II. EXAMPLES OF ACHIEVEMENTS REPORTED IN FY 2000

NSF is proud to share just a few of the many highlights of the research and education results reported by awardees in FY 2000. These examples were selected as some of the most exciting discoveries and results reported this past year. They reflect the broad range of achievements important to NSF's mission. Each result was obtained in part or entirely through NSF support. Highlights of research and education projects reported by NSF's Office of Legislative and Public Affairs (OLPA) are presented first, followed by examples reported by awardees and recognized by external committees as noteworthy achievements in FY 2000. Additional examples relevant to each of NSF's outcome goals are presented in Section V.A, *"Outcome Goals and Results for FY 2000*," and also in Section XIV, "*Appendix of Additional Examples Illustrating Outcomes of NSF Investments*."

FY 2000 RESEARCH AND EDUCATION HIGHLIGHTS – EXAMPLES REPORTED BY OLPA (BY TITLE)

Below are titles for NSF supported research discoveries and results that were reported as highlights by NSF's Office of Legislative and Public Affairs (OLPA). To look at the stories associated with these titles, and to look at more examples, search the NSF highlights reported at http://www.nsf.gov/home/news.html. This web site will present more detail, and is a source of additional stories of recent newsworthy highlights and exciting findings.

- Astronomers Find Evidence for the First Planet Seen Orbiting a Pair of Stars
- Scientists Report First Complete DNA Sequence of Plant Chromosomes
- Earthquake Network Intended to Help Save Lives and Money
- Bacteria May Thrive in Antarctic Lake
- Report Shows Students Improving in Math and Science Preparation
- Global Seismographic Network Establishes Internet Connection to Remote Africa
- Solar "Heartbeat" Discovered
- Astronomers Sight an Asteroid's Moon
- Exploring the Far Frontiers of Sea and Space
- Membrane Protein Research Yields New Insights into Inner Workings of the Cell
- New England Experienced "Ice Age" El Niño
- Human-Computer Interaction Gets a Helping Hand, Eye, and Voice
- Researchers Discover Evidence of Microscopic Life at the South Pole

Three examples of NSF Highlights from the OLPA Exciting Findings are:

REPORTED JANUARY 14, 2000

- **SCIENTISTS REPORT FIRST COMPLETE DNA SEQUENCE OF PLANT CHROMOSOMES**

  Scientists involved in an international effort to sequence the entire genome of Arabidopsis thaliana reported the first complete DNA sequence of a plant chromosome in the December 16, 1999, issue of the journal *Nature*. The results provide new information about chromosome structure, evolution, intracellular signaling, and disease resistance in plants. The research conducted by U.S. participants was funded in large part by the National Science Foundation, as well as the U.S. Department of Agriculture and U.S. Department of Energy.

REPORTED JUNE 22, 2000

- **NEW ENGLAND EXPERIENCED "ICE-AGE" EL NIÑO**

  The New England region underwent El Niño-like climate changes during the Ice Age, NSF-supported researchers have found. Scientists define El Niño as a disruption of the ocean-atmosphere system in the tropical Pacific, which has important consequences for weather around the globe. The team's findings show a strong three-to-five-year cycle of El Niño activity during the latter part of the last Ice Age–the same frequency with which El Niño occurs today.

REPORTED FEBRUARY 7, 2000

- **TWELVE PIONEERING RESEARCHERS RECEIVE 1999 NATIONAL MEDAL OF SCIENCE**

  On January 31, 2000, President Clinton named 12 of the nation's most respected researchers, three of them Nobel Prize winners, to receive the 1999 National Medal of Science. Honoring the discoveries and lifetime achievements of the nation's top scientists, the Medal of Science recipients named by the president represent a widely diverse group that: created wholly new scientific fields, such as conservation biology and speech sciences; led to discoveries that determined why the ozone "hole" exists; and legitimized theories about technological progress on economic growth, among others.

FY 2000 RESEARCH AND EDUCATION HIGHLIGHTS
EXAMPLES CITED BY EXTERNAL EVALUATORS

Examples of results cited by committees of external evaluators in the performance assessment process are presented below. These examples are but a few of the many that were recognized as contributing to the successful performance of NSF in FY 2000. Examples are presented here to give the reader a more tangible feeling for the value and impact of NSF investments. Many of these examples illustrate the broader impacts of NSF-supported research and education activities on the Nation and its citizens. Each example has been recognized as contributing toward the achievement of one or more of NSF's Outcome Goals. Additional examples illustrating outcome achievements appear in Section V.A.. "*Findings from Program Assessments*

and Evaluations: Outcome Goals and Results for FY 2000," and also in Section XIV, as an Appendix to this report.

- **NANOSCIENCE AND ENGINEERING - NANOMOTORS** The merger of molecular biology and nano-fabrication in engineering research has led to the assembly of a spinning molecular motor through the nanoscale assembly of protein flagella onto an array of nickel posts. The researchers grafted these bacterial motors to an ordered array of nano-scale metal posts and measured the revolutions per second, horsepower, and motor efficiency. This is a critical first step in integrating biological-mechanical components with deliberately patterned inorganic nanostructures that will produce entirely new classes of more powerful nanostructured devices. Ultimately, the researchers envision these nanomotors powering nanofactories that synthesize and deliver drugs directly to the tissues that need them, reducing toxicity to other tissues and increasing the effectiveness of drug therapies.

- **A FLAT UNIVERSE** A spectacular burst of new information about the Early Universe – Cosmic Microwave Background, or CMB – is transforming the field of cosmology. The CMB radiation is considered to be a residue from the Big Bang origin of our universe some 12-15 billion years ago. Using balloon-borne microwave detectors as a telescope, the Boomerang project is an experiment that maps the CMB radiation using highly sensitive arrays of microwave detectors. The balloon-borne telescope circumnavigates the Antarctic continent suspended at an altitude of 120,000 feet (36,576 meters). The high-resolution maps of the primeval cosmic microwave background showed that the overall large-scale geometry of the universe is surprisingly flat to unprecedented accuracy – a truly fundamental discovery.

- **ALIVE AFTER 250 MILLION YEARS: ISOLATION OF LIVE PERMIAN MICROORGANISMS** Recent interdisciplinary experiments conducted by NSF- supported researchers on salt crystals taken from the Permian Salado Formation in Southeastern New Mexico, have shown that some ancient crystals still contain viable micro-organisms trapped within tiny fluid inclusions. The careful use of stringent geological and microbiological selection criteria support the hypothesis that the bacteria are at least 250 million years old. The salt crystal that contained the organisms was taken from an ancient dissolution pipe located within primary sedimentary beds 564 meters below ground surface. The entire sedimentary layer was examined before removing the crystal, to be sure that the sample was taken from a primary bed. Two of these inclusions held trapped, microorganisms that were still viable. The isolated microbes are salt tolerant and respond to concentrated brines by forming spores. One of the organisms is related to several modern day bacilli but does have several unique characteristics.

- **LIFE IN EXTREME ENVIRONMENTS** The discovery of viable microbes in Lake Vostok accretion ice provided the first evidence that Lake Vostok, a large subglacial lake located 4 km (~2.5 miles) beneath the East Antarctic ice sheet, supports a microbial community. Results from the Vostok work was reported widely in the popular media and resulted in a

BBC documentary entitled "The Lost World". Studies on the accretionary ice of Lake Vostok have led to predictions of a large and diverse population of bacteria within the lake itself, and large interdisciplinary studies of Lake Vostok are planned for the near future. These investigations have implications for life on Earth and serve as models for future interplanetary investigations.

- **TECHNOLOGY SPIN-OFFS FROM GRAVITY** Fourteen billion years after the Big Bang, gravity is such a weak force that experiments to test gravity push the frontier of technology. Gravity is the least tested of all known forces in nature. Thus, any advance in our knowledge of gravity from laboratory experiments is of key importance. Recent laboratory tests have pushed measurements to new levels of accuracy, resulting in new technology spin-offs, such as:
  - Development of high power solid-state lasers, up to 120 watts;
  - Development of pre-stabilized laser power amplifiers, in collaboration with industry;
  - Advances in large optics and metrology with sub-Angstrom smoothness and losses approaching one part per million;
  - Innovative software originally designed for huge numerical calculations in relativity was applied to oil exploration analysis.

- **UNDERSTANDING FUNDAMENTAL ECONOMIC PHENOMENA** Research on risk sharing and financial markets has brought new and deeper understanding of fundamental economic phenomena. One line of discovery has dealt with individual behavior. How and why individuals fail to fully use available financial markets to buffer themselves against variations in their income has had important implications for economic policy. Another area of research concerns currency crises in the 1990s, where it has been found that the usual cause of currency crises – too rapid expansion of the money supply– was not a factor in the Asian crisis of 1998. Perhaps the most important result in this field stems from a recent discovery known as "Taylor's Rule," which has become a powerful and effective monetary policy guideline. What is the optimal Federal funds rate? According to Taylor's rule, the Fed should adjust the federal funds rate to respond to differences between actual and desired performance on the Fed's dual objectives of price stability and full employment. This is done by setting the real federal funds rate equal to 2% plus one half the difference between actual and targeted inflation and one half the percentage difference between actual and potential GDP (assumes potential real GDP growth of 3.5%). The nominal funds rate should be set equal to the targeted real funds rate plus actual inflation. The Federal Reserve and a growing number of central banks use the results of this NSF project to achieve sustained economic growth without high rates of inflation.

- **EDUCATION - IMPROVED ACHIEVEMENT IN MATHEMATICS AND SCIENCE SKILLS** This year NSF's continuing emphasis on systemic reform, teacher education and professional development has yielded exciting advances. In general, investments in educational systemic reform have led to increased achievement for a diverse student population and substantial narrowing of the gaps between minority and majority students. For example,

  - Over the first six years of the Miami-Dade Urban Systemic Initiative (USI), the median percentile scores on the Stanford-8 test for grade 4 students increased from 26 to 40 for African-Americans, from 26 to 59 for Hispanics, and from 74 to 77 for Whites, showing substantial progress toward closing the achievement gap.

  The Systemic Initiatives have also brought about substantial increases in the number of students taking more challenging science and mathematics courses in high school. For example,

  - Over a five-year period advanced placement science enrollment in Los Angeles USI schools increased by 53%, compared to 17% for non-USI schools in the city, with remarkable increases of 196% and 146% respectively for African-American and Hispanic students.

- **TRAINING WORLD-CLASS SCIENTISTS IN MODERN TECHNOLOGIES** NSF support provides a unique opportunity for undergraduates to have a "hands-on" exposure to science by working in NSF-funded laboratories. At Massachusetts Bay Community College, a program in biotechnology for minority students reaches a pool of under-served students, notably those from an urban community college, and provides them with opportunities for research at Boston University and other institutions, including field stations such as the Savannah River Ecology laboratory and Skidway Institute of Oceanography. A measure of the success of this program is that in the last five years it has produced eight recipients of the prestigious Barry M. Goldwater Scholarships for students planning to pursue a Ph.D. in science, mathematics or engineering.

- **INNOVATIVE RESEARCH AND EDUCATION EXPERIENCES** An important role for NSF is to catalyze innovation in the ways that we apply science, mathematics, and engineering. Undergraduate students participating in the Research Experiences for Undergraduates site at the Milwaukee School of Engineering helped solve a local murder case that had remained unsolved for 2 years. The students developed a technique for creating a facial image from a skull, which allowed police to determine the race of the victim. After this image was published in local newspapers, someone came forward to identify the victim as an immigrant from Africa, the clue that broke the case. The FBI is now interested in working with the Milwaukee School of Engineering to develop advanced forensic methods based on the modeling technique developed by the undergraduate students.

- **THE INTERNET** was based on experience gained from the Defense Advance Research Projects Agency-funded ARPANET that connected a few military labs and universities and established TCP/IP as the "language" of internetworking. Building on that experience, NSF funded a series of civilian network projects that led to the Internet of today. The CSNET of 1980 provided networking capability to computer science and engineering academic researchers and educators and encouraged this wider group of researchers and educators to engage in networking research and training. During the 1980's, CSNET was expanded as the NSFNET to connect university researchers to the NSF funded supercomputer sites and to NCAR. This increased the demand and uses for packet-based networks and drew the private sector into developing the expertise to further expand the technology. Major accomplishments in the 1980's include the design of the architecture for Internet routers that provided the foundations for companies such as Cisco and Bay Networks, the domain name system that gives us World Wide Web addresses such as www.nsf.gov or www.cisco.com, and the structure for connecting networks of different owners. In 1992, Congress asked NSF to open the Internet to competition and plan for its privatization. The result led to the system of Internet Service Providers and backbone providers that is now the acclaimed Internet.[1] Continuing development for the Internet includes very high-speed services, vBNS by NSF and Internet2 by the private sector, as well as applications support from NSF for scientific visualization, the sharing of scientific data sets, and distributed computing on "grids" of computers. The Internet is surely one of NSF's premier long-range impacts of the last decade.

- **COPING WITH INTERNET TRAFFIC GROWTH** Internet traffic is growing at an incredible pace. While optical communications technologies are well able to accommodate these increases, a severe bottleneck is the electronics implementing the packet routing functions. NSF-supported research in how Internet routers look up addresses rapidly to achieve high speed throughput is leading to new information to cope with speed issues. New techniques have decreased the address lookup time by a factor of eight, without having to add new hardware. The ideas have been patented and licensed to several routing-equipment manufacturers, including Lucent, GTE, NEC, Microsoft, Onex and Quary Systems. NSF's research support has created an entirely new approach to designing high speed internet routers, estimated to comprise a several billion dollar per year market segment.

[1] *Funding a Revolution - Government Support for Computing Research*, Computer Science Telecommunications Board of the National Research Council 1999, National Academy Press, 286 pages. This extended study has a detailed history of the ARPANET and Internet and places the development in a broader context of networking research and development.

FY 2000 NOBEL PRIZE WINNERS

Of the 11 Nobelists announced in 2000, six have been supported by NSF at some time in their careers. This is consistent with an historical connection: of about 400 Nobelists named since 1960, 109 have received NSF funding. This year's NSF-funded Nobelists - neuroscientist Paul Greengard, physicist Herbert Kroemer, chemists Alan Heeger and Alan MacDiarmid, and economists James Heckman and Daniel McFadden – demonstrate and reflect the multi-disciplinary influence of NSF support. Some have been funded by NSF for decades, and together they have received dozens of merit-reviewed NSF grants.

James Heckman and Daniel McFadden, who share the 2000 Nobel Prize in economics for their development of statistical methods that are widely used in the social sciences for predicting group behavior and evaluating the impact of public programs, have long been supported by the National Science Foundation. Dr. Heckman has been principal investigator on 21 NSF grants and Dr. McFadden on 33 grants since the 1970s. Dr. McFadden used his economic theory methods to help design the BART transportation system in San Francisco, guide investments in phone service, and allocate housing for the elderly. More recently, McFadden has developed new conceptual approaches and statistical methods for estimating the value of natural resources, used in such applications as quantifying the welfare losses due to the Exxon Valdez oil spill.

For a list of 2000 Nobel laureates, see: http://www.nobel.se/announcement/2000/index.html. For historical context on NSF's connection to the Nobel prizes, see: http://www.nsf.gov/od/lpa/news/media/2000/nsfnobels.html.