XIV. APPENDIX OF ADDITIONAL EXAMPLES ILLUSTRATING OUTCOMES OF NSF INVESTMENTS

FY 2000 EXAMPLES OF ACHIEVEMENTS CITED BY EXTERNAL EVALUATORS

OUTCOME GOAL 1

DISCOVERIES AT AND ACROSS THE FRONTIER OF SCIENCE AND ENGINEERING

External evaluators cited the following examples of results from NSF awards as demonstrating success in support of Outcome Goal 1. These examples illustrate important discoveries, new knowledge and techniques, both expected and unexpected, within and across traditional boundaries; and high-potential links across these boundaries.

The examples shown illustrate NSF-supported results reported in the FY 2000 areas of emphasis for this outcome goal: balance of innovative, risky, interdisciplinary research; new types of scientific databases and tools to use them; life in extreme environments; biocomplexity; and nanoscience and engineering. It is interesting to note that many results cross the boundaries between discoveries, new knowledge, interdisciplinary research, biocomplexity, and nanoscience. The diverse portfolios of awards show potential for significant impact in these areas.

- **TRACKING TURBULENCE** Turbulent flow of fluids is important in many fields, from atmospheric sciences to combustion science to fundamental fluid physics. For example, in the design of engines, fuel combustion leads to the production of hot gases that are very turbulent. This turbulence affects the amount of fuel that is actually burned and significantly affects the efficiency of the engine and the level of pollutants it produces. Being able to measure turbulence can lead to the design of more efficient engines. A major problem is to monitor the fluid flow, which is characterized by high "Reynolds Numbers". A low Reynolds Number indicates smooth flow, and a high Reynolds Number indicates chaotic flow. Recent innovative work has begun to apply particle physics techniques and particle detectors to follow the motion of numerous small buoyant 'particles' to map out the complex turbulence patterns. In other recent work, seminal studies of turbulence over an unprecedented range of Reynolds Numbers was achieved using cryogenic helium, near its critical point of 4.5 Kelvin, a very low temperature. (A Kelvin is a measure of absolute temperature. A temperature of 0 Kelvin, equal to absolute 'zero' at which all motion of atoms and molecules would theoretically cease, would be colder than –273 degrees. Most materials would be frozen solid at much higher temperatures.) Liquid helium is the fluid of choice for ultra-high Reynolds studies because its physical properties lead to the ability of scientists to create turbulent flow at possibly the highest Reynolds Numbers in the universe, right in an

earth-bound cryostat. Turbulence studies done at very low temperatures will impact aeronautical, chemical, and mechanical engineering fields.

- Innovative adaptation of retired undersea telephone cables to establish a sea bed seismological observatory, called H2O, under 5 km (about 4.6 miles) of water in the Pacific Ocean halfway between California and Hawaii. This resource will enable detailed characterization of the Earth's mantle under the northeastern Pacific Ocean.

- In the Antarctic a high-risk, international project netted impressive results about the long-term evolution of the Antarctic climate and ice sheets, marine life, and also topography and tectonics. The recorded Antarctic changes help to explain some of the puzzling major changes in global climate on timescales of millions of years.

- The tundra regions on the Alaskan North Slope were found to have recently shifted from being sinks for greenhouse gases to being sources for these gases in winter This is important because the large regions of Arctic tundra now represent a potentially significant addition to the global greenhouse gas budget. In the Antarctic, discoveries of rapid and episodic algal blooms in the Ross Sea were linked to fluctuations in the export of carbon from the ocean surface. When extrapolated to larger spatial scales, such blooms have the potential to explain major fluctuations in atmospheric carbon dioxide concentration.

- NSF recently funded the continued development of a small, long-range, long- endurance robotic aerosonde for use in cold regions. Typically, aircraft of this type are not designed with anti-icing capabilities in order to maintain their weight and endurance characteristics. In August 2000 two weeks of flights were conducted to test new instruments, ice detectors and anti-icing coatings. The tests were highly successful and will continue with more miniature instruments, an upgraded aerosonde design and a new catapult launch device.

- An interesting example of research focused on Life in Extreme Environments is the discovery of bacteria actively metabolizing at –17°C in snow at the South Pole. This unexpected result reduces the lower temperature limit for life. This evidence for the resilience of life exposed to heavy doses of damaging ultra-violet radiation, extreme cold, and darkness has important implications for the possibility of life existing elsewhere in the Solar System.

- **NEW TYPES OF OCEAN BACTERIA THAT CONVERT LIGHT INTO ENERGY** A new strain of bacteria was recently discovered that employs bacteriorhodopsin, a protein that demonstrates light-harnessing abilities previously known only to exist in fungi and archaea. These organisms thrive in hostile environments where sustenance is scarce—like the open ocean. NSF-supported researchers found a bacteria that uses a type of

chlorophyll never before seen in open ocean bacteria. Two teams isolated DNA directly from seawater samples and compared many of the fragments to those already on file in public databases. The gene that stood out was that which codes for bacteriorhodopsin. They developed a fluorometer to search for bacteria that might use dim infrared light emitted from deep sea vents. They found none at the vents, but when scanning the surface waters they picked up many positive signals. The types of bacteria discovered by these two teams employ different mechanisms to harness light and convert it into energy. What they have in common is the ability to thrive in the open ocean where nutrients are limited and in turn provide nourishment for other organisms higher up the food chain.

- NSF-supported collaborators have developed a new biosensor based on fiber optic technology that can directly monitor microbial community structure and activities in coastal and estuarine waters and sediments. The biosensor design will allow multiple assays in the future. Such a sensor should lead to new knowledge regarding biogeochemical processes in these environments including the "relationships between cell abundance, gene expression, and actual microbial metabolic activities under different environmental conditions".

- Invaluable insights into the evolution of vertebrates have been provided by NSF-supported groups working to understand important evolutionary steps in the transition from invertebrates to vertebrates. Using comparisons of gene expression, and model vertebrates such as mice and zebrafish, these labs have provided important insights into the development of the brain, spinal cord, and neural crest. In addition, the researchers have been able to develop methods to perturb gene expression in non-model systems and have paved the way for important future studies by all researchers in the field.

- **NEW NANOWIRES** Nanoporous templates were created by exploiting the self-assembling nanoscale structure of cylindrical phase diblock-copolymers. Functional materials are deposited into the nanopores to create the final functional nanostructure. This fast and easy-to-use method was used successfully to fabricate an array of magnetic cobalt 'pillars' (or nanowires) of very high density. These may find use in new magnetic hard disks that can have 200 times the storage capacity of present commercially available disks.

FY 2000 EXAMPLES OF ACHIEVEMENTS - OUTCOME GOAL 2

CONNECTIONS BETWEEN DISCOVERIES AND THEIR USE IN SERVICE TO SOCIETY

External evaluators cited the following examples of results from NSF awards as demonstrating success in support of Outcome Goal 2. These examples made the connections between discoveries and their use in society and were rapidly and readily available and used as appropriate in education, policy development, or by other federal agencies or the private sector.

- **FIRE-WEATHER** Ongoing wildfire research supported by NSF is directed at improving the understanding of fire behavior and dynamics. This research involves collaboration with a growing number of colleagues including the U.S. Forest Service, Monash University, University of Colorado, the Country Fire Authority (CFA) of Victoria, and Australia's Northern Territories Bushier Council. The groups combine models, instrument development, and observations of forest fires and grass fires in field experiments conducted in the Northwest Territories of Canada, Australia, and the western United States to gain a better understanding of fire behavior and spread. This new knowledge helps the fire captain to better position his firefighters and equipment to fight a fire. The increased understanding of fire dynamics can help prevent firefighters from being overrun by fire and can save lives.

- **LIGHTER-WEIGHT ELECTRONICS** Consumer demand for smaller, more-reliable, lighter-weight electronic devices is a strong contributor to our nation's economic growth. One center located at Georgia Institute of Technology is helping to meet that demand. Flip-chip microelectronic packaging, the technology of attaching semiconductor chips directly to circuit cards, can deliver the needed functionality. However, costly manufacturing processes and materials have hindered wide-scale proliferation of flip-chip technology. The center has created a suite of next-generation flip-chip manufacturing processes, advanced materials, and manufacturing equipment in cooperation with their 20 industrial partners. These new methods could reduce flip-chip costs by 50-80 percent. The new materials are now commercially available from organizations such as Dexter, National Starch & Chemical, Emerson and Cuming, Loctite, and Alpha Metals. Manufacturing equipment for using these new materials is available from Cookson and Siemens. Seagate has already integrated some of the new technologies, materials, and equipment into their manufacturing lines. Large industrial organizations, whose products span the spectrum of commercial and military electronic devices, such as Advanced Micro Devices, Chrysler, Ericsson, Honeywell, Texas Instruments, Nokia, Lucent Technologies, and Northrop Grumman now are poised to implement flip-chip technologies into their next-generation of products and systems.

- **CRACKS ALONG THE CONTINENTAL SHELF** NSF-supported researchers discovered cracks along the edge of the continental shelf off the coast of Southern Virginia. The researchers suggest that the cracks could be the start of underwater landslides that could, in turn, create tsunamis. The investigators received additional support to carry out a detailed geological and geophysical investigation of these features. Initially thought to be caused by faults. The cracks appear to be depressions formed by continuous and massive blowouts of gas. The researchers maintain that such blowouts could trigger landslides and tsunamis and note that similar gas blowouts have damaged or destroyed oil rigs in the Gulf of Mexico and the North Sea. The implications of these findings are important for identifying geo-hazards on the east coast of the United States.

- **IN THE AREA OF DESIGN AND MANUFACTURING** NSF-supported researchers have been very successful in disseminating their research results to the private sector, where they have become useful tools. For example, in the areas of rapid prototyping and rapid fabrication, there have been spin-offs significant for commercial ventures. NSF research resulted in patented technology licensed to DTM Corporation. Subsequently, DTM developed and manufactured the Sinterstation 2500® System. The Sinterstation 2500® is a commercially successful rapid prototyping technology used in US European university and government research laboratories, including Sandia and Los Alamos National Laboratories and the Jet Propulsion Laboratory, and in several large corporations, including The Gillette Company. A 3D Printing technology was licensed to several companies, all of whom have used the technology to manufacture a wide variety of products. Several large companies have options for licenses in place. Both of these technologies have led to significant reductions in the time from design to manufacture. A further effect of this reduction in lead time is the potential to diminish the need to maintain large spare-parts inventories, particularly in Department of Defense applications.

- **NSF-SUPPORTED PROJECTS ON THE NSFNET** developed new techniques in cross vendor route registry and its management. The major activities include advancement of Internet routing algorithms with respect to scaling and stability issues, routing information registration and dissemination for the network service providers serving the Internet, deployment of route servers to aid in the dissemination and real time maintenance of the global Internet routing system, and coordination and sharing of technical information in support of the Internet operation community. Several leading vendors have licensed routing algorithms developed by this project.

- **GLOBAL SHARING OF SCIENCE RESULTS** E-print Archives, the electronic-print system, allows physicists to post the results of their research in a timely manner on the web, allowing other scientists to have rapid access to their work as important discoveries are made.

- **IMPROVING EFFICIENCY OF NETWORK DESIGN TO SAVE TIME AND MONEY** Solving problems in local access and network layout are fundamental to optimizing computation. NSF-supported work addresses some fundamental issues in the area of network design with practical relevance since small improvements in network layout can translate into savings of many millions of dollars. The NSF-supported research has resulted in solutions and associated software packages capable of solving network design orders-of-magnitude faster on available computers. The work applies methods from operations research to networking problems, and has already received recognition from the operations research community. It will have substantial impact on network service providers.

NSF awards produced a wide variety of important discoveries in both the Arctic and Antarctic. Many discoveries concern regional environmental change which have implications for global climate change.

- Greenland ice core studies have produced evidence that rapid climate change – 8 degrees C in less than a decade – has occurred.
- Studies have shown that the sea ice cover of the Arctic Ocean has undergone a major decrease in the past decade as a result of melting and redistribution due to atmospheric circulation changes.

Protection of the environment and human health in a context of continual development and economic growth is perhaps the most significant global challenge for the next millennium. Issues such as sustainability, pollutant avoidance, and remediation drive the direction of many NSF investments. NSF programs continue to participate substantially in the NSF/EPA initiative, "Technology for a Sustainable Environment". Other notable NSF-supported programs include studies on environmentally-benign processing, development of environmentally-safe products, destruction methods for pollutants, and diagnostics of known carcinogens. Recent fundamental breakthroughs under NSF support in clean chemistry, diagnostics, and new concept development show the promise of minimizing/controlling emissions and improving our quality of life.

- NSF supported researchers have demonstrated the use of high pressure carbon dioxide (super critical conditions) as a solvent for cleaning clothes, computer parts, and textiles. This technology has the potential for replacing organic and halo-carbon solvents. They are the principal pollutants in the cleaning industry. The NSF- supported fundamental science has led to the creation of a small business and a center of study at North Carolina universities.

- Simultaneous reduction of nitric and nitrous oxide (NOx) and soot emissions from practical combustion systems to meet tight emission standards is an extreme challenge due to competing formation/destruction processes. NSF-supported researchers have developed a catalytic filter for diesel engines that captures soot particulates formed

during low temperature operation and then oxidizes this soot to reduce NOx emissions under high temperature conditions.

- **IMPACT ON THE DEVELOPMENT AND MANUFACTURE OF SPECIALTY CHEMICALS, NOVEL MATERIALS AND BIO-BASED AGENTS** Our ever-rising standard of living is accompanied by an ever-increasing demand for better and more affordable specialty chemicals, novel materials, and chemical/biological therapeutic agents. The production of these chemicals and materials requires highly sophisticated, and often prohibitively expensive, reaction processes and/or separation and purification steps. Advances made with support from NSF have greatly contributed to the technological developments in these areas.
  - NSF-supported development of a low-cost technique to use immobilized affinity chromatography to separate valuable blood proteins such as protein C, prothrombin and vitamin K-dependent proteins from plasma was developed. These natural plasma proteins are much more effective than those derived from currently available recombinant DNA technology. This work is closely coordinated with and done in collaboration with the American Red Cross.

- NSF awards frequently result in application software, patents, and an educational exchange between academic researchers and industry engineers. Researchers learn about the domain and adapt their research agendas to industrial needs. Industry engineers have access to recent research results and course materials and, as the relationship progresses, access to a pool of potential employees skilled in the domain. A few examples that highlight these connections are:
  - NSF engineers in partnership with apparel manufacturer Levi-Strauss, have developed and implemented an adaptive, closed-loop production control system. Thanks to a donation of equipment from a factory being closed by Levi-Strauss, a production line identical to an operating line at another factory was installed in the engineer's laboratory space, allowing a rigorous comparison of the traditional and proposed lines. The research has helped the manufacturer to supply quantities of a large mix of products rapidly and economically while maintaining minimal surge capacity to meet occasional peak demands.
  - A tricycle "cobot" for removing doors from newly painted automobiles prior to assembly of the cabin has been developed with NSF support. On the basis of this research prototype, General Motors developed a rugged, highly maneuverable device for this task. The cobot is patented. Various educational courses were provided to GM engineers.

Science and Technology Centers (STCs): Integrative Partnerships have responsibilities in the area of knowledge transfer that go beyond those of individual investigators by design. The first new set of STC awards in almost a decade were made in FY 2000. Assessments address both the effectiveness of existing centers in establishing connections and the potential for strong performance in the new class.

- One Science and Technology Center is dedicated to exploiting the atmospheric conditions at the South Pole to do astronomy and cosmology. The Center also has an active program of education and outreach. The core program, Space Explorers, targets African-American students at inner-city high school students in Chicago to enhance their science abilities before they enter college. Each August, thirty students attend a week-long summer residential institute at Yerkes Observatory. A 2-day version of the summer institute is given each December. The Space Explorers teach in grammar schools during the academic year. Space Explorers and Adler Planetarium astronomers present programs using a portable planetarium to 30 schools, reaching nearly 3,000 students, annually.

- NSF-supported research in cognitive science has focused on the cognitive aspects of language acquisition, structure and processing, logic and computation, and perception and action. Recent accomplishments include progress on the integration of research on language acquisition with statistical learning theory, simulations of language learning, and online methods to study children's language acquisition.

FY 2000 EXAMPLES OF ACHIEVEMENTS - OUTCOME GOAL 3

A DIVERSE, GLOBALLY-ORIENTED WORKFORCE OF SCIENTISTS AND ENGINEERS

External evaluators cited the following examples of results from NSF awards as demonstrating success in support of Outcome Goal 3. Noteworthy examples taken from committee reports have been selected to demonstrate results in FY 2000 areas of emphasis that include integrative research and education opportunities, and participation of under-represented groups in integrative research and education.

- **LIVING IN A GLOBAL WORLD** NSF programs are at the forefront of study of the emerging area of globalization. Increased economic, technological, and social interconnections among nations have resulted in new transnational, international, and supranational legal practices. Our increasingly global world calls for continued development and innovation of legal theories. Several NSF funded projects have already made significant findings on new forms of global law and global legal processes. Studies have examined and explored
  - the quality of the practice of law internationally by looking at lawyers' roles in social movements and human rights campaigns;
  - international networks of lawyers to understand how the practice of law and experience of practitioners have changed in response to global processes;
  - the new culture of finance, which draws on innovative methodology such as monitoring an internet discussion group.

- **INCREASING STUDENTS' EXPOSURE TO QUANTITATIVE DATA AND EMPIRICAL ANALYSIS** The principle purpose of the American National Election Study (ANES), has been the development of high-quality data on public opinion and political choice in American national elections. With a history of support spanning 25 years, the data generated by this enterprise increasingly is used in college and even in high school texts, not only to inform students about elections and voting, but also to teach them the rudiments of data analysis and statistics. Because American government is a required course at the college level in many state universities, all students, not just those interested in Political Science, are exposed to quantitative data and empirical analysis. Frequently ANES data on diskette are now included in introductory American government textbooks, along with basic statistical software, and lesson plans include suggestions for the effective integration of these data in courses.

- NSF support at the University of Hawaii provides widely distributed educational kits that undergraduate students use to effectively learn how to design low cost, complex systems. The kits consist of a prototyping card, with network capability, in a book with companion materials. There is a strong team involving researchers at the University of Hawaii, several industrial organizations, and a publisher. The kit is in accordance with the emphasis on design in the new Accreditation Board for Engineering and Technology

(ABET) accreditation requirements and is expected to make a significant impact in undergraduate education in engineering and science.

- NSF support to a researcher at the University of Maine has led to the development of an outreach program that supplements research on geospatial databases. Work covered by this project is part of a high school outreach program called "Spatial Horizons". The program is typically attended by more than 100 high school students per year. Another high school outreach program affected by this project is the University of Maine organized "Expanding your Horizons" program. It is targeted at female high school students attempting to increase their participation in science and engineering disciplines. The lead researcher on this project won the 1998 Outstanding Young Faculty Research Award at the University of Maine and the 1999 Presidential Citation of the American Society for Photogrammetry & Remote Sensing.

- **DEVELOPING AN ENVIRONMENT FOR THE WORKFORCE** NSF support to Mississippi State University has led to the development of methodologies for enabling industry to better accommodate disabled employees. Specifically this work targets persons with paraplegic and/or visual disabilities. It should lead to the development of an intelligent computer system to assist in making decisions associated with designing and retrofitting work tasks and the workplace to accommodate persons with disabilities. It may also address some of the major problems associated with the high unemployment rate of persons with disabilities.

- **RESEARCH EXPERIENCES FOR UNDERGRADUATES (REU)** One mechanism NSF uses to increase support for under-represented groups is the REU site award. Participation in REU sites frequently includes high percentages of under-represented groups. For example, one NSF organization has invested in over 200 REU sites. One NSF division provides resources for 60 REU sites in 33 states and Puerto Rico, with about 550 students supported at these sites. Typically, half the participants are female, and over 16% are from under-represented minority groups.

- With funding from some 24 NSF-supported centers, about 370 undergraduates participated in research activities. The undergraduates included 145 females and more than 100 minority students. Outreach to Native Americans is a focus of two of the centers.

- NSF administers the four-year undergraduate and graduate program Significant Opportunities in Atmospheric Research and Science (***SOARS***) to provide education and research opportunities in the atmospheric sciences to students from under-represented groups. Typically, about 20 students worked with scientific mentors from NSF supported labs, DOE and NASA laboratories, the University of Colorado, and other national and international universities.

- An NSF program funds a collaboration between the University of Pittsburgh and the Carnegie Museum of Natural History, in which minority high school students serve as interns, working on web-site development, exhibit and seminar development, and as museum docents. All of this is in connection with Earth science museum exhibits. The internships target African-American students interested in math and science in the Pittsburgh area.

FY 2000 EXAMPLES OF ACHIEVEMENTS - OUTCOME GOAL 4

IMPROVED ACHIEVEMENT IN MATHEMATICS AND SCIENCE SKILLS NEEDED BY ALL AMERICANS

External evaluators cited the following examples of results from NSF as demonstrating success for Outcome Goal 4. Noteworthy examples taken from committee reports have been selected to demonstrate results in FY 2000 areas of emphasis, which include K-12 systemic activities; research on learning and education; graduate teaching fellows in K-12 education; and K-16 digital libraries.

NSF considers many of the K-12/16 activities listed to be of interest to students in order to engage them at an early stage in their education in science, mathematics and computer science. Early involvement is extremely important to retaining students in science and engineering in the future. Educating in science is educating for the future.

- Research on learning has provided important findings for middle and high school. At Rutgers University a longitudinal study of the development of proof-making in students has found that students at the middle school and high school level are capable of much more advanced mathematical thinking than expected. For example, although high school students did not use the symbolic representation or procedures of college students studying calculus, they developed powerful and correct solutions to calculus-type problems.

- Hampshire College found that students enrolled in inquiry-based classes performed better on essay style assessments of general scientific reasoning in comparison to students in more traditional classes.

- NSF supports a focused project on "at-risk" students at the Kieffer Institute for Development of Science-based Education, entitled "Science: Day-by-Day, Life-by-Life, Community-by-Community". The goal of the project is to formulate an Earth-science-based curriculum for K-12 education for at-risk students. At-risk students are defined as any group of students who are not able to participate in a continuous K-12 curriculum. The curriculum uses the Earth sciences to capture students' interests and to stimulate learning in other fields such as mathematics, social sciences, and language arts.

- Pre-service and in-service science teachers work together in NSF-supported research projects at Towson State. This teaming of experienced teachers with teachers-in-training facilitates the acquisition of important new expertise, the development of a deeper understanding of research, and the unique opportunity to share invaluable experience. By targeting both active and developing science teachers, the benefits of this experience will be rapidly and widely distributed to K-12 students.

- Critical to the goal of science education for all Americans is the development of creative ways of reaching the public. Support for museum collections promotes this goal in a number of ways. Museum displays and the computerization of collections and distribution of data over the World Wide Web provide broad accessibility to the American public. Equipment supported by NSF and placed in museums often becomes the focus of education-related activities. Museums are also involved in web-based science and education programs that are directly related to supported collections.

- NSF-supported researchers at the University of Massachusetts are studying ways to improve the abilities of K-12 students to find, evaluate, and organize information available on the Internet. These skills comprise a significant subset of the Information Literacy skills that Library Science teaches. The approach consists of building a Web search interface in which Information Literacy skills are matched to Information Retrieval (IR) tools in a way that teaches skills while helping students locate information on the Internet. Improved queries are created from the student's information need, supporting information from the surrounding educational environment, and query expansion from educationally-focused databases. Information filtering techniques identify, and if desired eliminate, retrieved information at the wrong grade-level or containing inappropriate content. One of the goals is to establish a long-term research relationship to address the use of information technology and the Internet in K-12 education.

- NSF supported collaborators at Carnegie Mellon have supported development of a computer based reading tutor for elementary school students. An early evaluation showed rapid improvement in reading skills among poor readers.

- **QUARKNET** partners high school physics teachers and their students with particle physics research groups at 60 U.S. universities and laboratories. Students learn fundamental physics, investigate particle physics through live, online data and collaborate with other students worldwide. About 25 teachers complete summer research appointments and these teachers go on to offer workshops to another hundred teachers. Each teacher who has skills and knowledge enhanced in such research experiences then communicates that knowledge and excitement to all of the students in his or her classroom.

- Recent results from research on the learning of science and mathematics have shown that elementary school children are capable of more sophisticated forms of reasoning, modeling, and higher order learning that previously thought or that are currently embedded in teaching materials and teaching practice:
  - Homeless students and Latino students for whom English is a second language, or whose command of English is still limited, do learn to high national standards when properly taught.

- Fourth and fifth graders can talk appropriately about sampling and distributions and how these ideas can help explain the growth of organisms and populations of organisms.
- Research projects constructed by elementary school students reveal understanding of experimental controls and extraneous variables even at the first grade level.

- NSF has actively supported research in Digital Libraries since 1994. The research has made major strides in developing techniques to advance digital technologies for searching, indexing and storing objects beyond traditional text. For example:
  - The e-skeletons project enables students to study comparative anatomy of humans and baboons (gorillas are coming soon!). With low cost 3-D printing equipment schools can supplement high resolution images with 3-D copies of bones that otherwise would be unavailable for most schools and colleges. (See http://www.eskeletons.org)
  - Digital library research in the humanities for the Perseus Digital Library extends access to a wide range of unique museum materials to students and scholars. A timely presentation on the Greek Olympics showed vases and also referenced text material.

- School children, with the help of staff at the University of Colorado, are able to sample current and fossil remains of a particular gastropod throughout its historical range. They do this in order to explain outstanding problems in predator/prey relationships through geologic history.

- Several hundred volunteer observers, ranging in age from 6 to 80, have been trained to make rain and hail observations across the state of Colorado. Rain and hail patterns are mapped daily, disseminated to students, businesses, government and scientists, and used by the National Weather Service, the local mosquito control program, and community water conservation programs.

- The Lawrence Hall of Science has developed Student Radon Research Kits, that contain all of the equipment necessary for secondary school students to conduct radon and meteorological research at school sites.

- UCLA geoscientists have developed "Geoscience Interactive Simulations for Teaching (GIST)," student-controlled numerical simulations of Sun-Earth interactions.

- The IRIS Consortium has developed a museum display and educational materials that bring research quality seismograph data to the public to help understand earthquakes and the role they play in shaping our dynamic Earth.

- **THE *WORLDWATCHER* CURRICULUM: INTEGRATING VISUALIZATION INTO INQUIRY-BASED SCIENCE LEARNING** explores use of cutting-edge scientific visualization as a teaching tool in middle school and high school classrooms. This effort has received an A+ by *Education World*. The *WorldWatcher* website includes revolutionary and downloadable scientific visualization environment software. Students engage in inquiry-based learning, exploring, creating, and analyzing scientific data.

- **THE ALTERNATIVES FOR REBUILDING CURRICULA** (ARC) is a center promoting awareness and effective use of the elementary mathematics curricula: *Math Trailblazers*, *Investigations in Number, Data, and Space*, and *Everyday Mathematics*. The release of these curricula is relatively recent, but they are making determined inroads to the market. In 1998, these NSF-supported programs were used in about 3% of the nation's school districts; adoptions and large pilot tests have nearly doubled each year. Currently, the curricula are being used by almost 2,600,000 students in about 11% of the 14,000 school systems in the country.