from leaf surfaces, which exerts a "pull" on the water column. This allows the plant to draw water from the soil through hollow xylem cells, which form conduits for water transport through the stem -- essentially using the stem as a straw. Because the water is under tension, air is sucked into the xylem occasionally, causing an embolism that blocks water flow. It is well known that air embolism occurs in plants, sometimes to the extent that water delivery to leaves is significantly impaired. The goal of this study is to understand the mechanisms by which plants may be able to

[4] www.pbs.org/wnet/brain

repair air-filled conduits such that they are able to reuse them in water transport. It is only in the past decade that researchers have realized that plants can reverse embolism, and there is some evidence that this repair may occur even during the day when the water in the xylem is under substantial tension. This study is increasing our understanding of how plants survive periods of low water availability and has improved our ability to predict plant responses to environmental factors such as drought and temperature extremes.

Self-tightening bolts. At a laboratory at the Virginia Polytechnic Institute and State University, when bolts and screws are used, NSF-supported researchers also use sensors and washers made of the "smart" materials known as piezoelectric (PZT) or PZT patches and shape memory alloys (SMAs) respectively. The former provide an electrical signal used for continuous monitoring of the mechanical load or torque on the bolt or screw, and when something changes, for example in response to vibrations, extreme loads, or perhaps something as simple as temperature induced changes that allow the nut to loosen, the SMA washer changes it shape to "take up the slack" and restore the tightness of the bolt to its design load.

Superconductivity. Conventional superconductivity in materials like lead and tin results from interaction of electrons with lattice vibrations (phonons). NSF-supported researchers have now used the facilities of the National High Magnetic Field Laboratory to show that superconductivity can also result from the existence of charge density waves, in an organic material at low temperatures. This kind of superconductivity was first predicted to be possible in 1954. Such superconductivity had never been seen before. The sample had to be cooled to within one degree of absolute zero in a magnetic field five hundred thousand times as strong as the Earth's field.

Composite bone materials. An NSF project has developed a nanoscale self-assembly technique to create composite materials very similar to bone tissue. This technique has developed new polymeric molecules that self-assemble on their own to form cylindrical nano-sized fibers. These fibers direct the growth of reinforcing minerals such as hydroxyapatite into an alignment that is very similar to that in natural bone. This new technique holds promise not only for development of artificial bone, but also for repairing nerve fibers, creating nano-electronic wires, and preparing high-strength polymeric composites. This result was published in *Science* and elicited major coverage in *Chemical & Engineering News* and other publications.

Cosmology. The spectacular burst of new information about the early universe (Cosmic Microwave Background or CMB) is transforming the field of cosmology. A new approach to the study of cosmology, which involves both direct observations and intensive computer modeling of the early universe, has come to dominate the field, much of it accomplished with NSF support. The Degree Angular Scale Interferometer (DASI), Balloon Observations of Millimeter Extragalactic Radiation and Geophysics (BOOMERanG), and the Cosmic Background Imager (CBI) experiments all have contributed new or more precise measurements of the CMB emission that are analyzed to create images of the early universe. These images are combined with complex theoretical calculations to test different cosmological models and measure fundamental cosmological parameters such as the overall density of the universe.

Indicator I2. Discoveries that contribute to the fundamental knowledge base

Discovery of largest object in solar system. The largest object in the solar system orbiting far from the sun (a Kuiper Belt Object), even larger then the largest asteroid, was discovered with the Cerro Tololo Inter-American Observatory (CTIO) 4-meter telescope. This discovery, by astronomers from Lowell Observatory, arose from collaboration with the National Aeronautics and Space Administration (NASA) to characterize these outermost objects with the objective of gaining fundamental information on the formation of the solar system.

Early history of whales. Three articles published in Science and Nature this year by two groups of scientists point out great advances being made in understanding the early history of cetaceans (whales). Both groups arrive independently at the same startling conclusions about the early evolution of whales based on new fossil finds in Pakistan. Whales evolved approximately 50 million years ago from land-based even-toed ungulates (hoofed animals) rather than mesonychians (an extinct group of carnivorous ungulates) as has been traditionally believed. These fox- and wolf-sized four-footed animals were surface paddlers in the shallow seas of Eocene time that evolved into modern whales.

Opening of the Bering Strait. A U.S.-Russia collaborative research project determined the date of the Bering Strait's opening by studying *Astarte* clams found in southern Alaska. The results indicate that the Strait opened about 2 million years earlier than previously thought. The revised opening date will allow researchers to more accurately document ancient climates.

Indicator I3. Leadership in fostering newly developing or emerging areas

Molecular electronics. Molecular electronics is based on the notion that the molecular organization of matter can result in very different electronic properties than are seen in more traditional semiconductor structures. The critical issue has to do with how charge is shared between molecules (discrete nano-scale structures) and electrodes (continuous metals). The most general picture for how these things work focuses on the interface, and on transport at that interface. In this area, an NSF-supported group at Northwestern University has developed robust general theoretical methodologies for *designing* interfaces that would be most effective in producing charge flow in molecular nanostructures. *Science* magazine cited this as the breakthrough of the year in 2001.

3-D models of solid-state lasers. A US-Bulgaria project encompassed coordinated experimental and theoretical work on novel techniques in ultra-short light pulse generation and measurement. The scientists developed the first completely 3-D models of solid-state lasers.

Adaptive optics. NSF started support of adaptive optics over 15 years ago. Today, adaptive optics is maturing into a very powerful tool for high spatial resolution imaging. A few years ago, astronomical adaptive optics were limited to correcting for atmospheric turbulence over a small area of about 6 arc-seconds and required that a bright star be in the field. Today astronomers have learned how to create an artificial star in the sky using lasers, and have learned enough about the dynamics of the turbulent atmosphere to measure and forecast correction over arc-minutes field of view for telescopes in the 10 to 20 meter size category.

Extreme pressure research. An NSF-supported research project has developed a new and inexpensive diamond anvil cell making extreme pressure research available to a larger body of researchers.

Indicator I4. Connections between discoveries and their use in service to society

Effects of increased atmospheric carbon dioxide. An NSF-supported project has discovered that rising levels of atmospheric carbon dioxide that are associated with global warming can interfere with plants' ability to incorporate certain forms of nitrogen, dramatically altering the flora worldwide and forcing significant changes in agricultural fertilizer use. Previous studies have shown that increased concentrations of carbon dioxide in the atmosphere initially lead to increases in carbon intake and growth in plants, but eventually the accelerated carbon assimilation declines. This NSF-funded project has shown that the decline in growth rate is attributable to inhibition of nitrogen incorporation in the plant tissues. Nitrogen is an element that is key to producing proteins and nucleic acids such as deoxyribonucleic acid (DNA) in plants. Because it is so important to plant growth, farmers and gardeners commonly apply nitrogen-rich fertilizers to their crops. The researchers found that nitrate fertilizer is not nearly as efficient as

ammonium fertilizer when atmospheric carbon dioxide levels are unusually high. In laboratory experiments they discovered that elevated levels of carbon dioxide inhibited the processing of nitrate compared to ammonium. This study suggests that a shift to increase ammonium availability might be needed in the coming years as atmospheric CO2 levels increase.

Fisheries management models. An NSF-project has looked at problems with current fisheries management models and management plans that simply ignore the theory of fish harvesting. The fishing industry is highly selective in the fishes that are targeted – both because fishers want larger fish, but also because regulations mandate size selectivity. In their research, the researchers hypothesized that harvesting of the larger members of a population would cause evolutionary changes resulting in slower growth rates and smaller size at a given age. These are not features that are desired in fished species. Furthermore, slower growth and smaller sizes can conceivably lead to higher natural levels of predation where predator avoidance is assisted by being larger. According to the researchers, "Management plans that ignore the evolutionary consequences of fishing may repeat the lessons learned in attempts to control pests and pathogens, albeit over a somewhat longer time scale. Moreover, the genetic changes caused by selective harvest may be irreversible; cessation of harvest does not guarantee reverse selection back to the original state. Ignoring evolutionary consequences of selective harvest contradicts the precautionary approach to resource conservation. No take reserves would help to preserve genetic diversity and the elimination of the genes for faster growth and size-at-age; so might the elimination of minimum size restrictions without having complementary maximum size refuges from fishing."

Hidden damage to buildings from earthquakes. Earthquakes cause buildings and bridges to collapse and highways to crack, but much of their most severe damage does not meet the eye. University of Southern California researchers at the Multidisciplinary Center for Earthquake Engineering Research (MCEER) (headquartered at The University at Buffalo) have been seeking ways to make public utility systems more resilient in the face of earthquakes. The researchers, including geotechnical, structural, risk and electrical engineers and economists from multiple institutions and municipalities, identify elements that are at risk, evaluating the geotechnical causes of damage, and estimating potential losses due to continuing service outages. The system allows municipalities to anticipate areas of greatest damage, strengthen those vulnerable areas and make preemptive repairs, develop better emergency plans, and respond faster to needs in the event of an earthquake.

Thin-film material may have important applications in drug synthesis. An NSF-supported team has developed a thin-film material with nanometer-sized cavities that serves as a molecular gatekeeper. The material can be manipulated to allow the passage of certain molecules but not others depending on size, shape and other properties. The scientists have also found a means of chemically transforming molecules within these cavities. The tiny cavities of the array serve as a filter, but in solution the cavities can also be used to encapsulate catalysts that chemically transform molecules. The next step is to combine the filtration and catalytic steps. This would allow conversion of plentiful low-cost hydrocarbon molecules into valuable complex molecules with potential applications such as selective drug delivery, synthesis of specialty chemicals or new types of semiconductors.

Indicator I5. Connections between discovery and learning or innovation

A new route for polymer synthesis. Kris Matyjaszewski received this year's American Chemical Society (ACS) Polymer Chemistry Award for his innovations through development of the new technique of Atom Transfer Radical Polymerization (ATRP). This new synthetic tool has found very widespread application all over the world and is considered the most robust method for creating many polymeric materials. This work has created a market in polymer synthesis that is expected to exceed $20

billion/year. His technique is now used by dozens of laboratories around the world.

Gliders for 4-D measurement of bio-optical and chemical parameters. Scientists from the University of Maine and the University of Washington, in partnership with industry, have been developing new and advanced autonomous underwater vehicles (gliders) and biological sensors. Recent advances in sensor development will provide unprecedented views of the biology of the ocean, specifically phytoplankton, both in time and in space. NSF and the National Oceanographic Partnership Program (NOPP) currently support these efforts. The work with gliders is revolutionizing the way that measurements are being made in the coastal and open ocean waters and provide oceanographers with a 4-dimensional view of the ocean,

Indicator I6. Partnerships that enable the flow of ideas among the academic, public or private sectors

Advanced numerical hurricane model. An NSF-supported scientist, in collaboration with the National Oceanic and Atmospheric Administration has developed an advanced numerical hurricane model. In addition to providing better understanding of ocean/atmosphere interactions, the numerical model developed has demonstrated significant improvement in storm intensity prediction compared to the previous operational (uncoupled) numerical model. The new system has been run in parallel with the prior model and the ocean coupling has improved hurricane intensity forecasts by about 25%. The National Weather Service has adopted the model developed under this award as their new operational model.

Suppercritical carbon dioxide process – partnership with DuPont Teflon. DuPont Fluoroproducts has introduced the first commercial DuPont Teflon® fluoropolymer resins made using proprietary and fundamentally new manufacturing technology that replaces traditional water-based polymerization with a process based on supercritical carbon dioxide. According to DuPont, the new technology produces Teflon® with enhanced performance and processing capabilities, while generating less waste. The new products are being manufactured at the company's Fayetteville, N.C., plant in a new $40 million facility that started up in late 2000. The new technology was developed jointly by DuPont and scientists at the University of North Carolina, Chapel Hill. The fundamental chemical processes in supercritical carbon dioxide that form the basis of this new technology were developed with NSF support.

International long-term ecological research. To promote the establishment of International Long-Term Ecological Research (ILTER) sites in the southern Africa region, NSF supported the travel of 16 researchers (from Botswana, Namibia, Mozambique, South Africa, Tanzania, and Zimbabwe) to various U.S. LTER sites in May 2001. Currently one ILTER site exists in Namibia. Other proposed sites include areas of transboundary importance, such as the Okavango Delta in Botswana, and a shared river basin in Mozambique, as well as sites in the Kruger National Park (South Africa) and the Serengeti National Park (Tanzania). The sites draw on each area's unique resources, but the environmental and ecological problems to be explored concern many other parts of the region, as well as the rest of the world. Many of the sites will also afford researchers the opportunity to study the impact of transboundary issues (such as shared water resources or the development of transnational parks), and the results can be a valuable benefit in the development of scientifically based ecosystem management plans

Undergraduate research experience in Native American archaeology and heritage preservation. The University of Arizona (UA) and the White Mountain Apache Tribe (WMAT) have established a REU Site that focuses on archaeology and heritage preservation in east-central Arizona. The primary goal of the project is to teach students how to combine scientific research and tribal heritage preservation goals through collaborative activities.

TOOLS

Indicator T1. Provision of facilities, databases, or other infrastructure that enable discoveries or enhance productivity by NSF research or education communities

Global seismographic network. The Earth's interior remains a major scientific frontier holding the key to understanding the origin of the planet. Recent developments in seismic sensor design, and the acquisition, transmission and storage of data have resulted in dramatic improvements in the resolving power of seismic imaging of the interior. Earthquake research, including rapid and accurate location and characterization of the earthquake source, its magnitude and a better understanding of the physical process involved, has also benefited greatly from recent technical advances. The *Incorporated Research Institutions for Seismology* (IRIS) facility serves the research needs of the national and international seismology community by making available state of- the-art designs in seismic sensors and data acquisition systems. In addition to its role in providing the observational data essential for basic research in geophysics and earthquake dynamics, IRIS plays a significant role in seismic monitoring of the Comprehensive Test Ban Treaty and in bringing seismology to students and the public through the activities of its Education and Outreach program.

Center for Spatially Integrated Social Science. Over recent decades, major advances in three sets of technologies (geographic information systems, the Global Positioning System, and remote sensing) have provided dramatic new insights into patterns, processes, and changes on the Earth's surface. Although many disciplines have adopted these technologies and use them successfully for a variety of inquiries, fewer social and behavioral scientists have begun to use them on a significant scale. To accelerate the adoption and use of these technologies, a national center based at the University of California-Santa Barbara is focusing on the methods, tools, techniques, software, data access, and other services needed to promote and facilitate a novel and integrating spatially enabled approach to the social and behavioral sciences. The center builds on the efforts of the National Center for Geographic Information and Analysis, engaging in six core programs that are targeted across the full spectrum from inductive, exploratory science to theory-based, confirmatory science. Among major research areas that are benefiting as a result of these efforts are human environmental interactions, urban studies, social and economic inequality, social and business networks, health and disease, criminal justice, and community-based grassroots organizations.

Indicator T2. Provision of broadly accessible facilities, databases, or other infrastructure that are widely shared by NSF research or education communities

Continual queries of databases. NSF-supported researchers at the Georgia Institute of Technology have introduced the concept of Continual Queries and have developed techniques to support efficient processing of continual queries that monitor events using distributed triggers, and notify the user of changes whenever updates of interest happen. The continual query project has produced two operational systems: Open continual queries (CQ) for monitoring semistructured information updates, and Web CQ for monitoring changes in arbitrary Web pages. The National Cancer Institute has used the Web CQ system to track cancer clinical trial information over a dozen information sources. Web CQ helps cancer researchers, patients, friends, and relatives track new treatments and new cancer trials of interest. CQ technologies are being applied to application areas including logistics and unified access to about 500 biological databases.

Assessment of children's attention. Accurate assessment of children's attention is essential for continued examination of the role of attention in the development of skills such as literacy and numeracy as well as examination of the neurological substrates of attention. NSF-supported scientists at the Sackler Institute for Developmental Psychobiology at the Weill Medical College of Cornell have developed the

Attention Network Task to reliably assess orienting and alerting aspects of attention in children. In their own work, the Attention Network Task is being used to track an attention-oriented literacy-training program that is showing initial promise in the laboratory and in public school settings. As well, they are using this task to link genetic, electroencephalograms (EEG), and magnetic resonance imaging (MRI) findings to attentional behavior. Other researchers have begun to use the Attention Network Task to study Attention Deficit Hyperactivity Disorder (ADHD), autism, child abuse, and other conditions that might affect attentional functioning[5].

Indicator T3. Partnerships, e.g., with other federal agencies, national laboratories, or other nations, to support and enable development of large facilities and infrastructure projects

Macromolecular Structure Database (MSD). The Macromolecular Structure Database (MSD), formerly the Protein Data Bank, collects, archives and distributes high quality structural data to the scientific community on a timely basis. It is a distributed collaboratory, involving Rutgers University, the University of California San Diego, and the National Institute of Standards and Technology. The MSD systems are reliable and stable. The challenges of large data rates and complex structures, such as the ribosome, have been met. Legacy data from Brookhaven National Laboratory have been evaluated and restored. A new more robust query and distribution system has been developed. A target registration databases for structural genomics has been created to prevent duplication of efforts. All of the software for data deposition and validation has been distributed. Two sites, one in Japan and one in Europe, also handle data deposition and validation, an important aspect given the anticipated increase in structures.

Toxic heavy metal contamination. Contamination of soils with toxic heavy metals is a serious worldwide problem both for human health and agriculture. Cleanup of hazardous wastes by the currently used engineering-based technologies has been estimated to cost at least $400 billion in the U.S. alone. Recently, there has been considerable interest in the use of terrestrial plants as an alternative "green technology" for the remediation of surface soils contaminated with toxic heavy metals. A major factor behind the recent interest in phytoremediation of metal-polluted soils has been the growing awareness by the scientific community of the existence of a number of plant species that not only can tolerate high levels of toxic heavy metals in the soil, but actually can accumulate these metals to very high levels in the easily harvested above-ground shoot biomass. The ultimate goal of this research is to develop transgenic plants that both are metal hyperaccumulators and produce high-shoot biomass, and thus will be well suited for the phytoremediation of metal-contaminated soils.

Indicator T4. Use of the internet to make SMET information available to the NSF research or education communities

Internet teacher network. Teachers' tacit knowledge about teaching is an important influence on how they teach, but is rarely made explicit and shared. The project seeks to design and evaluate salient features of an on-line network of pre-service and in-service mathematics and science teachers. Teachers can virtually visit each other's classrooms to observe and discuss approaches to teaching mathematics and science topics and to share lesson plans, student work and assessment. The site includes 30 classrooms, each of which includes a video of an entire lesson, artifacts from that lesson (lesson plan, teacher reflections, examples of student work, links to national and state standards, etc.), and web forums to discuss issues that arise from that particular lesson or more general topics such as the nature of inquiry learning and teaching. The site also includes collaborative workspaces called "Inquiry circles" and modules for professional development that can be completed for self-growth or for university graduate credits. There is an "Auditorium" event for many participants (*e.g.*, a webcast), personalized spaces for

[5] http://www.sacklerinstitute.org/_homepages/posner/index.html

participants for storing their preferences and individual resources, and a shared library of resources relevant to secondary mathematics and science teaching.

The HERO collaboratory. Understanding global environmental change in local places cannot happen in isolation. To build a picture of the local causes and consequences of global change, scientists who study and monitor this problem must share data, methods, and ideas. The World Wide Web makes it possible for scientists to work collaboratively without leaving their home institutions. Researchers working on the Human- Environment Regional Observatory (HERO) project are developing a collaboratory to foster remote collaboration among scientists studying global change in far-flung local places. Collaboratories use the interconnectivity of the Web to link scientists in near-real to real time. Collaboratories go beyond e-mail and instant messengers to include such novel ideas as Web-based videoconferences, electronic Delphi tools for collective discussion and decision making, shared notebooks and databases, and interactive maps and graphs. This tool makes it possible for scientists from around the world to meet routinely at nominal expense. The techniques being explored by HERO have greatly facilitated their collaboration.

The Panel Study of Income Dynamics (PSID). The PSID[6] is a longitudinal survey initiated in 1968 of a nationally representative sample for U.S. individuals and the family units in which they reside. The major objective of the panel is to provide shared-use databases, research platforms and educational tools on cyclical, intergenerational and life-course measures of economic and social behavior. The PSID's innovative design and long-term panel have been central to the fundamental understanding of key social science issues with substantial broad impacts on society: income, poverty and wealth; cyclical behavior of wages, labor supply and consumption; savings, wealth accumulation and transfers; demographic events (teen childbearing, marriage, divorce, living arrangements, mortality); labor market behavior; and the effects of neighborhoods. PSID data transformed research on poverty from a static view of poor and rich to a dynamic one in which families experience episodes of poverty or affluence. PSID data are being used to assess current government policies such as the impact of welfare reform on low income, African-American and Hispanic families. The project currently delivers more than 10,000 customized data sets a year to researchers via its Internet Data Center. Since 1968, over 2,000 journal articles, books and chapters, dissertations and other works have been based on PSID data. A consortium of government agencies supports the PSID, including NSF, the National Institute on Aging (NIA), the Department of Health and Human Services (HHS), the U.S. Department of Housing and Urban Development (HUD) and the U.S. Department of Agriculture (USDA).

Indicator T5. Development, management, or utilization of very large data sets and information-bases

Dissemination of statistical data and protecting confidentiality. Algorithms were developed that use geographical aggregation to disseminate as nearly as possible at the county level data that previously were disseminated only at the state level; and also allow characterization of inferences drawn from the release information. Systems were built to implement geographical aggregation in real time, producing maps and other forms of output that disseminate information safely and in unprecedented detail. The Web-based system for geographical aggregation, with its powerful graphical user interface, is usable by researchers and by citizens. The project is developing an entirely new paradigm for disseminating information derived from confidential data, balancing the utility of the released information against disclosure risk.

Community Data Portal. For decades, the National Center for Atmospheric Research (NCAR) has maintained one of the world's premier archives of weather data, including the output from uncounted runs of global climate models. To access this archive, researchers have relied on sophisticated code while NCAR

[6] http://www.isr.umich.edu/src/psid/

technicians swap out tapes and disks. Now the NCAR computing center is building a more direct path to some of its collections, whose size is now approaching one quadrillion bytes of data. The Community Data Portal (CDP) is a pilot effort that will allow users to access NCAR holdings through the World Wide Web and a variety of client-based applications. It also serves as a key node for real-time geoscience data made available by the University Corporation for Atmospheric Research (UCAR) Unidata program. Several large data sets became available on the CDP in experimental fashion starting in 2001. A side benefit of the portal is to dramatically reduce the entry cost of becoming a data provider, making it possible for programs and projects of all sizes to participate and thereby making more data available to users.

Distributed realtime ocean data from multiple sites. The Joint Global Ocean Flux Study (JGOFS) is an international collaboration spanning several years and designed to elucidate fundamental knowledge of the ocean carbon cycle. JGOFS efforts include time-series measurements at two locations (Hawaiian Oceanic Time-series and Bermuda Time Series), process studies, global surveys, synthesis and modeling efforts, and data management. Sponsored internationally by the Scientific Committee on Oceanic Research and the International Geosphere-Biosphere Programme and nationally by the U.S. Global Change Research program, the program spawned a new field of ocean biogeochemistry with an emphasis on quality measurements of carbon system parameters and interdisciplinary field studies of the biological, chemical and physical processes that control the ocean carbon cycle.

National Virtual Observatory (NVO). The first concept of the virtual observatory was developed with the help of a Small Grant for Exploratory Research (SGER) award that enabled fuller discussions in the community and the creation of a white paper on the idea. This year saw the culmination of this effort with the support of a large collaborative project to build the framework for the NVO. This project will federate astronomical data sets and establish them as a common resource for both researchers and the public. The project also establishes the protocols, standards and tools that will permit the large astronomical datasets of the future to be fully utilized. Coordinated efforts are also underway at collaborating institutions to develop archives, visualization tools, and related resources.

Indicator T6. Development of information and policy analyses that contribute to the effective use of science and engineering resources

Electronic publishing in science and authorship rights in the digital age. The emergence of electronic journals in scientific publication has the potential to transform the management and communication of scientific information. Electronic publication is not likely to reach its full potential without a stable legal framework that balances the protection of researchers' intellectual property with the open dissemination and exchange of scientific information. This project describes the challenges that advances in information technology pose for intellectual property law, and identifies a set of "core values" that should be embedded in a system of scientific publishing. Those core values can serve as a basis for defining a common ground on which all stakeholders can build new publishing systems and legal frameworks. The report recommends new patterns of licensing that will enable scientists and scientific publishers to build a publishing system that will promote broad access to and use of scientific information, all within existing copyright law.