II. SOME NSF ACHIEVEMENTS

NOBEL PRIZES FOR 2001: Of the eleven 2001 Nobel Prize winners in the sciences, eight[2] have been previously funded by NSF (http://www.nobel.se).

The 2001 Nobel Prize in Chemistry was awarded to William S. Knowles, Ryoji Noyori and K. Barry Sharpless, for their development of catalytic techniques for asymmetric chemical synthesis. In nature, many molecules are found in mirror image, right-handed or left-handed, forms. Often only one of these asymmetric forms is biologically active. Sharpless developed highly efficient catalytic synthetic techniques to selectively produce only one of these mirror image forms. These techniques have allowed pharmaceutical companies to synthesize only the mirror image form that they need. The catalytic techniques developed as a result of this discovery are now used by pharmaceutical companies to produce, for example, beta-blocker medication to control blood pressure.

The 2001 Nobel Prize in Economics was awarded to three NSF-supported economists, George A. Akerlof, A. Michael Spence, and Joseph E. Stiglitz, for their fundamental contributions to our understanding of asymmetric markets – markets in which one side has more information than the other. More recent research by economists following up on the earlier theoretical work has shown that job candidates can signal to prospective employers their motivation, ability and training through the wage their current employer is willing to pay or the type of contract they will accept. "Signaling theory" has been widely applied, most notably to understanding the Internet and e-commerce.

The 2001 Nobel Prize in Physics was awarded to three researchers – Eric A. Cornell, Wolfgang Ketterle, and Carl E. Wieman – for their achievement of Bose-Einstein condensation in dilute gases of alkali atoms and for early fundamental studies of the properties of the condensates. The Bose-Einstein Condensate is regarded as a new state of matter in which all the constituents, by virtue of their near-absolute zero low temperature, are in the same quantum state. For this new state of matter the corresponding atom waves are coherent. Current speculation suggests that this new level of "control" of matter is going to bring revolutionary applications in such fields as precision measurement and nanotechnology.

Louis Stokes Alliances for Minority Participation: A variety of current initiatives are directed toward broadening participation of underrepresented minorities in science, technology, engineering, and mathematics. A principal one, the Louis Stokes Alliances for Minority Participation (LSAMP), shows increasingly positive results with growing numbers of students in this program entering these fields and a higher percentage earning degrees, including advanced degrees, in these disciplines. Particularly noteworthy are the increased graduation rates (from 48% to 62% in science and from 53% to 76% in engineering over a five-year period) at Puerto Rico LSAMP institutions.

Aging: A new model system was developed to study telomeres, structures that seal the ends of chromosomes in plants and animals much like the plastic tips on shoelaces, and which wear out, allowing the "lace" to fray. Telomeres break down in most cells in the

[2] George A. Akerlof, Eric A. Cornell , Wolfgang Ketterle, William S. Knowles, K. Barry Sharpless, A. Michael Spence, Joseph E. Stiglitz, Carl E. Wieman.

human body over time and have been implicated in aging. By exploiting the completed genome sequence of *Arabidopsis*, it is possible to uncover the contributions of the DNA damage surveillance machinery in identifying dysfunctional telomeres (http://www.nsf.gov/od/lpa/news/press/01/pr0115.htm).

Deep Green: The "Deep Green" project has made radical new discoveries about the history of plant life on earth. The findings significantly rearranged the "family tree" of green plants since it was learned that ferns and horsetail are not, as was previously believed, transitional between mosses and flowering plants. They are, in fact, the closest living relatives to seed plants. Ramifications of these findings span practical areas ranging from agriculture to economics (http://www.nsf.gov/od/lpa/news/press/01/pr0109.htm).

Extra-solar planets: A major impetus to the observational and theoretical studies of the formation of stars and their planetary disks was provided in the last few years by the discovery of extra-solar planets. The most recent discovery finds a planet three-quarters the mass of Jupiter in a circular orbit around the solar-like star 47 Ursa Majoris. Although more than 70 extra-solar planets have been found thus far, this is the first system with two planets in circular orbits, and at distances that make the planetary system similar to our own.

The oldest material: Reports of the Hadean detrital zircons from Western Australia include the discovery of one that is approximately 4.4 billion years old. This tiny crystal formed within 160 million years of the formation of Earth and is the only sample known from the earliest history of Earth. The zircons also indicate that there was liquid water, and perhaps even oceans, i.e. a cool early earth, at a time when many have hypothesized the existence of magma oceans.

Clouds and climate models: One of the most uncertain aspects of climate models is the treatment of clouds. Recent work has led to a discovery with potentially significant implications for global climate change scenarios. An analysis of the distribution of upper-level cirrus clouds and sea surface temperatures (SSTs) shows a strong inverse relation between cirrus cloud area and the underlying surface temperatures. The finding suggests that the earth has a natural adaptive infrared 'iris' that opens and closes the upper dry regions in order to control the heat radiated by the Earth in response to SST changes, in a manner similar to how a human iris reacts to changing light levels. If confirmed, this could significantly affect current global climate models.

Intelligent robots used at World Trade Center: Intelligent Autonomous Marsupial Robots, prototyped with NSF funds, were used for search and rescue at the World Trade Center (WTC) during the disaster recovery efforts following the September 11, 2001 attack. Just as kangaroos carry their young in a pouch, these "marsupial" robots possess unique characteristics: the "mother" robot carries smaller ones in its "pouch" into the site as far as it can maneuver and it then releases and provides power as the "babies" descend from it to perform their search – negotiating smaller crevices and hidden spaces. Equipped to maintain balance on rough terrain, the robot "mother" and its "children" can reach, sense, and report on spaces that are too small and/or too dangerous for human rescue workers to approach or enter. The robots located five victims and a set of remains, and surveyed three buildings and two voids in the debris. As a result of watching the robotic creatures in action, the Federal Emergency Management Agency (FEMA) Task Force has ordered various small and semi-autonomous robots for future use (http://www.nsf.gov/od/lpa/news/press/01/pr0178.htm).

Newly discovered animals in hydrothermal vents: In the spring of 2001, an interdisciplinary team of scientists and engineers explored a newly discovered hydrothermal vent field in the Indian Ocean. They collected biological samples, samples of vent and smoker fluid and plumes, rocks and sediment samples from the seafloor, and precisely mapped the area. Newly discovered animals living in the hydrothermal vent system as well as ancient bacteria found at the site may help scientists better explain how and whether the fauna living at hydrothermal vents in the Atlantic and Pacific Oceans are genetically related. The research expedition was fully integrated with an educational component entitled "Dive and Discover," co-funded with the Woods Hole Oceanographic Institution and Ohio's Center of Science and Industry. "Dive and Discover" involved live webcasts, interactions between students and researchers, and companion materials that assisted teachers in explaining the science and technology behind the expedition (http://www.nsf.gov/od/lpa/news/press/01/pr0136.htm).

Learning technologies: Just as human teachers need to listen as well as speak, some researchers believe that learning technologies should observe and react to students' needs, not just present material in an informative and appealing way. Researchers supported by NSF are opening up new avenues of education research. Here are several examples:

- A series of participatory simulations has been developed by which middle and high school students, using handheld and networked devices, each become independent agents in simulations of system dynamics. These simulations may be as varied as chemical molecule collisions or automotive traffic. They all yield entirely different kinds of content-rich experiences.
- Tracking devices that examine students' eye movements as they interact with a computerized algebra tutor have already proven effective as an instructional agent. Eye movements may be indicative of changing cognitive states on a fine time scale. When the tutor's feedback was contingent on eye movement data, students learned 20% faster (preliminary unpublished results).

Wisdom of practice: Findings from NSF supported research on learning are directly applicable to the classroom and help to identify the most effective types of interventions or instructional approaches. A commonly held "wisdom of practice" is that one of the best means to learn a subject is to teach it. Research has documented this phenomenon and has used it to design agent-based technology by which mathematics and science students have to master disciplinary content at a sufficient level to "teach" computer agents. Programs were developed that enable analysis not only of progress in writing proficiency but also in evolution of content knowledge. Research of this type supports the conclusion that children learn better if they are put into the position of reconstructing or explaining newly learned scientific material to others. Work in the Detroit Public Schools suggests that youngsters as young as sixth grade can build and analyze models of complex systems that without technology would require use of undergraduate mathematics.

Underwater robots: The first autonomous underwater vehicle with the endurance to work under ice in the Arctic was developed. This is part of a continuing effort to obtain better all-season ocean data. Strategically related efforts continue to develop robotic samplers for the atmosphere (aerosondes) and to develop an autonomous, under-ice ocean bottom seismometer.

Modeling contamination events: Newly developed computer models enable modeling of the flow of water in shallow basins. These models include factors such as river inflow and standard tidal flow, and allow for the presence of contaminants being transported by the flow. These computational methods have been used in

the development of a complex shallow water simulator, called UTBEST (University of Texas Bays and Estuaries Model). It has also been possible to model a simulated contamination event in the Houston Ship Channel with the domain modeled being all of Galveston Bay.

Cyber-terrorism: A computer system was built that is capable of identifying and stopping intrusive behavior on the system it is protecting. The technology can identify assaults in progress, stop the offending process, and disable the IP address of the culprit. As a proof of concept, the team that developed the system placed a highly vulnerable version of the Linux system (no security patches) on the net as a web server and invited hackers throughout the world to root the machine. There were over 13,000 attacks on this box and not one successful intrusion.

Lost City: Hydrothermal vent structures, dubbed the "Lost City," were discovered in December 2000 in the mid-Atlantic Ocean. These vent structures, including a massive 18-story vent, taller by far than any seen before, are very different from all others discovered across the world since the 1970s (http://www.nsf.gov/od/lpa/news/press/01/pr0156.htm).

Antifreeze proteins in fish living in extreme environments: The question of how cold-blooded creatures such as fish survive in the frigid waters off Antarctica is being investigated by studying the role of antifreeze glycopeptides, antifreeze proteins of Antarctic fishes involved in freezing avoidance. We anticipate that the results will lead to major advances in understanding molecular biology and evolution of antifreeze systems and will be applicable to a wide range of disciplines.

Researchers on another project, also focused on Antarctic fishes, seek to determine at the molecular level those adaptations that enhance the assembly and movement of microtubules and the expression of related genes. In the broadest sense, this research program should advance the molecular understanding of the survival of cold-blooded organisms.

Another project is a phylogenetic study of Antarctic microorganisms to understand the unique adaptations required for survival. The application of DNA microarray technology to studies of life in extreme environments offers an outstanding opportunity for identifying new genes for biotechnological use. Discovering specific adaptations to extreme environments by detecting genes that are uniquely expressed in the natural environment is an ultimate goal of this research.

Sounds of the Sea: An NSF informal science education project that serves diverse students and engages diverse communities directly in the scientific enterprise is *Sounds of the Sea.* This project empowers a generation of students and teachers to explore scientific concepts and engage in understanding an array of scientific professions that are not a traditional part of the K-12 experience. It created a national model for engaging blind and visually impaired students and adults in experiencing hands-on science. The program provided curricula to urban school districts that will reach 15,000 teachers annually through the Teacher Resource Center. The program will remain in use beyond the grant period. A legacy of the project is a four-page "advanced organizer," as well as in-home, in-school, and after-school activity guides distributed to over 10,000 educators to facilitate students' exploration in marine science.

Replacing chlorine-based processes: Catalysts for the activation of hydrogen peroxide in water for green oxidation processes have been developed. They may replace environmentally harmful chlorine-based processes used in the textile, paper and laundry industries.

Astroflow: The activities of faculty members who are active in bringing their

research results to the public are well illustrated by work taking place in Rochester, NY. A research group is making the results of their research directly available to the public through a variety of venues including programs at local grade, middle and high schools. A program called Astroflow is a suite of software tools allowing users to interactively control, visualize, and explore realistic simulations of cosmic events: exploding stars, comets diving into planetary atmospheres, jets of hypersonic gas driving through interstellar clouds, and more. Astroflow gives students and non-scientists the opportunity to learn by experimentation and exploration. Currently Astroflow is installed in a specially designed kiosk at the Strasenburgh Planetarium in Rochester, NY. The technology behind Astroflow has been successfully commercialized.

The **Macrogalleria,** a pioneering educational polymer web site, is continuing to garner broad recognition. NSF Director Rita Colwell described it in these terms in one of her speeches: "Many of you have seen the wonderful Web Site called 'Macrogalleria.' It is set up like a shopping mall. The site bills itself as 'the Internet mall where you net surfers can learn all kinds of nifty stuff about polymers and polymer science.' The student or the Internet surfer clicks on the shops and learns that polymers are everywhere. As he or she ascends to the different levels of the mall, more complex concepts are conveyed." The Macrogalleria was recently selected by *Scientific American*[3] as one of its "50 Top Websites." This follows many other distinctions, such as the Education Index Top Site and the Top 5% of Chemistry Sites. The worldwide popularity of the Macrogalleria is so high that it has already been translated into Afrikaans, French, and Spanish, and is being translated into Italian and Portuguese.

VORTEX – Predicting tornadoes: The benefits of education and research within the atmospheric sciences are extremely visible to the public at large. The importance of the daily weather to individuals is self-evident. Severe weather prediction is of paramount importance. The Verification of Origins of Rotation in Tornadoes Experiment (VORTEX) used airborne and surface mobile Doppler radars and other mobile sensors to map in detail the structure of tornadoes and their near environment. The modeling and observations indicated that a localized downdraft is an important ingredient in the final stages of the formation of a tornado. This knowledge was directly translated to more accurate tornado forecasts (tornado watches) being issued by the National Weather Service.

Hazard loss: A major research project on "2nd National Assessment of Research and Applications on Natural Hazards" involved over 130 national experts in hazards and disasters from all fields of science, engineering, policy, and practice. The results of this effort greatly influenced policies for and approach to hazard loss mitigation in the Federal Emergency Management Agency's (FEMA) Project Impact. The objectives of Project Impact are to establish a national risk assessment, meet the need for computer-aided systems to inform local hazard decision-making [e.g., FEMA's Natural Hazard Loss Estimation Methodology (HAZUS)], and assist local efforts to design safer communities, such as efforts underway in Berkeley, California and Tulsa, Oklahoma. A summary brochure of the assessment was distributed to every member of the U.S. House of Representatives. The document was subsequently used internationally. It provided the basis for redrafting New Zealand's environmental and hazards legislation to link sustainable development with environmental management and hazards mitigation.

3 http://www.scientificamerican.com/explorations/2001/051401top50/#ScientificAmerican

COPLINK: A collaboration between a university artificial intelligence laboratory and a local police department has led to development of an integrated justice information database available over a secure intranet. COPLINK is still in the deployment phase with 32 law enforcement professionals currently using this system. Plans are being developed to deploy COPLINK in other areas of the U.S. COPLINK is an excellent example of multi-agency partnerships supported under the Digital Government program. NSF and the Defense Advanced Research Projects Agency (DARPA) supported the fundamental research that led to COPLINK under the Digital Library 1 initiative.

Astro coalitions: This project links amateur and professional astronomers, school children, their teachers, and families around a variety of activities, such as creation of scientific records, production of student research journals, and collaborative investigation of astrophysical phenomena. In addition to having formed partnerships that connect groups who have never worked together before, this project has created a system that has engendered new coalitions beyond those targeted in the funding cycle. The project has launched a new idea for public collaboration in science that is regenerating itself in a variety of forms across the nation.

Wavelets and their uses: The theory of wavelets has had a profound impact on data compression, signal analysis, scientific calculation, medical imaging and radar detection. In one application wavelets are used to identify the key features of an image and allow reconstruction of the image with only a tiny amount of information about the original object.

Environmental changes in Antarctica: The Cape Roberts Project is a major international drilling program involving more than 50 people from seven countries. Researchers have collected more than 1,700 m of sediment core that is providing a record of environmental changes extending back more than 30 million years. These cores reveal periods of high frequency instabilities in the Antarctic climate during the Miocene (e.g., 24 million years ago) age. A detailed record of environmental changes extending back this far has not been available previously; the new discoveries from the cores are expected to make significant contributions to many areas of Antarctic geosciences.