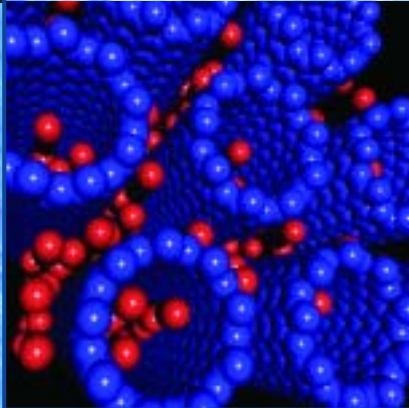


# SCIENCE

FOR THE 21<sup>st</sup> CENTURY

JULY 2004



## **ABOUT THE NATIONAL SCIENCE AND TECHNOLOGY COUNCIL**

The National Science and Technology Council (NSTC) was established by Executive Order on November 23, 1993. This Cabinet-level Council is the principal means by which the President coordinates science and technology policies across the Federal Government. The NSTC acts as a virtual agency for science and technology to coordinate diverse parts of the Federal research and development enterprise.

An important objective of the NSTC is the establishment of clear national goals for Federal science and technology investments in areas ranging from information technologies and health research to improving transportation systems and strengthening fundamental research. The Council prepares research and development strategies that are coordinated across the Federal agencies to form a comprehensive investment package aimed at accomplishing multiple national goals.

To obtain additional information about the NSTC, contact the NSTC Executive Secretariat at (202) 456-6101

### **About This Document**

This document was produced under the direction of the National Science and Technology Council's Committee on Science. The document details, from a Federal agency perspective, the science policies and accomplishments of the current Administration and illustrates how today's science sets the stage for benefits to the economy and national quality of life far into the future.

The document is available electronically at <http://www.ostp.gov/nstc/21stCentury>.

This website also provides links to

- supplemental information about the examples provided in the text
- additional examples of agencies addressing the four major responsibilities of the Federal science enterprise





**S C I E N C E**

**F O R T H E 2 1 <sup>s</sup> t C E N T U R Y**

EXECUTIVE OFFICE OF THE PRESIDENT  
NATIONAL SCIENCE AND TECHNOLOGY COUNCIL  
WASHINGTON, D.C. 20502

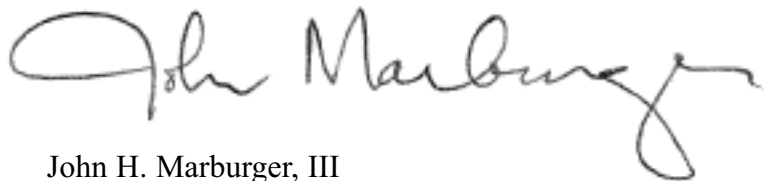
July 2004

Dear Colleague:

The Federal government plays a key role in supporting the country's science infrastructure, a national treasure, and scientific research, an investment in our future. Scientific discoveries transform the way we think about our universe and ourselves, from the vastness of space to molecular-level biology. In innovations such as drugs derived through biotechnology and new communications technologies we see constant evidence of the power of science to improve lives and address national challenges. We had not yet learned to fly at the dawn of the 20<sup>th</sup> century, and could not have imagined the amazing 20<sup>th</sup> century inventions that we now take for granted. As we move into the 21<sup>st</sup> century, we eagerly anticipate new insights, discoveries, and technologies that will inspire and enrich us for many decades to come.

This report presents the critical responsibilities of our Federal science enterprise and the actions taken by the Federal research agencies, through the National Science and Technology Council, to align our programs with scientific opportunity and with national needs. The many examples show how our science enterprise has responded to the President's priorities for homeland and national security, economic growth, health research, and the environment. In addition, we show how the science agencies work together to set priorities; coordinate related research programs; leverage investments to promote discovery, translate science into national benefits, and sustain the national research enterprise; and promote excellence in math and science education and work force development.

Sincerely,

A handwritten signature in black ink that reads "John Marburger, III". The signature is fluid and cursive, with a large loop at the end of the last name.

John H. Marburger, III  
Director, Office of Science and Technology Policy  
Science Advisor to the President

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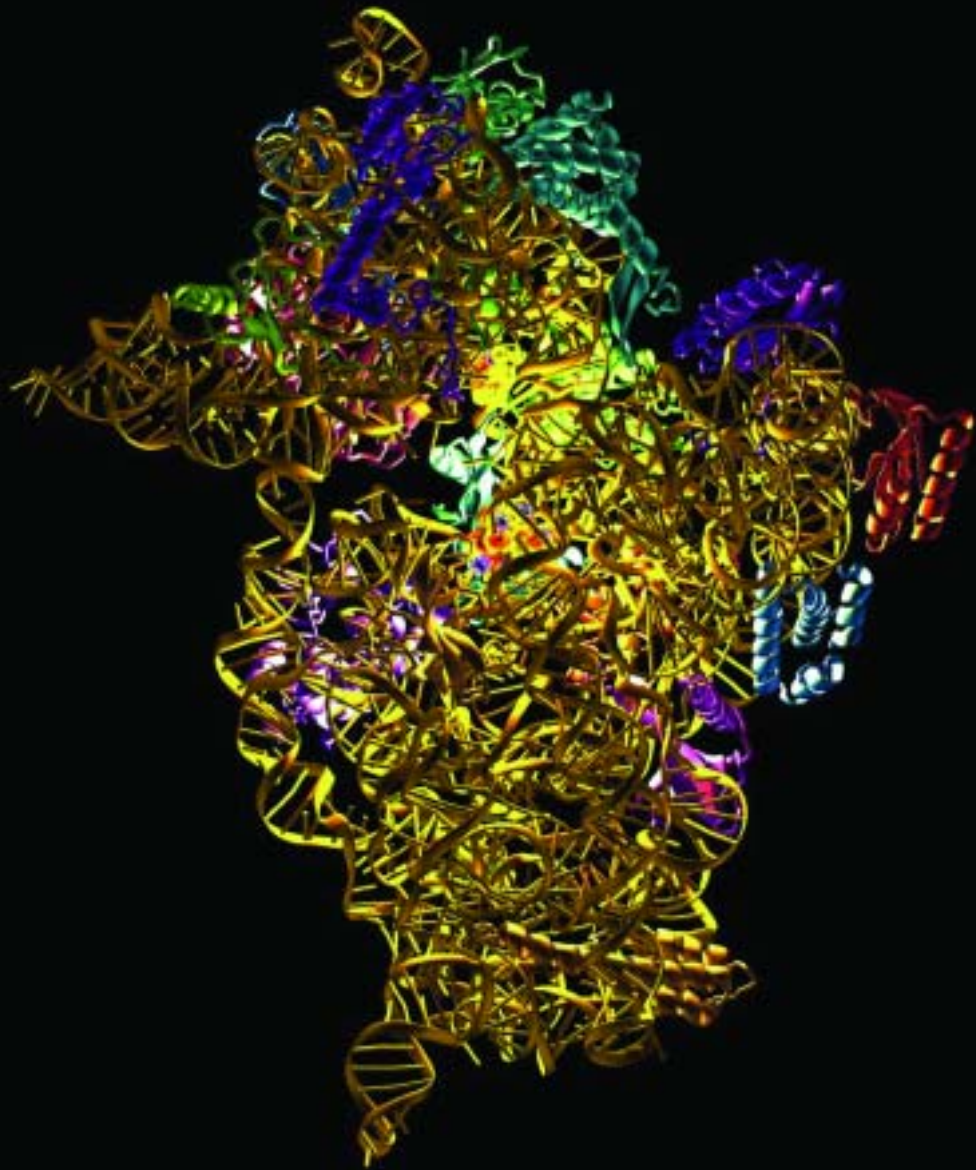
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**SCIENCE IN SOCIETY**



Through science we generate new knowledge and discovery, become inspired as we coax nature to reveal her myriad secrets, and expand our understanding of the physical and living world. A strong scientific enterprise produces new tools for analysis and investigation and increases our capacity to question, learn, and build on previous accomplishments. Science points us toward innovative solutions to today's major challenges, provides the foundation for economic growth and development, and enhances our quality of life.

This model of the small "30S" subunit of the ribosome molecule, nature's protein factory, is based on data gathered at Argonne National Laboratory's Advanced Photon Source.

Since the founding of our nation, leaders across the political spectrum have recognized the importance of science and technology to our future prosperity. This responsibility was argued more than 50 years ago by Vannevar Bush in his famous report, *Science: The Endless Frontier*, establishing a policy that is as relevant now as then. Today, as we embark upon the 21st century, dynamic forces drive the scientific enterprise. We must carefully analyze our research investments and engage in collective priority setting as we respond to the requirements of a new age.

### Enabling the US Research and Development Enterprise

Across the varied institutions that make up the US science enterprise—academe, Federal research agencies and government laboratories, non-profit institutions, professional and advisory organizations (e.g., the National Academies), and industry—and with the international community, a high degree of collaboration has evolved over time in shaping directions of scientific progress. The Federal investment in research and

development (R&D), although only about 28% of our national investment (see Figure 1), plays a crucial role in maintaining our nation's preeminence in science. The Federal Government supports

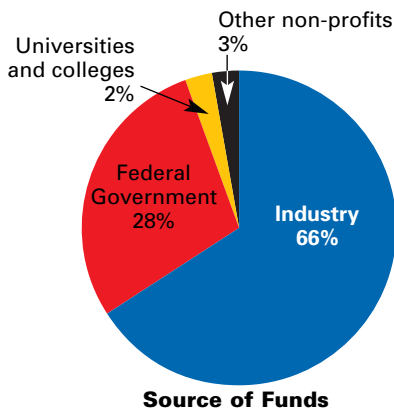
- The majority of funding for fundamental research that may have no immediate application;
- Research that requires sustained levels of long-term investment;
- Major research facilities that are beyond the capacity of private industry to build or sustain;
- An infrastructure of measurements and standards that pervade the nation's science and technology base and that are essential to the progress of science and innovation;
- Applied research and development for national priorities combined with partnership efforts that accelerate the transition of Federal research results into practical applications; and
- Programs for ensuring excellence in our national science and technology (S&T) education and workforce development.

These Federal investments provide the foundation for tomorrow’s great discoveries and inventions and facilitate the timely realization of benefits from our investments.

### Responding to New Opportunities

The increasingly interdisciplinary nature of science is driving many changes. Some disciplines are becoming irrevocably intertwined, as in particle physics and astronomy, where the discovery of dark energy in 1998 radically altered our view of the universe. Progress in one field of science makes possible progress in seemingly disparate fields, and increasingly the most exciting research problems involve multidisciplinary collaborations, require the use of large-scale research facilities, and use advanced information technology. The explosive growth of computing capabilities and the development of advanced instrumentation have spawned a revolution that is transforming all science.

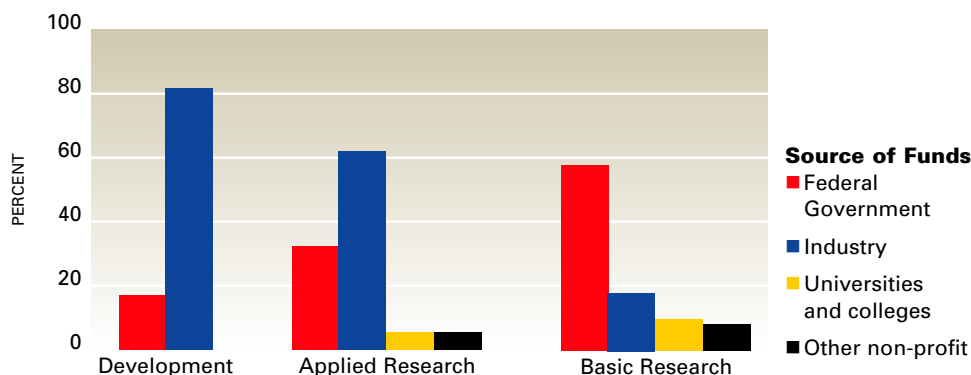
**Figure 1. National R&D expenditure by source of funds and character of the work for FY 2001.**



Ultra-high-resolution imaging, sensor-network technology, and increasing supercomputing simulation power are allowing the creation of data sets that can be fully exploited only through broad access by a diverse scientific community—a development that allows new types of research investigations, more speedily conducted, in a highly cost-effective framework. Recent Nobel Prize selections highlight this trend of increasing scale in scientific research and in bridging the traditional scientific disciplines. One of the recipients of the 2003 prize for physiology or medicine was a chemist who entitled his Nobel lecture “All Science Is Interdisciplinary.” The 2003 prize for chemistry was given for the discovery of ion channels in cells, incorporating both new discoveries in biology and the large-scale instrumentation normally associated with the field of physics.

Given the increasing scale and interdisciplinary nature of today’s investigations, a healthy scientific enterprise depends on the vigorous pursuit of progress across the full spectrum of inquiry and the proper

balance of funding among scientific disciplines. Many arguments have been put forward for increased support in the physical sciences, in part because the benefits of investments in the physical sciences extend well beyond new disciplinary knowledge and address needs across science for more computing power, scientific instrumentation, and other tools that enable investigation and experimentation (e.g., advances in robotics, which could transform some types of medical research and clinical applications). Others argue for increased support of social sciences research, including potential for applications directed toward homeland and national security and understanding the ethical and social implications of research to develop new technologies. These arguments, and competing ideas for what constitutes the proper mix of ingredients in a robust scientific enterprise, must be evaluated and translated into priorities for a finite Federal R&D budget. It requires a variety of mechanisms, both within the Government and across the broad scientific community, to develop these priorities.



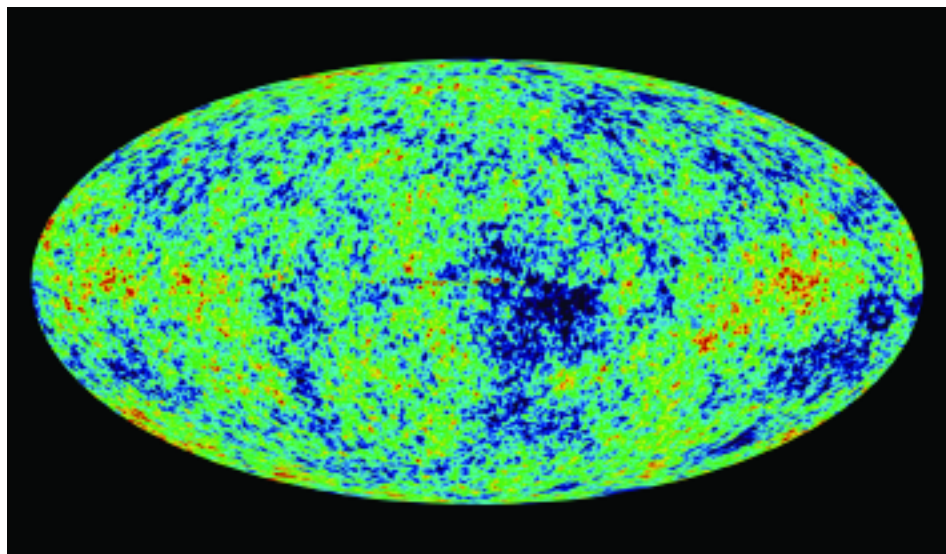


## Ensuring Excellence in Education and the Workforce

The Federal Government also takes responsibility for ensuring excellence in our national science and technology education and workforce development. Our ability to produce the trained scientists, post-doctoral researchers, and graduate students who work on investigator-initiated research proposals that are analyzed through a rigorous peer-review process maintains US scientific preeminence. Fostering a highly skilled US S&T workforce supports this research and helps in the translation of scientific discoveries into practical applications, societal benefits, and relevant policies. Promoting a scientifically educated and aware public is necessary if we are to make the appropriate decisions about the nation's R&D investments, guide the adoption and debate the societal implications of new science and technologies, and reap the maximum benefits from our investments. The quality of these efforts underpins the entire US scientific enterprise.

## Delivering Accountability

It is also the responsibility of the Federal Government to ensure that the people's investments in Federally sponsored research are well managed and wisely used, which is the focus of the President's Management Agenda. The American people, in the words of President Bush, deserve a government that is "not just making promises, but making good on promises." To this end, the Federal agencies, through entities such as the National Science



NASA / WILKINSON MICROWAVE ANISOTROPY PROBE SCIENCE TEAM

## Discovery of dark energy driving physics and astronomy research

In 1998, scientists discovered that the universe is expanding at an accelerating rate, meaning that some previously unknown energy source is counteracting the force of gravity. Called "dark energy," this repulsive force is literally tearing the universe apart. In February 2003, dark energy was shown to be the dominant force in our universe when the Wilkinson Microwave Anisotropy Probe (WMAP) released the best "baby picture" of the universe ever taken. It shows that the first generation of stars in the universe ignited only 200 million years after the Big Bang, much earlier than scientists had expected. The new portrait also precisely pegs the age of the universe at 13.7 billion years old and determines the content of the

## Full sky map of the oldest light in the universe.

universe to be 4% ordinary matter, 23% "dark matter," and a remarkable 73% "dark energy."

These discoveries are shaping research in the very small arena of particle physics as well as the vast universe of astronomy, and are also reshaping the scientific community's research agenda and research investment strategy. Recently, the nation's leading physicists and astronomers proposed 11 compelling science questions for the new century in the National Research Council's report, *Connecting Quarks with the Cosmos*. The NSTC report, *Physics of the Universe*, provides an interagency blueprint for future Federal investments based on these questions. ■

and Technology Council (NSTC), regularly review and revise program management and evaluation practices, priority-setting processes, and partnership mechanisms with the scientific community to ensure the maximum return on the people's investment.

## Science in This Administration

This Administration has, as a first priority, responded to the urgent need to combat terrorism and safeguard homeland and national security. Second, together with security we must ensure continued economic growth, both in the short term and in setting the stage for innovations and technologies that will ensure our

## Who are the Government's scientists?

Federal science funding supports hundreds of thousands of researchers in the private sector, particularly at universities (the Government provides the majority of all funding for academic R&D). The funding also supports, behind the many agency acronyms, a small cadre of Federal scientists, engineers, and other highly skilled research staff. According to an NSF survey of the nation's PhD workforce, the slightly more than 38,000 Federal workers (in 2001) who held PhDs in science and engineering represent only about 7% of the total US doctoral scientists and engineers, but they perform critical roles. They and other Government scientists conduct their own research, often in areas that are inherently governmental in nature; collaborate with colleagues in academia and industry; and contribute their expertise to the management of Federal science and technology programs and the development of national science policy.



COURTESY OF L.G. UNGERLEIDER, NIH



COURTESY OF E. CORNELL, NIST



COURTESY OF J.M. SHEPHERD, NASA GSFC

**Left: Leslie G. Ungerleider, Chief, Laboratory of Brain and Cognition, National Institute of Mental Health. Member, National Academy of Sciences. Center: NIST physicist Eric A. Cornell, winner of the 2001 Nobel Prize in Physics. Right: J. Marshall Shepherd, NASA, winner of a 2002 Presidential Early Career Award for Scientists and Engineers.**

Early career researchers reenergize the Federal workforce as they grow into satisfying careers, applying their skills to a variety of agency programs and projects. Nearly 20% of the Government's doctoral scientists and engineers are recent (within five years) degree recipients. Others bring established expertise to Federal service after many years in academia or industry. At all career levels, scientists working for the Federal Government make important contributions, and many have achieved wide recognition. They

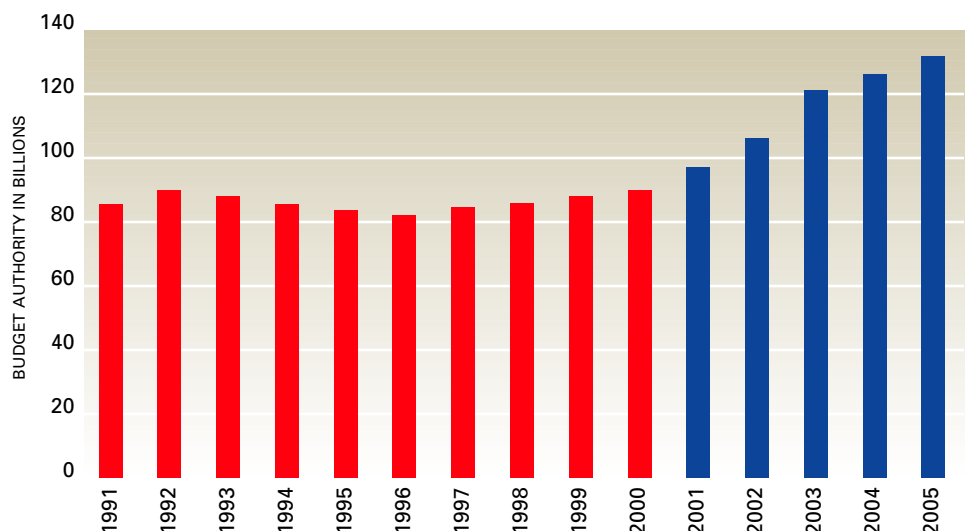
serve as editors of scientific and professional journals, lead major scientific societies, and some have won notable awards, including Nobel Prizes. The Government's scientists are active in the larger science community and often move between Federal service and employment in academia and industry. An expert, engaged, and mobile Federal science and engineering workforce helps improve science planning, inform policy, and strengthen the collaborative nature of the nation's research enterprise. ■

nation's future growth and prosperity. We must also take steps to maintain and increase the quality of American life—sufficient, affordable health care; affordable and abundant supplies of energy; and a healthy environment now and into the future.

Solutions to these and other challenges will depend on scientific discoveries and new technologies just as surely as the development of today's remarkable medical diagnostic tests or the information technology revolution depended on the fundamental breakthroughs in biology, physics, and mathematics that

preceded them. Funding for R&D has increased steadily in this Administration (Figure 2). To sustain the needed science and technology, the

President's 2005 budget request commits 16% of total discretionary budget authority to R&D. Funding requested for R&D in 2005 is the



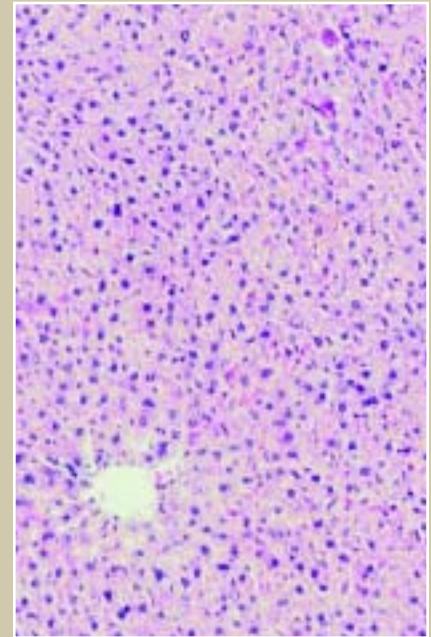
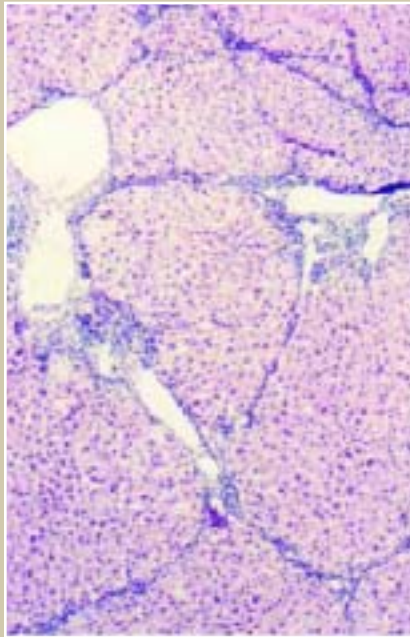
**Figure 2. Federal R&D spending, 1991–2005 (constant 2005 dollars).**

highest level ever, and among the highest in recent decades when measured as a share of discretionary funding or gross domestic product. In President Bush's words, "Science and technology have never been more essential to the defense of the nation and the health of the economy."

### Setting Priorities

The President has outlined broad policies that apply across the board to the conduct of Federal research and development and the making of investment decisions. The Office of Science and Technology Policy (OSTP) and Office of Management and Budget (OMB) provide an annual memorandum on research and development priorities in the Federal budget that gives early guidance to the research agencies in developing responsive agency and interagency research initiatives.

The memorandum directs that the conduct of Federally funded research be optimized through interagency coordination of related programs. This memorandum also outlines the Administration's performance assessment and review policies for R&D programs. Programs must be relevant; they must set clear goals that are germane to agency missions, national priorities, and stakeholder requirements. They must be of high quality, as determined by the appropriate use of outside expert assessment, peer review, merit-based competitions, and the preservation and development of unique capabilities and infrastructure. They must demonstrate a record of performance, as evidenced by strategic planning, an outline of appropriate



**Interference:** Mice with hepatitis given a placebo suffered serious liver scarring (left, lines) from inflammation, whereas the livers of those receiving targeted RNAi were protected.

### RNAi: Discovery of ubiquitous cellular system leads to powerful research tool

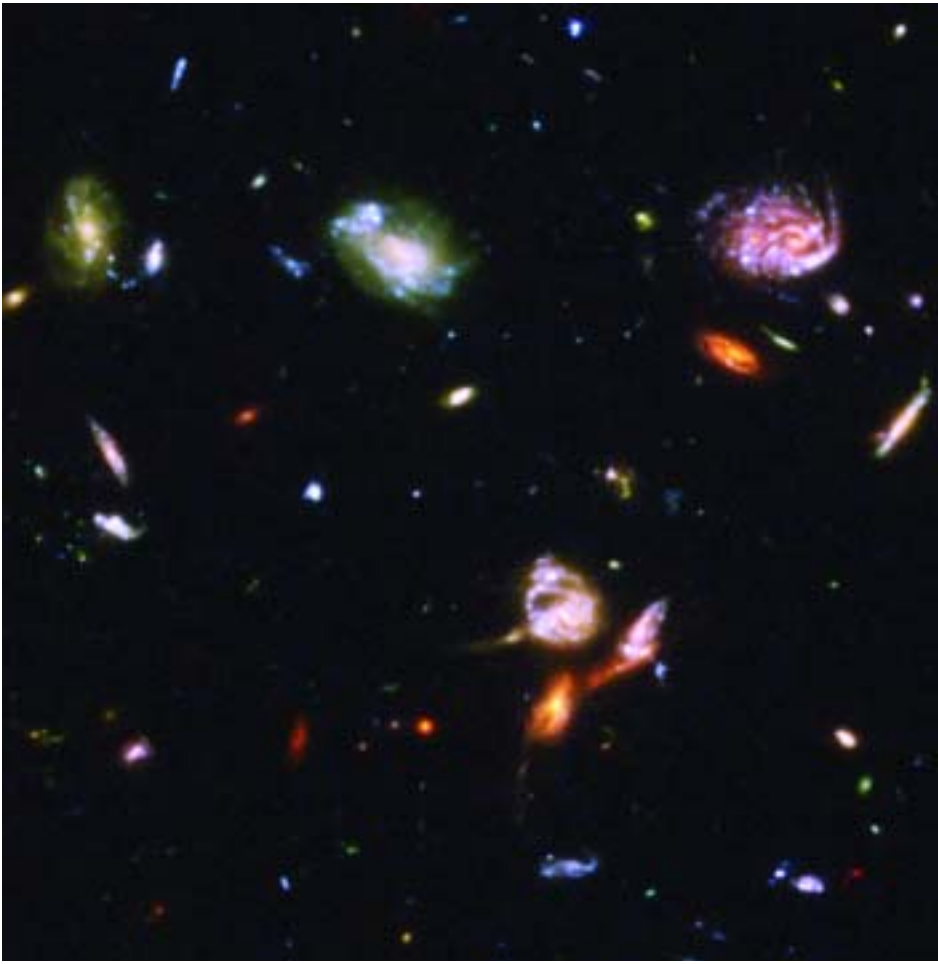
It is not every day scientists uncover one of nature's deepest secrets. The discovery of a simple way to turn off genes—gene silencing by RNA interference (RNAi)—is this kind of breakthrough. RNAi has been found in plants, animals, and man. Researchers believe that RNAi's natural role is to modulate the activity of genes, reducing their expression for purposes of growth and/or self-defense. Viruses, for example, direct the cells they infect to produce specialized RNAs that help the virus survive. Researchers believe that RNAi is an ancient mechanism used to wipe away such unwanted, extra RNA.

RNAi was discovered after a simple experiment produced results completely opposite to what was expected. Scientists studying the genetics of plant growth were

attempting to deliver an extra "purple" gene to petunias, but the flowers bloomed stark white. How could adding genetic material somehow silence an inherited trait? The mystery remained until researchers funded by NIH and NSF identified a similar process in diverse organisms and discovered RNAi, which operates like a molecular "mute button" to quiet individual genes. Further investigations found that the RNAi technique could be applied nearly universally to manipulate gene activity.

Researchers believe that RNAi holds promise for new medical therapies. Scientists have crafted clever tools for getting living cells to produce specific forms of RNAi, enhancing researchers' ability to explore RNAi's medical promise in research animals and with human cells. For example, in recent lab tests with isolated human cells, researchers have succeeded in using RNAi to kill HIV, the virus that causes AIDS. ■





**Three galaxies collide (lower right) in the early universe: from Hubble's ultra-deep field photo.**

measures to achieve priorities and goals, and use of insightful metrics that demonstrate results.

As we enter the 21st century, the Federal agencies are using interagency collaboration and joint priority-setting more than ever to outline cohesive strategies that maximize the return on the Federal research investment, including strategies for forming effective private-sector partnerships and international collaborations. Working through the NSTC and other interagency mechanisms, we have identified four broad responsibilities for the Federal science enterprise that will guide us in sustaining the global pre-eminence of the US science enterprise, foster critical national and international partnerships, and focus activities on areas of critical national interest. The agencies have produced

immediate results that respond to the President's challenges and have laid a strong foundation for the realization of multiple, long-term benefits from today's Federal science investments.

### **Responsibilities of the Federal Science Enterprise**

Broad investments in basic research, sometimes called discovery science, result in new knowledge and spur invention and innovation in ways that are sure but unpredictable. We don't know what the next fundamental discovery will be, or where and when it will lead to new economic growth or benefits for our quality of life. Yet, we know enough of history to see that it is America's investment in research and development, and the innovation that results, that underlie our national prosperity. Activities emanating from

Federal R&D investments that produce new economic growth have never been higher. Of the increasing numbers of patents issued each year, 40% cite Federal research as their source.

The Federal research enterprise is agile, able to direct great expertise and inventiveness to the challenges of the day. Directing funding to specific priorities such as homeland security, energy technology, environmental quality, or research on specific health challenges enables us to increase the rate of progress in those sectors and will spur the development of new knowledge products and technologies. Perhaps the greatest recent example of mobilizing the Federal scientific enterprise on a national challenge occurred after September 11, 2001, when the research agencies quickly began to work together on measures for enhancing national and global security while minimizing the impact on our daily lives and accustomed freedoms.

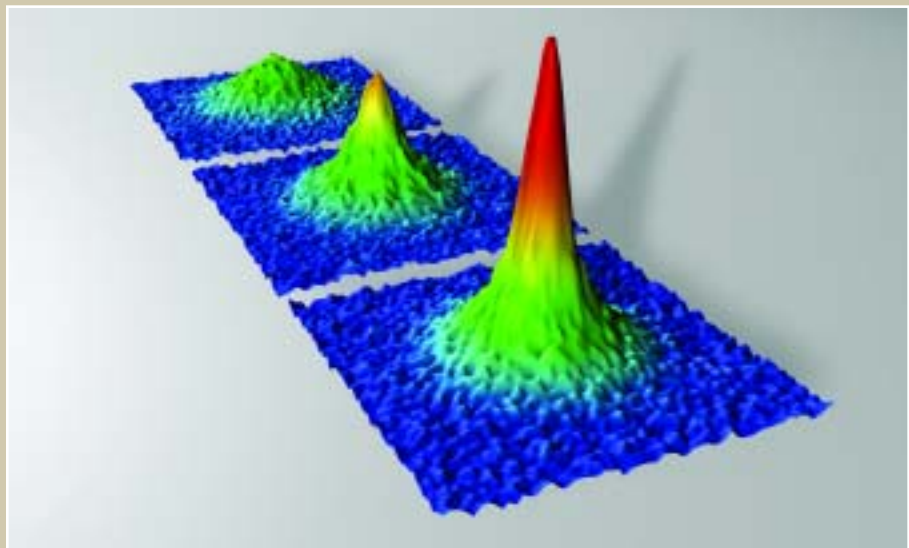
### **Four Major Responsibilities**

Federal agencies, through the auspices of the NSTC and other coordinating mechanisms, work together to develop priorities for the Federal science budget; to coordinate cross-agency programs that address broad national priorities; to simplify science management practices; and to make sure that our activities bring to students and the general public the excitement of discovery and help them prepare to be productive in a rapidly changing world.

## A Quantum Leap for Quantum Physics

It's been an amazing decade for accomplishing things in science once thought to be impossible. In 1995, a team of physicists created a superatom—a set of 2000 rubidium atoms all doing exactly the same thing at exactly the same time. They had produced a new form of matter called a Bose-Einstein condensate, a “Holy Grail” that physicists had been pursuing for more than 70 years. The accomplishment earned Eric Cornell of the National Institute of Standards and Technology (NIST) and Carl Wieman of the University of Colorado, Boulder a Nobel Prize in Physics in 2001. It also helped set off a renaissance of research in all things quantum, the study of the unusual, often downright strange, behavior of the smallest particles of matter.

Two years later, in December 2003, another NIST/CU Boulder team, this one led by NIST physicist Deborah Jin, created yet another, new form of matter, a fermion condensate. To a physicist even the term “Fermion condensate” sounds like an oxymoron. The bosons in Bose-Einstein condensates are inherently gregarious; they



DOC: NIST

**False color images of a condensate formed from pairs of fermion potassium atoms. Higher areas indicate a greater density of atoms.**

would rather adopt their neighbor's motion than go it alone. But fermions, the other half of the particle family tree and the basic building blocks of all matter, are inherently loners. No fermion can be in exactly the same quantum state as another fermion. To get around this problem, the Jin team used ultra-cold temperatures and finely tuned magnetic fields to match up the fermion atoms into pairs. A similar phenomenon appears to be happening in

superconductors, in which pairs of electrons (also fermions) flow without any resistance. Physicists hope that further research with such fermion condensates eventually may lead to ways to produce superconductivity in room-temperature materials, a development that would dramatically improve energy efficiency across a broad range of applications. ■

These activities support the execution of four major responsibilities of the Federal science enterprise

1. Promote discovery and sustain the excellence of the Nation's scientific research enterprise.
2. Respond to the Nation's challenges with timely, innovative approaches.
3. Invest in and accelerate the transformation of science into national benefits.

4. Achieve excellence in science and technology education and in workforce development.

Each of these responsibilities, and the related science policies that flow from them, are addressed in this report with examples that illustrate how the stage is being set for benefits that will continue long into the future.

**PROMOTE DISCOVERY**  
and Sustain the Excellence of the Nation's  
Scientific Research Enterprise





Many secrets of nature are revealed through “accidents” of science that require prepared minds, the right tools, and a view that extends beyond the horizon. A long-term strategy will seek discoveries and new knowledge from both expected and unexpected sources and will have the flexibility to follow new paths as they emerge. The serendipitous nature of many scientific discoveries and the increasingly interdisciplinary character of science raise the importance of the breadth of scientific excellence. Discovery today in one discipline can lead to major progress in another area tomorrow. Anticipated long-term breakthroughs in life and medical sciences also rely on strengthening the physical sciences, mathematics, and engineering.

**Basic laboratory science remains essential for promoting discovery. Here a researcher demonstrates stimuli sensitive polymers that remain in a liquid form when dissolved in water, but form a solid gel under various stimuli.**

### **Policies**

Some basic policies guide the agencies’ programs of discovery science

- Sustaining the nation’s preeminence in fundamental scientific research is a major Federal responsibility;
- The programs in the basic discovery sciences are shaped by the needs and advice of the scientific community; and
- The results of Federally supported basic research should be readily accessible to all.

### **Strengthening Coordination**

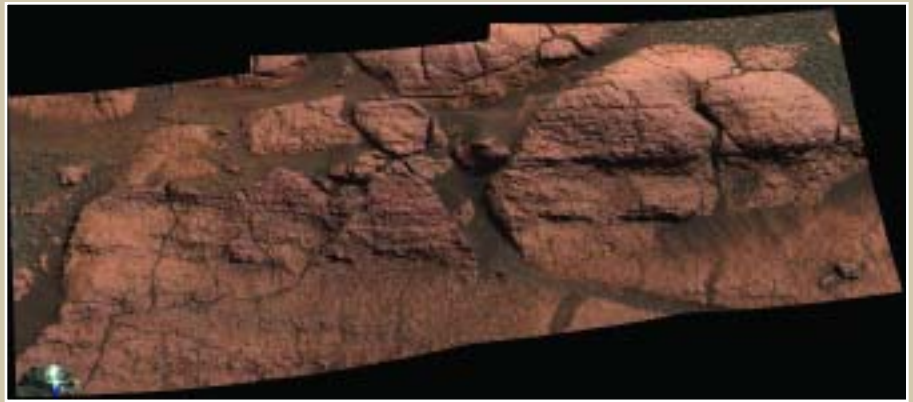
The Federal research agencies coordinate the ongoing evaluation of opportunities and identify collective priorities both in the fundamental scientific disciplines and increasingly at the intersections of disciplines in the life sciences, physical sciences, social and behavioral sciences, mathematics, and engineering. Various interagency mechanisms, such as the NSTC, exist to enhance the communi-

cation between interrelated discipline communities and encourage the cross-fertilization of ideas. This improves strategic planning, development and implementation of complementary programs, and creation of integrated program management mechanisms. A few examples illustrate agency and interagency priority setting and coordination

- The role of the social and behavioral sciences in the Federal research portfolio is becoming increasingly important in a rapidly changing world. Several agencies coordinate programs in this area, including the National Science Foundation (NSF), National Institutes of Health (NIH), Department of Defense (DOD), Department of Homeland Security (DHS), National Institute of Justice (NIJ), National Aeronautics and Space Administration (NASA), and National Oceanic and Atmospheric Administration (NOAA). The agencies address a wide variety of topics such as health behaviors (behavioral and social factors are linked

## A new vision for space exploration

President Bush has announced a new vision for the nation's space exploration program. The President committed the United States to a long-term human and robotic program to explore the solar system, starting with a return to the Moon that will ultimately enable future exploration of Mars and other destinations. Preparing the way for space exploration later in this century, scientists are examining what NASA's Mars rovers, Spirit and Opportunity, are showing them about Mars rocks and are seeing into the planet's past. What they are seeing indicates that water once flowed there. The outcrop next to where Opportunity landed, dubbed "El Capitan," holds evidence that the rocks have spent time drenched in liquid water. Clues from the rocks' appear-



**This mosaic of images taken by Opportunity's panoramic camera shows the rock region dubbed "El Capitan."**

ance and composition support the conclusion that the rocks were altered by exposure to liquid water after they were formed. However, the clues don't tell how long the wet conditions lasted, and they are only tantalizing, not conclusive, about whether the environment was watery when the rocks formed. NASA's scientists will continue to examine evidence from the rovers to pursue other possible evidence about

the rocks' water history. This information will help scientists evaluate the possibility that Mars once had an environment wet enough to be hospitable to life and determine the directions for future Mars missions. ■

to half of all causes of disease and death in the United States), maximizing performance of border guards and airport personnel, and evaluating the societal impacts of emerging technologies (e.g., genomics, nanotechnology, reproductive technologies). Recent breakthroughs have occurred in the analysis of the stability of social institutions in response to terrorism and other disasters and in the linguistic and text analysis of large arrays of information. To facilitate coordination across Federal agencies, the NSTC Subcommittee on Social, Behavioral, and Economic Sciences was established in 2003.

- The NSTC Subcommittee on Water Availability and Quality has been formed to address science and technology issues relevant to the US and global water supply. The subcommittee brings together expertise across multiple agencies and is coordinating with the National Academies and the international

research community (through the Department of State) on research directions and recommendations to address the important issues of water availability and quality, especially in relationship to land use.

- Systematics is a discipline that supports a wide range of scientific research through the development of taxonomies that organize the relationships between plants and animals as well as through the preservation of unique collections of species from around the world. In addition to providing the raw material for biological research, systematics contributes to the understanding of biodiversity and invasive species essential to solving problems in sustainable and conventional agriculture. Several Federal agencies collaborate in supporting systematics, including the Department of Agriculture (USDA), which recently developed a strategic plan for future investments to enhance access to its research and

collections, and NOAA, which contributes expertise in aquatic species as well as in information technologies. These investments will be used to build electronic databases and fund the preservation of existing collections.

### Optimizing Performance

The increasingly interdisciplinary nature of science, the growing scale of required research infrastructure investments, and the international nature of modern science call for new management structures and a global commitment to scientific progress. As

**President Bush announces the new space vision on January 14, 2004.**

WHITE HOUSE PHOTO BY ERIC DRAPER



opportunities become more complex, science management and collaboration across institutions must be improved to better align funding and capabilities with opportunities. Several ongoing initiatives illustrate this process

- The NSTC Subcommittee on Research Business Models was formed to identify and recommend improvements to the Federal research process for all stakeholders. The subcommittee sponsored a series of four stakeholder workshops to identify issues and listen to concerns. It identified a list of 10 issues to address in the short term and will continue discussions with the community on other issues to be addressed at a later date. Some of the short-term issues include stability and predictability of support for facilities and instrumentation, standard progress and financial reporting procedures across agencies, and consistent Federal Government-wide rules for conflict of interest.
- The President’s Management Agenda calls for a process of continuous improvement in the effectiveness of Government R&D spending and holds agencies and departments accountable by tracking management practices against five broad initiatives. The National Science Foundation was the first agency to meet all standards and be given a “green for success” for any one initiative (according to the traffic light analogy used by the agency scorecard). For the December 2003 performance data, NSF and NASA were the only two agencies that

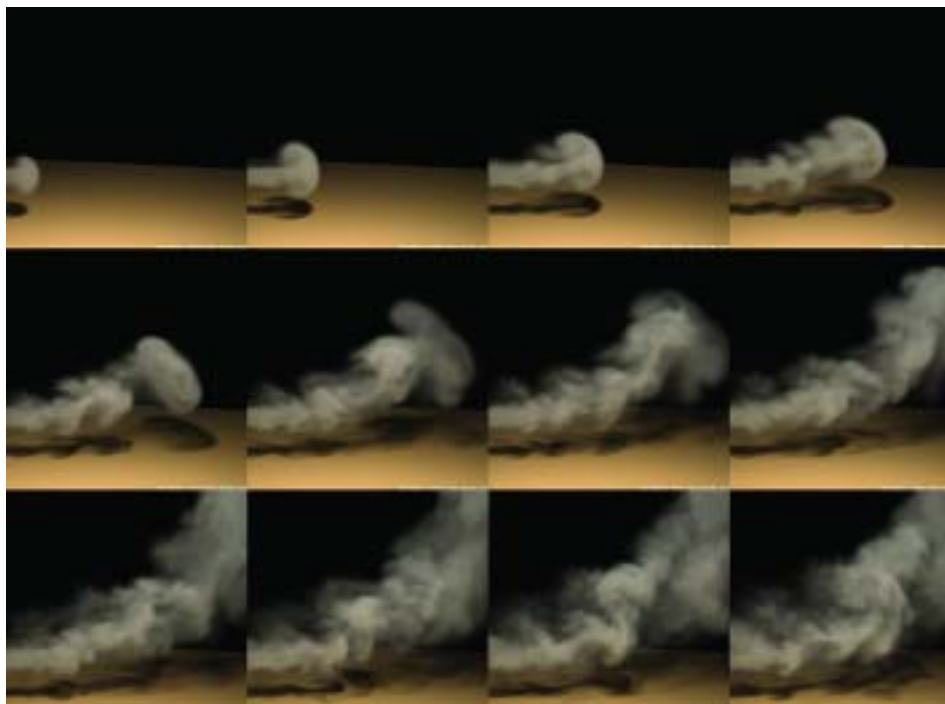
achieved as many as two out of a possible five green scores.

- Characteristic of several agency initiatives to improve long-term effectiveness, the Department of Energy (DOE) has established its top 20 large-scale scientific investments for the future. The result of broad consultation with the science community, the report *Facilities for the Future of Science: A Twenty-Year Outlook* lays out the rationale for the high-priority investments

needed for future discoveries in the agency’s top-priority research areas.

### Broad Collaboration

Federal science planning must also recognize the importance of new ways of working with the national and international research communities as we increasingly take on projects that involve multiple research institutions, other governments, and multinational research organizations as partners. Such research collaborations can



COURTESY OF RON FEDKIW AND HENRIK JENSEN, STANFORD UNIVERSITY

### Mathematics animating science discoveries

Mathematics is a powerful tool of insight and a unifying force across science and engineering. The importance of mathematics to scientific discovery continues to grow with the increased complexity of much interdisciplinary research and the need to work with very large data sets. Sophisticated mathematical models and computational algorithms provide the link from measurable quantities to the phenomena we want to study. Advances in fundamental mathematics played a crucial role in generating

**Smoke animated using an algorithm based on the computational fluid dynamics technique of “vorticity confinement.”**

and assembling the fragments of the human genome. New computational algorithms also lie behind many of today’s dramatic animation sequences that appear on movie screens and in video games. Federal support for basic mathematics is provided by NSF. Other agencies including the Office of Naval Research and DOE provide funding for new advances in mathematics related to specific applications. ■





**Game theory: The fruits of economic research are everywhere.**

### From basic science to auction markets to public policy

In the 1950s, the business world thought game theory, the study of individuals' behavior in situations where their behavior affects others, was arcane theory with little practical potential. NSF thought differently and has invested in decision sciences for several decades. Now, this collaboration between game theorists and economists has evolved to produce new, practical insights into how businesses compete in markets, including behavior in high-stakes auctions. These findings have been applied to energy, telecommunications, pollution control policy, and agricultural land conservation. The design of an auction mechanism contributed to the success of EPA auctions and emissions trading to control sulfur dioxide emissions and reduce acid rain. The cost savings to emissions trading have been estimated to be one third compared with reasonable alternative approaches for the same reduction in sulfur dioxide. Research continues to make auction markets more efficient by tackling problems such as sale of multiple items and collusion by bidders. ■

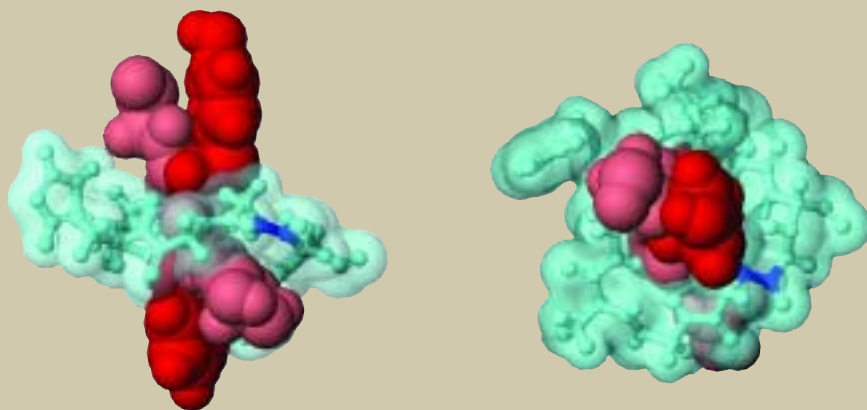
provide global benefits. Some examples of international coordination and globally beneficial projects follow

- The Rice Genome Sequencing Project involves 10 countries and both private- and public-sector partners. The NSTC Interagency Working Group on Plant Genomes has played a strong coordinating role in developing the research priorities and pursuing innovative cross-boundary collaborations. Knowledge of the rice genome not only adds to understanding of genetic patterns across species and provides benefits to US and international rice producers but can strengthen food security across the globe (rice is the staple food of half the human population).
- The Intergovernmental Group on Earth Observations involves 47 nations plus the European Commission and 29 international organizations. This group, which is co-chaired by the United States, the European Commission, Japan, and South Africa, was established following a July 2003 Summit on Earth Observations that was

sponsored by the US Departments of Commerce, Energy, and State. During the summit, a declaration was adopted that calls for intergovernmental cooperation in moving forward on global systems of Earth observation and for the development of a 10-year implementation plan. The Earth observations plan will address the research and policy communities' requirements for land, atmospheric, and ocean observations, including a number that are detailed in the recent report of the President's Commission on Ocean Policy, whose study is the first comprehensive look at the state of our oceans in 30 years.

### Impact

These investments illustrate the Federal research agencies' commitment to a broad program of fundamental science that is integrated across the agencies, exploits the appropriate national and international partnerships, and is based on the best advice from the larger scientific community. They are the result of long-term planning and far-sighted vision, as well as a commitment to supporting the appropriate instrumentation and research infrastructure that make discoveries possible, and to the best possible management of finite resources. By taking advantage of the emerging opportunities in interdisciplinary science, as well as fully exploiting recent breakthroughs in information infrastructure and instrumentation, the agencies are setting the stage for long-term advances across the full spectrum of opportunities.



### Structure of the antibacterial peptide, microcin J25.

organisms. Data from the PSI centers are deposited into the publicly accessible Protein Data Bank, the single worldwide repository for data on biomolecular structure, funded by NIH, NSF, and DOE and managed by a consortium including NIST, the University of California at San Diego, and Rutgers University.

## Advances in genomics and proteomics

Global partnerships in massive genome sequencing projects have facilitated numerous advances in structural genomics. Partners include NIH, DOE, USDA, and NSF; many international groups; and several private-sector companies. With access to completely sequenced genomes, scientists are now better equipped than ever to make breakthroughs in proteomics. A single gene codes for an estimated five to six proteins on average. Because most of the chemistry inside of cells occurs at the protein level, examining the proteins produced from genes is essential to gaining a more complete understanding of disease.

In the Federal, university, and industry collaboration known as the Protein Structure Initiative (PSI), led by the National Institute of General Medical Sciences at NIH, effort is aimed at dramatically enhancing our ability to determine protein structures. The PSI focuses on experimentally determining the structures of thousands of proteins and using computational techniques to obtain structural models of many more proteins based on their chemical sequence. This knowledge may ultimately solve key biomedical problems and help to develop new treatments and prevention techniques for genetic and infectious diseases. An important early result is a schematic map of the most common protein shapes that nature uses to construct the multitude of complex proteins that make up all living

The DOE Genomics: GTL (formerly Genomes to Life) Program uses the new genomic data and high-throughput technologies for studying proteins encoded by the genome to explore the diverse natural capabilities of microbes. The program targets microbes with remarkable capabilities to degrade organic wastes, detoxify heavy metals, produce fuels, and remove carbon dioxide from the atmosphere. Starting with the complete genome sequences for dozens—eventually hundreds—of microbes, the GTL program seeks to characterize all of the proteins that carry out cellular functions, understand how proteins work together in multi-protein complexes to bring microbes to life, and understand how communities of microbes work together. ■

## Decoding the cow genome

Domestic animals play a central role in the food supply as well as in biomedical research. High-quality genome sequences exist for humans, microbes, plants, and other model organisms. Sequencing livestock and poultry genomes will have many benefits such as increased food safety, higher-quality food for lower cost, reduced environmental impact, greater economic competitiveness, and novel products containing additional nutritional and health benefits. The new genome sequences will also contribute to basic research in comparative genomics, adding to our understanding of the diversity of species.

Through consultations with Federal research agencies, the academic research community, and private industry, the cow was identified as the highest priority livestock animal for sequencing (the complete assembly of the chicken genome was announced on March 1, 2004). A coordinated effort played an important role because the bovine genome is similar in size to the human genome and that of other mammals. The International Bovine Genome Sequencing Project brings together a broad set of interests including USDA, NIH, the state of Texas; international partnerships with GenomeCanada, Australia, and New Zealand; and private-sector partners from the US Cattlemen's Beef Board and the Texas and South Dakota Beef Councils.

This collaboration highlights the potential for combining scientific expertise and financial support to advance common research priorities. ■



USDA/AGRICULTURAL RESEARCH SERVICE FT. KEOGH LIVESTOCK AND RANGE RESEARCH LAB

**One of two animals providing DNA from the USDA/Agricultural Research Service Ft. Keogh Livestock and Range Research Lab at Miles City, MT.**



**RESPOND TO THE  
NATION'S CHALLENGES**  
with Timely, Innovative Approaches





Some of the most pressing issues facing our nation are in the areas of homeland and national security, health, environment, and energy. Scientific research has already provided the basis for biomedical countermeasures to enhance homeland security; established a foundation to develop cutting-edge energy technologies; and brought life-saving medical technologies to patients. Science also provides the Administration with a foundation for the development of public policy surrounding these and other high-priority issues.

In their diagnostic analyses, scientists at the CDC, as well as other laboratories have detected a previously unrecognized coronavirus in patients with SARS. Here a scientist examines structural proteins derived from virus particles.

### Policies

To continue to meet these increasingly complex emerging priorities, there must be policies that guide the allocation of resources

- Flexibility in funding is required to redirect resources to the most pressing needs; and
- New programs will be targeted toward the most appropriate research performer or partnership (e.g., international, Federal, academe, industry).

### Identifying Priorities

An annual OSTP and OMB memorandum on R&D priorities provides guidance on critical issues. Agency budget proposals illustrate the cross-agency response to the Administration's priorities and reflect their consensus on the appropriate performers and ways to direct funding and resources to the critical topics identified. Recent interagency proposals for climate change, homeland security (including the food and agriculture defense initiative in the FY 2005 budget proposal), and nanotechnology illustrate how agencies have collaborated to develop new proposals in response to this budget guidance.

Development of responsive research plans takes into account advice from the NSTC and other science advisory bodies such as the President's Council of Advisors on Science and Technology (PCAST) and the National Academies.

To further illustrate the Federal response to high-priority national needs, several examples in select critical priority areas follow

### Homeland and National Security

- The events following September 11, 2001, show the strength of the scientific community in responding to a national emergency. Early in the national response, OSTP established a formal relationship, including shared personnel, with the newly created Office of Homeland Security to ensure that the full force of the Federal science enterprise was available to engage in critical early activities. The Antiterrorism R&D Task Force was formed under the NSTC to quickly develop coordinated research initiatives on the highest priority issues including biological, chemical, and radiological/nuclear



## Rapid response to infectious disease

In response to homeland security concerns, multiple Federal agencies have joined forces to develop new tools to protect the public from both deliberately introduced and naturally occurring pathogens. These involve cooperation among NIH, CDC, the US Army Medical Research Institute of Infectious Diseases (USAMRIID) and other components of DOD, DHS, CIA, FBI, DOE, USDA, and NSF.

One example of the positive synergy among Federal agencies is the development of an Ebola vaccine. In 2000, NIH, together with CDC, tested an experimental Ebola vaccine that fully protected monkeys from the lethal virus. One component of that early Ebola vaccine is now being assessed for safety in a human clinical trial at NIH and is the result of NIH/USAMRIID collaborations. This vaccine uses a strategy similar to that of other investigational vaccines that hold promise for controlling diseases, such as those for HIV/AIDS and SARS.

## Researcher working in a BSL-4 laboratory.

Genome sequencing projects, involving several Federal agencies and various international partners, are ongoing for high-priority pathogens.

Not only are we better prepared to protect citizens against deliberately introduced pathogens, we have also increased our capacity to tackle the tide of naturally emerging agents such as SARS and West Nile Virus. To facilitate this type of important research, several agencies are investing in research infrastructure that will be available to assist national, state, and local public health efforts in the event of a bioterrorism or infectious disease emergency. For example, NIH is supporting the construction of biosafety level 3 (BSL-3) and BSL-4 laboratory facilities across the country. (The higher BSL numbers, which range from 1 to 4, imply increased occupational risk from exposure and the need for additional containment measures.) ■

countermeasures; social, behavioral, and economic issues in risk assessment and risk communication; and rapid response. Later, the NSTC Committee on Homeland and National Security was established to coordinate interagency research directed toward homeland and national security. Some of the most significant areas of contribution include developing vaccines; developing biometrics; mapping the genomes of anthrax and other pathogens; developing sensor (“sniffer”) technologies to detect minute concentrations of chemicals; research on atmospheric dispersion to inform responses to chemical, biological, or radiological dispersal events; and new techniques for data mining, to extract patterns from large and unwieldy data sets.

- Drawing on a research program to develop new concepts for countering the increasing use of caves and bunkers by terrorists in Afghanistan to store their caches of weapons, DOD R&D agencies took less than 90 days to accelerate the development of thermobaric weapons from a concept that was little more than “basic chemistry” to systems that could be used for destroying cave targets. “Thermobaric” comes from Greek words for “heat” and “pressure.” The thermobaric explosives operate in two stages with a primary explosion that releases the fuel for a secondary explosion that causes an extremely high-pressure wave. If the explosive is detonated within a cave, the blast wave rushes through the tunnel without causing a tunnel collapse around the initial

explosion. These systems can be useful for destroying chemical and biological weapons sites, because they do not spread the agents as a conventional explosion does but can incinerate the agent outright.

- University-based Homeland Security Centers have been established by the Department of Homeland Security to leverage the multidisciplinary capabilities of the nation's universities to fill scientific and technological knowledge gaps. The first award was made to the University of Southern California in 2003 to establish the Homeland Security Center for Risk and Economic Analysis of Terrorism Events. In April 2004, DHS announced awards to Texas A&M University, to lead the National Center for Foreign Animal and Zoonotic Disease Defense, and the University of Minnesota, to lead the Center for Post-Harvest Food Protection and Defense. Future Homeland Security Centers will leverage university capabilities in the social and behavioral sciences and may address research to support operational response.

## Health

- The scientific response to severe acute respiratory syndrome (SARS) epitomizes the new model of collaboration that is emerging to meet today's global scientific challenges. A multifaceted scientific effort brought together governmental research agencies, academic institutions, and private industry around the globe. Within the United States, intense collaboration took place

among the Centers for Disease Control and Prevention (CDC), NIH, Food and Drug Administration (FDA), DOD, Department of Veterans Affairs (VA), academic institutions, and private industry. Working together, they rapidly deciphered the genetic code of SARS. This was followed by the development of antiviral agents and candidate vaccines. One example encapsulates how Federal research agencies have helped create a multiplier effect to spur further research. The NIH National Institute of Allergy and Infectious Diseases sponsored an alliance of government, non-profit, and industry partners to distribute for free a new "SARS chip" that will enable researchers to rapidly detect tiny genetic variations among different SARS virus strains and speed development of new drugs.

- Faced with the recent possibility of a serious West Nile Virus (WNV) epidemic, US Government scientists sprang into action and developed a promising hybrid vaccine. NIH scientists collaborated with the Walter Reed Army Institute of Research to capitalize on recent advances in recombinant DNA technology and previous research on another virus (dengue) in the same family of flaviviruses to produce a new candidate WNV vaccine. Their early successes are due to the virus' similarity to other flaviviruses and to recent efforts to increase research on newly emerging pathogens. To prevent the spread of WNV through the nation's blood supply, FDA and CDC worked closely with the states and the

## Adding a human dimension to solving problems

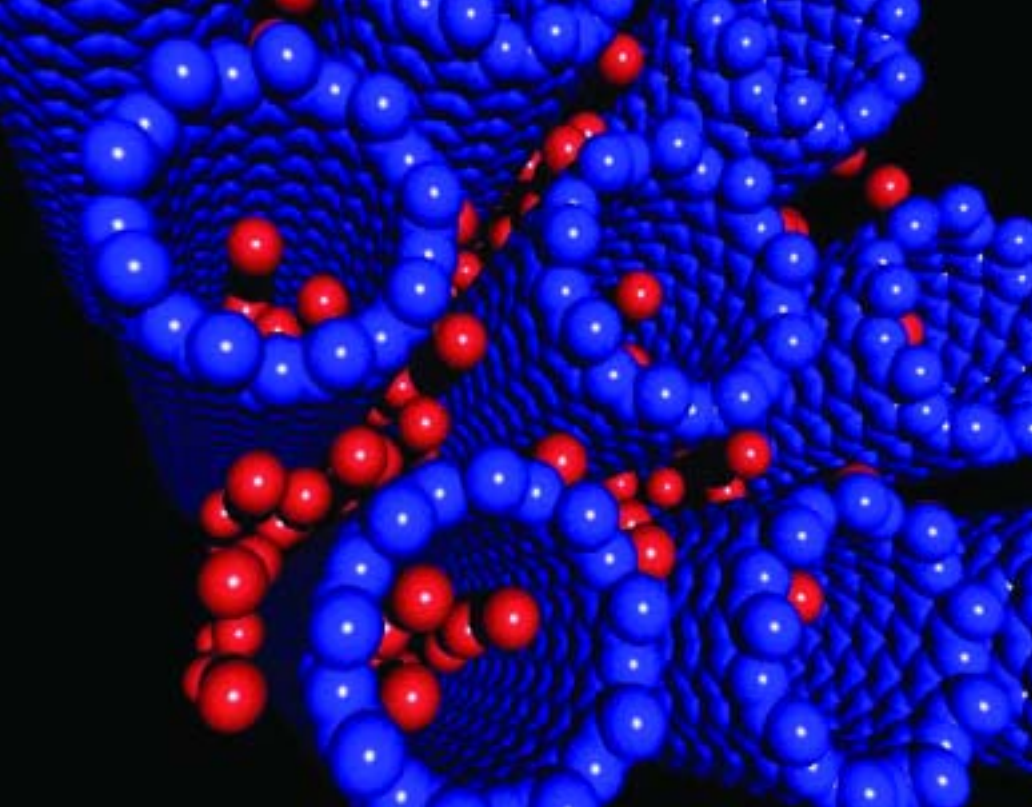
The social networks among people in an organization or community can be the most important factor in group process and information flow. Data and maps of social networks have provided important insights into human behavior since they were drawn by hand in the 1930s. Today, Internet technology and newly developed mathematical network analysis tools have transformed this research. NSF's new program in Human and Social Dynamics will enhance the ability of organizations and individuals to understand change in society and anticipate its complex consequences. The new tools, combined with advanced temporal and spatial information analysis tools such as geographic information systems, contribute to antiterrorism efforts, epidemiology, public safety, and education. ■

### Schematic of two types of social networks.



COURTESY OF MIKE NEWMAN,  
UNIVERSITY OF MICHIGAN





**Simulation of the structure of absorbed hydrogen in an array of nanotubes at 298K and 200 bar of hydrogen pressure.**

energy is to play a part in future, cleaner energy sources.

## Environment

- In June 2001, the President announced the US Climate Change Research Initiative, a new approach to prioritizing scientific research to improve our understanding of global climate change. The new US Climate Change Science Program (CCSP) developed a strategic plan for research in this area. By July 2003, the CCSP, a collaboration of 13 Federal agencies, had published a research vision and strategic plan that provides a strategy for developing knowledge of climate variability and change and for the application of this knowledge. The plan's objectives include reduction of scientific uncertainty about the climate effects of aerosols (tiny particles) in the atmosphere, better understanding of the carbon cycle in the Earth system, improved climate modeling, enhanced Earth observations, and development of scientific information to support decision making. This strategy has been endorsed by the National Academies. The President's FY 2005 budget request seeks nearly \$2 billion to fund this important research.
- The Environmental Protection Agency (EPA) and NIH National Institute of Environmental Health Sciences are studying the role of particulate matter in cardiovascular disease, the leading cause of death in the United States. Recent studies suggest that air pollutants, especially particulate matter, may be a

blood and diagnostics industry to develop appropriate tests based on existing platform DNA technologies. As a result, within eight months of identifying the risk of WNV exposure from blood and tissue, universal investigational blood donor screening was made available, preventing the introduction of more than 1,000 units of potentially infectious blood into the nation's blood supply.

## Energy

- The President announced a US Hydrogen Fuel Initiative in January 2003. In November 2003, 15 nations and the European Commission—representing a collective 85% of the world's gross domestic product and two thirds of the world's energy consumption—agreed to establish the International Partnership for the Hydrogen Economy. Chaired by the US Departments of Energy and Transportation, this multinational program will coordinate the high-risk/high-payoff science and advanced technology development that will turn this vision into a global reality. The Hydrogen Fuel Initiative has significantly increased the nation's investment in hydrogen energy R&D. Revolutionary discoveries and conceptual breakthroughs will be needed in the interdisciplinary areas of science enabling the production, storage, and use of hydrogen. Solutions will lie in the innovative synthesis of new classes of materials, particularly nanomaterials, coupled with the fundamental understanding of their structural, thermodynamic, physical, and chemical properties.
- In January 2003, President Bush committed the United States to participate in one of the largest and most technologically sophisticated international research projects in the world, the experimental nuclear fusion reactor known as ITER, to demonstrate the scientific and technological feasibility of nuclear fusion energy for peaceful purposes. International partnerships are essential in this research because of the huge investments required in facilities and experimentation. ITER represents an essential step forward if fusion

J. KARL JOHNSON, UNIVERSITY OF PITTSBURGH

factor in the development of heart disease. Currently documented risk factors for heart disease are age, lifestyle (smoking, physical inactivity, and diet), gender, race, and genetics. The new research will investigate mechanisms by which air pollutants adversely affect the cardiovascular system, an area where few data presently exist. Researchers also will identify and investigate the factors that make certain people more susceptible to the cardiovascular effects of air pollutants. The research fosters innovative collaborations between environmental health and cardiovascular researchers.

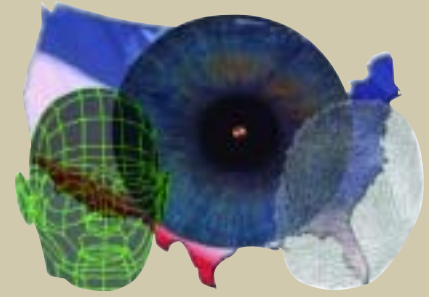
## Impact

The agencies call upon the resources of the entire national science enterprise and, where appropriate, international collaborators to address the concerns of the day in the most efficient and appropriate way possible. The above examples are but a few of the ways Federal agencies have responded to the high-priority concerns that the Administration has called on them to address. Their research activities produce both physical products (e.g., new vaccines) that directly solve problems and knowledge products that are communicated to decision makers and the public to inform policies and facilitate decisions that affect nearly every aspect of our lives.

## Biometrics

Automated methods of recognizing an individual by his or her physical or behavioral characteristics have the potential of significantly influencing future Federal operations and business practices and enhancing homeland security. For this to happen, the accuracy of the technology must improve along with our understanding of its capabilities, limitations, and sociological factors. Coordinating through the NSTC Biometrics working group, the agencies are developing and implementing near- and long-term plans in the areas of modalities; systems and human interface; fusion, test infrastructure, and evaluation; and social/legal/privacy.

One of the early successes is a collaborative effort to define a standard set of biometrics test procedures and statistical methods to be used by researchers across the Federal agencies, as well as in industry and academia. This framework, known as the Biometrics Experimentation Environment (BEE), will reduce the cost of biometrics evaluations and will enable characterization of experiments, making it possible for other researchers to duplicate and analyze the experimental results. After a baseline capability has been demonstrated, a BEE Users Group will be established to allow the greater scientific community to participate in and manage further development and implementation activities.



Open consensus standards, and associated testing, are critical to providing higher levels of security through biometric identification systems. When biometrics are selected for implementation, NIST has the responsibility, in partnership with US industry and other agencies, to develop technology standards and tests that assure uniform results and high levels of accuracy.

The agencies have also developed a Biometrics Catalog (<http://www.biometricscatalog.org>), an information sharing resource that includes more than 1,350 research reports, 3,000 news articles, 300 conference presentations, as well as numerous commercial products, evaluation reports, and legislative documents. The Biometrics Catalog is open and free for public use. ■



**INVEST IN AND ACCELERATE**  
the Transformation of Science into  
**National Benefits**





The translation of science into solutions that enhance homeland security, spur economic growth, or improve health is not automatic. The mere existence of a scientific finding or result will not necessarily produce knowledge transfer or result in new technology. Current research that could lead to applications must be targeted for development, and we must continually examine the potential uses of existing discoveries to ensure maximum benefit from the public investment in science. This is a complex process that is, nonetheless, essential for our nation's prosperity and high standard of living.

**Doppler weather radar.  
Radar dish in the foreground.  
Triangular panels of  
protective fiberglass radar  
dome in the background.**

Although the emphasis of Federal science funding is on basic research and on R&D that is inherently the responsibility of the Federal Government, it is recognized that there is a broader national interdependence of basic research, applied research, technology development, and knowledge transfer. Dynamic, flexible partnerships are the strength of an "innovation system" to create new knowledge products, technologies, and jobs. Many of the Federal policies and actions to promote this innovation system (e.g., tax policy) are beyond the purview of the research agencies, but there are several elements of science policy and research program implementation that do enter into the picture.

### **Policies**

To support the national innovation system and encourage solutions that create economic growth and improve our quality of life, the Federal science policy is to

- Include a wide range of public and private stakeholders in an ongoing dialogue with Federal research

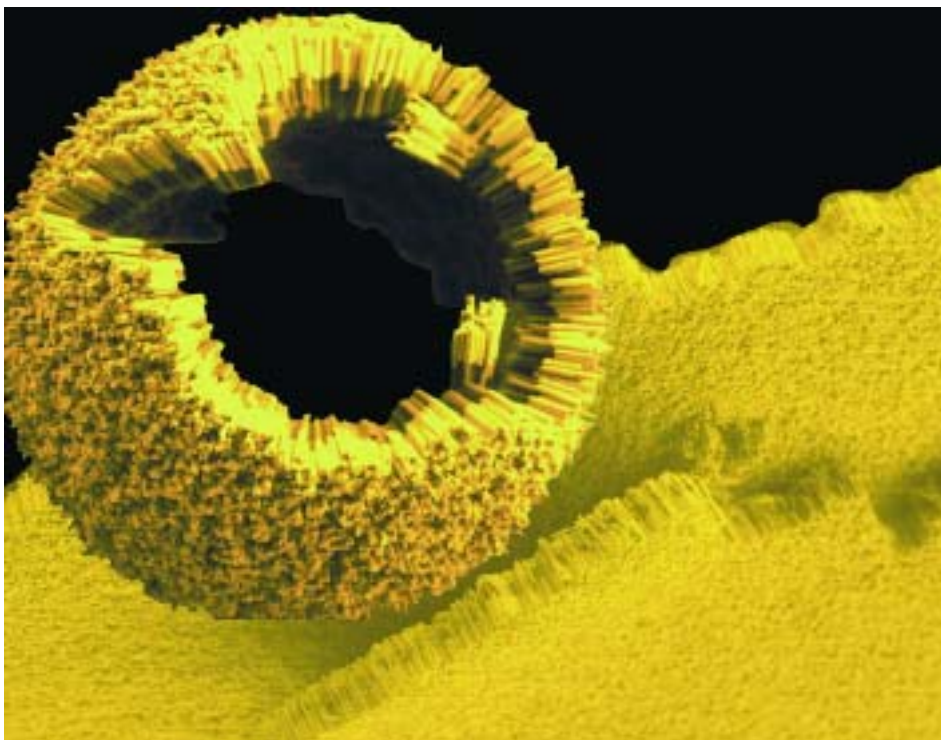
agencies so that Federally supported science programs appropriately support broad interests;

- Maintain a strong system of research support that includes protection for the intellectual property rights of the performer; and
- Support mechanisms that encourage innovative small businesses and result in job growth.

### **Developing New Products and Technologies**

Several agency programs and interagency collaborations illustrate the unique role of the Federal research agencies in developing products and technologies that improve lives and help the economy

- CDC has improved the ability to track chemical exposure in humans through development of biomonitoring, the direct measurement of chemicals in the human body. The technique delivers more precise and reliable predictions of the effects of environmental exposure to chemicals than previously available estimates produced by



**Self-assembly of gold-polymer nanorods results in a curved structure.**

## Materials science at nanoscales

Research with nanomaterials requires the ability to work—that is, to see, measure, and manipulate—at atomic and molecular scales (1–100nm). In lay terms, that is about 1/100,000th the diameter of a human hair. This is not merely the study of small things; it is the research and development of materials, devices, and systems that exhibit new and extraordinary physical, chemical, and biological properties. For example, scientists at Northwestern University created a new class of nanometer-scale building blocks that can spontaneously assemble themselves into ultra-tiny spheres, tubes, and curved sheets—scientific discoveries that could eventually lead to important applications in nanoscale electronics and drug-delivery systems.

The cost of nanoscience instrumentation, equipment, and facilities can be high, making it difficult for researchers at small businesses and most academic institutions to participate. NIST has recently constructed the most technologically advanced facilities in the world, the Advanced Measurement Laboratory, which will support industry in the conduct of this research with new ways to more accurately measure, quantify, and calibrate important processes and properties. The Departments of Energy and Commerce and NSF are supporting the development of additional nanoscale R&D user centers nationwide to provide access to the necessary infrastructure.

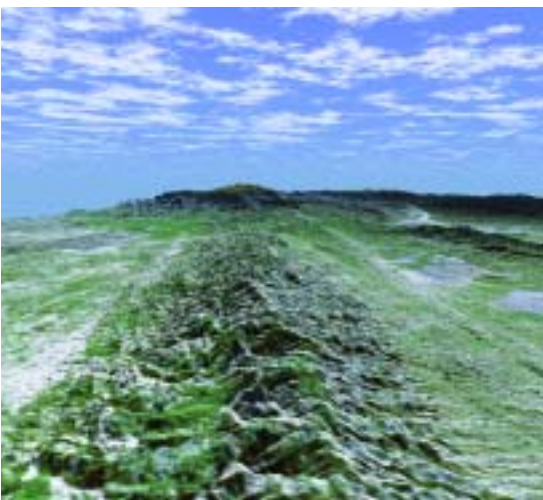
A total of 10 Federal agencies support research and development on nanomaterials. ■

mathematical models and provides a stronger scientific basis for regulations to protect human health. In 2003, the results of a large assessment of the US population using biomonitoring were published. The research continues, with new national data to be released approximately every two years. Biomonitoring has broader potential benefits because the technique can identify person-specific needs that can be matched with new drugs being developed through genomics.

- More accurate weather forecasts can save lives and money by predicting major storms and long-term trends such as rainfall or drought from El Niño events. For example, more precise prediction of hurricane routes allows communities to be better prepared and save costs of extensive storm preparations in those areas that can be certain they are out of the storm's path. NASA develops new instrument technologies and satellite monitoring devices that make it possible to collect the data vital to weather modeling. NOAA has developed new weather-modeling techniques that combine these vital data with aspects of weather, ocean, and hurricane models to improve forecasting ability for its own researchers and for meteorologists nationwide.
- Future research has the potential to provide early warning for earthquakes, with enormous expected benefits. Research sponsored by

NSF, the US Geological Survey (USGS), and NASA supports both fundamental research on Earth's structure and the development of maps and other information to aid in predicting vulnerability and help mitigate damage from earthquakes. The NSF/USGS-funded Southern California Earthquake Center has developed state-of-the-art maps of crustal distortion that provide a direct measure of the potential for future earthquakes and are used by earthquake engineers for strengthening structures and by the insurance industry for planning. The NSF-funded EarthScope uses a network of geophysical sensors and an observatory placed some 2.5 miles down in the San Andreas Fault to define and monitor the dynamics of Earth across the North American continent.

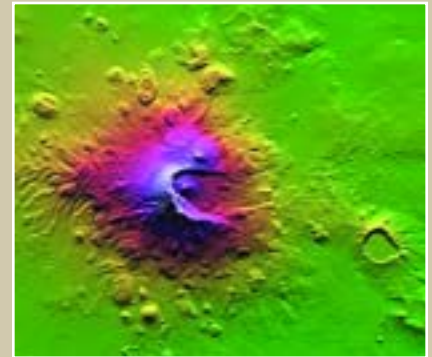
**San Andreas Fault in the Carrizo Plain. SRTM topographic data.**



NASA, NGA, USGS

## Mapping the world in three dimensions

The recent Shuttle Radar Topography Mission (SRTM) collected topographic data over nearly 80% of Earth's land surfaces, creating the first-ever near-global, high-resolution data set of land elevations. A global mapping project spearheaded by NASA and the National Geospatial-Intelligence Agency (NGA), the SRTM flew on NASA's Space Shuttle and used a technique called "radar interferometry" to produce the data. The processed SRTM data, archived with the USGS, can be tailored to meet the needs of the civil, scientific, and military user communities. Just about any project that requires accurate knowledge of the shape and height of the land can benefit from these data. Some examples are flood control, soil



NASA, NGA, USGS

**Mt. Meru, Tanzania**

conservation, reforestation, volcano monitoring, earthquake research, and glacier movement monitoring. Other uses of these data include improved water-drainage modeling, more realistic flight simulators, navigation safety, better locations for cell phone towers, and even improved maps for backpackers. ■

## Initiatives for Accelerating the Translation of Research into Applications

The Federal research system and its support for university- and Federal laboratory-based research are central to maintaining our innovation system, producing new knowledge, and educating the next generation of scientists, engineers, and skilled workers. The establishment of university-based and regional research centers across the country, and a favorable legislative environment for these centers to retain the intellectual property rights for their discoveries, have been recognized as incentives for companies to make investments in technology development that lead to regional economic growth.

Direct linkages between Federal agencies and industry are also critical and provide two-way benefits. This year, the Federal Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR)

programs will provide \$2 billion to small businesses through Federal programs to help entrepreneurs take their ideas from conception to reality. Federal agencies also depend on the contributions of the industrial science and technology base in pursuing their missions. Both parties leverage funds through creative partnerships to achieve common goals. National economic competitiveness is rooted in the health of this Government-academia-industry partnership at local levels, because that is where jobs are created. Strong alliances with state and local governments help to promote a favorable environment for innovation and incentives for business development.

Although NIST is the only Federal research agency with the express mission of working with industry to keep US technology at the leading edge, several agencies are developing industry-academia-government partnerships as well as institutional programs and



# TeraGrid and the Alliance



## Advanced scientific computing and cyberinfrastructure

Across the board, Federal agencies are adopting state-of-the-art computing, communications, and information technologies that are radically empowering the nation's scientific research and education communities. An explosion of collaborative research has resulted from new capabilities that link researchers over high-speed networks to advanced computational tools, often involving shared resources from multiple agencies and academic institutions. To highlight just a few examples

- The NSF Extensible Terascale Facility (TeraGrid) will be the world's largest, most comprehensive, distributed infrastructure for open scientific research. By late 2004, it will link 20 teraflops (a unit for measuring computer speed) of computing power at five sites.

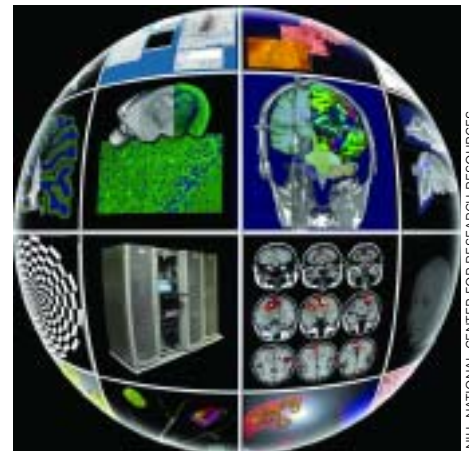
## NSF TeraGrid Network

- The NIH Biomedical Informatics Research Network (BIRN) is the nation's first test-bed for online sharing of research resources and expertise, and for effective data mining for both basic and clinical research.
- The DHS Advanced Scientific Computing Program will develop new infrastructure tools to enable law enforcement and intelligence analysts to mine multiple databases for critical information using a single, shared view of the data.
- EPA and DOE have agreed to link supercomputers in EPA's North Carolina facility and DOE's Sandia National Laboratory to allow better and faster collaboration on computational toxicology and genomics. ■

practices to accelerate the translation of science results into usable knowledge and applications

- DOE and the US Council for Automotive Research—representing DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation—announced cooperation on a FreedomCAR (cooperative automotive research) Partnership in January 2002. The goal of FreedomCAR is fundamental and dramatic—the development of emission-free cars and light trucks. FreedomCAR is fully integrated with the Department's Hydrogen Fuel Initiative. The FreedomCAR Partnership will also continue research into technologies such as advanced internal combustion engines, emissions control for diesel engines, lightweight materials, hybrid electric vehicle systems, advanced batteries, and alternative

**The Biomedical Informatics Research Network promotes advances in biomedical and health care research through the development and support of a cyberinfrastructure that allows sharing, analysis, visualization, and data comparisons across laboratories.**



fuels with potential for substantial energy efficiency and environmental benefits in the near term.

- NIH has undertaken an agency-wide endeavor, the NIH Roadmap, to provide a framework for the priorities that NIH as a whole must address to transform new knowledge into tangible benefits. In developing the Roadmap, NIH brought together more than 300 nationally recognized leaders in academia, industry, government, and the public to identify cross-cutting research approaches and resources that were beyond the scope of any single institute but would enhance the mission of every institute. The Roadmap includes three major themes to foster high-potential research. New Pathways to Discovery aims to generate new knowledge and to build a better “toolbox” for researchers in the 21st century, including new technologies, databases, and other resources. Research Teams of the Future recognizes that as the scale and complexity of research grow, scientists will need to move beyond the confines of their own disciplines and explore new organizational modes for team science. Re-engineering the Clinical

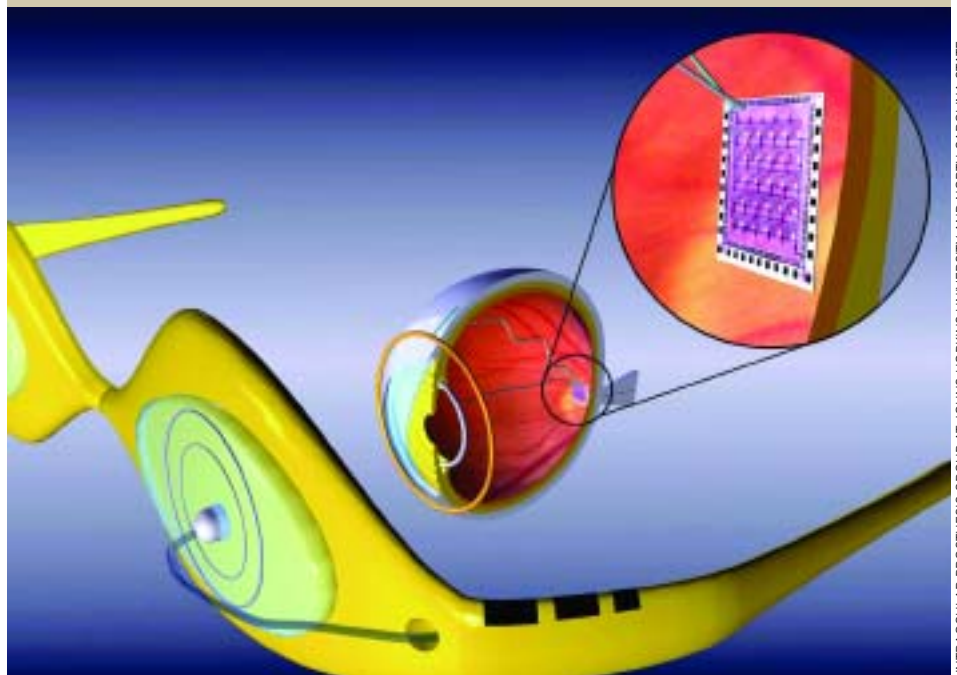
**The retina prosthetic system illustrated here, consists of an extrocular unit and an intraocular unit. The first is mounted on a pair of glasses and is responsible for collecting the image by means of a video camera and then transmitting an encoded digitized image to the intra-ocular unit. The second is composed of a receiving telemetry system, a simulation current driver, and an electrode array to stimulate retinal cells, thus imparting vision perception.**

### **Multidisciplinary research collaboration creates new hope for the blind**

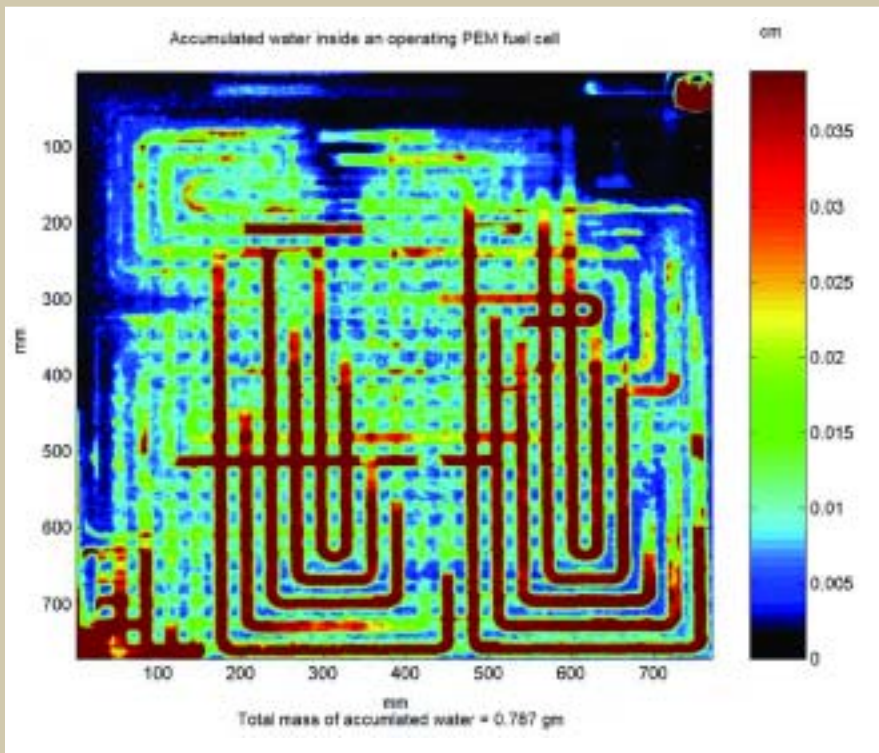
The marriage of electronics technology with biomedical science is creating advances in treating even the most intractable diseases. In one such union, specially designed computer chips implanted in the eye may make it possible to restore some measure of visual function to the blind. Retinal degenerative diseases such as macular degeneration and retinitis pigmentosa damage and destroy the light-sensitive photoreceptor cells in the retina. Although these cells die, much of the remaining nerve cell network in the retina remains healthy. The new device, called a retinal prosthesis, uses visual signals from a video camera mounted on a pair of glasses. These signals are sent to an intraocular electrode array attached to

the retina via a receiver that is implanted behind the patient’s ear. It is the first wireless implantable device of its kind. In a recently published study, a 74-year-old patient who has been blind for more than 50 years was implanted with a retinal prosthesis and participated in 10 weeks of visual assessment. Using the device, the patient was able to see spots of light, detect motion, and recognize simple shapes. Without the device, the patient could not perform any of these tasks.

Developed by researchers at the University of Southern California, this breakthrough represents many years of research involving numerous institutions and funding from public and private sources including NIH, NSF, DOE, DOD, the VA, the Whitaker Foundation, the Foundation Fighting Blindness, and Second Sight, LLC. ■



INTRACULAR PROSTHESIS GROUP AT JOHNS HOPKINS UNIVERSITY AND NORTH CAROLINA STATE UNIVERSITY; ILLUSTRATION BY JERRY LIM

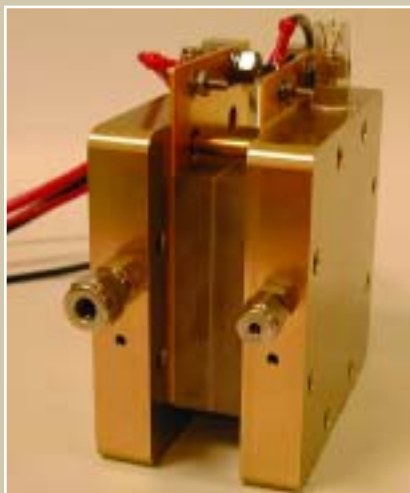


NIST, CENTER FOR NEUTRON RESEARCH

**Neutron image of the water (hydrogen) distribution inside a fuel cell while it is operating.**

## Hydrogen fuel cells

These images were taken at the NIST neutron imaging facility located at the NIST Center for Neutron Research. NIST has the only facility in the United States that can nondestructively visualize and quantify water (hydrogen) transport in operating cells. Understanding this water transport mechanism is one of the most critical issues in the development of robust, efficient, and commercially viable PEM fuel cells, which are likely to power everything from automobiles to hand-held devices in the future. This capability has attracted interest from major US industries that are involved in fuel cell research, a critical component of the President's Hydrogen Fuel Initiative. ■



**Proton exchange membrane (PEM) fuel cell.**

NIST, CENTER FOR NEUTRON RESEARCH

Research Enterprise will require new partnerships among patient communities, community-based physicians, and academic researchers; integration of clinical networks; harmonization of clinical research policies; and enhanced training for clinical researchers. Additional Roadmap initiatives include the NIH Director's Pioneer Award for high-risk/high-payoff research; novel public/private partnerships to move scientific discoveries from bench to bedside; and increased public involvement in the research process.

- DHS has created the National Biosecurity Analysis and Countermeasures Center (NBACC) as an integrated and responsive biosecurity enterprise to facilitate the homeland security, law enforcement, and medical and veterinary communities' ability to understand, respond, deter, and recover from the biological threats to the United States. NBACC directs and coordinates scientific efforts to improve our defenses against biological agents by gaining better information about current and future threats, understanding the risks associated with these threats, evaluating methods that may be used to deliver the threats, and conducting forensic analysis on threats to determine attribution. A knowledge management system is planned as a tool to integrate science, technology, and intelligence.



## Impact

This targeted involvement of Federal agencies with their academic and industry partners spurs economic growth and speeds the adoption of new products and technologies, increasing the return on the nation's investment. Although Federal science funding tends to be discovery-oriented and focused on the long term, the interdependence between these investments and the national economy is substantial, and the development of applications is a mutual responsibility. As demonstration programs, such as the first university-based research parks, show results and lessons are learned, the concepts are adopted on larger scales and result in significant national impacts.

P. WEST, NSF



## Science at the Earth's poles

Frozen in the ice at Earth's poles are many secrets, from clues to how the climate changes to unknown forms of ancient life. Twelve US science agencies support research in the Arctic; NSF is charged with managing all US activities in the Antarctic as a single, integrated program. At both poles, much of the research involves international collaborations.

A priority for research conducted at the poles is understanding regional and global environmental issues and climate change. In recent years, the Arctic Ocean has seen a rapid thinning of sea ice and shifts in ocean circulation. These changes are related to changes in the persistent pattern of atmospheric circulation in the northern hemisphere, which may have an important role in regulating the global climate. NASA's new ICESat mission, launched in January, 2004, will provide a satellite perspective for environmental issues relevant to polar research. It will provide multi-year elevation data needed to determine ice sheet mass balance as well as cloud property information, especially for stratospheric clouds common over polar areas. It will also provide topography

## The 2003 team arrives at the North Pole Environmental Observatory

and vegetation data around the globe, in addition to the polar-specific coverage over the Greenland and Antarctic ice sheets.

Beginning in April 2000, an international research team supported by NSF has conducted annual expeditions to the North Pole to obtain data on these and other factors. The team sets up a number of unmanned scientific platforms, collectively called the North Pole Environmental Observatory, to measure throughout the remainder of the year everything from the salinity of the water to the thickness and temperature of the ice cover.

In Antarctica, at the opposite end of the globe, researchers working in 2004 at separate sites thousands of miles apart found the fossilized remains of two species of dinosaurs previously unknown to science. One of the two finds, which were made less than a week apart, is of an early form of plant-eating beast that would have lived many millions of years before the other, a carnivore, existed. ■

# ACHIEVE EXCELLENCE

in Science and Technology Education and in  
Workforce Development



Science, technology, engineering, and mathematics education and workforce preparation are top Administration priorities. A strong S&T workforce is necessary to sustain and drive our economy and reach the Administration's goal of strong economic growth. Ongoing international exchanges of students and investigators serve to enhance cooperation, keep the research community vital, and make the global workforce flexible.

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**At Florida A&M University, a student helps sort aquatic insects to be used in biological monitoring of water quality.**

Preparation in science and technology supports a variety of careers beyond what we consider the “traditional” S&T workforce, such as patent law, teaching, journalism, entrepreneurship, policy, and diplomacy. Today, 55% of the CEOs of Fortune 500 companies have a science or technology background. Citizens in all walks of life need basic math, science, and technology skills and an understanding of the science behind the issues of the day. Education is crucial, and these challenges must be addressed simultaneously on multiple fronts.

### **Policies**

The policies that address education and workforce development include

- Provide better linkages between the higher education community and our primary and secondary schools to enrich and strengthen subject matter content;
- Provide improved access to all US citizens seeking an S&T education, and in particular, reduce barriers for women and underrepresented minorities; and

- Maintain vital international exchanges that capitalize on the worldwide S&T talent pool while simultaneously ensuring that security concerns are addressed.

### **Engaging Schools and Communities**

One critical element is guaranteeing a future pipeline of students prepared to study and work in scientific and technical fields. Outreach to schools and teachers as well as improved teacher training help ensure that students develop an early appreciation for science. Early interventions to foster interest in math and science can enhance student preparation for entering college or joining the S&T workforce. The President's No Child Left Behind Act of 2001 addresses this issue with measures that fill classrooms with teachers who are knowledgeable and experienced, assess students' progress at regular intervals, and combine stronger accountability with flexibility to optimize the use of Federal funds. To develop a new generation of citizens who have mathematical and scientific skills, the Administration has launched a major, 5-year, Mathematics and Science Initiative to





### The next generation of education research

The Institute of Education Sciences (IES), created at the Department of Education as part of the Education Sciences Reform Act of 2002, was born out of a shared sense among policy makers that education practice and research are badly in need of reform. In 1999, the National Research Council concluded that “the complex world of education—unlike defense, health care, or industrial production—does not rest on a strong research base. In no other field are personal experience and ideology so frequently relied on to make policy choices, and in no other field is the research base so inadequate and little used.” The mission of IES addresses the need for rigorous research on practices that improve academic achievement and the effectiveness of education programs and policies.

IES seeks to bring a new generation of education research to the classroom to improve mathematics and science education. Researchers are evaluating a computer-based instructional program designed to facilitate the learning of algebra, an Internet-

based teacher professional development program for middle school mathematics teachers, and a Web-based science curriculum for middle school students. One group is developing a system that will provide students with mathematics tutoring assistance from the computer while the system collects assessment data about what students know to inform teachers’ lesson-planning decisions.

IES also funds basic research on the learning of mathematics and science. Researchers are studying, for example, how young children learn mathematical symbols and the mechanisms by which memory influences math problem-solving accuracy in elementary school children.

Through the Interagency Education Research Initiative (IERI), IES collaborates with NIH’s National Institute of Child Health and Human Development and NSF to identify conditions under which new educational techniques that have been shown to work in trials succeed when applied on a large scale. Through IERI, the agencies also investigate the impact of technology on learning. ■

### A Web-based cognitive assessment system predicts student performance on state exams and helps teachers plan appropriate lessons.

improve mathematics and science achievement. The initiative is focused on three broad goals: 1) engage the public in recognizing the need for better mathematics and science education for all children, 2) initiate a campaign to recruit, prepare, train, and retain teachers with strong backgrounds in mathematics and science, and 3) develop a research base to improve our knowledge of what boosts student learning in mathematics and science. In February 2003 and March 2004, Summits on Mathematics and Science, respectively, were sponsored by the Secretary of Education to launch this initiative and engage the major constituents.

Outreach to communities is essential. A community awareness of the relevance of science to the issues of the day is needed to sustain the interest of the next generation in preparing for careers in science and technology, or simply for participating as good citizens in decisions that affect their lives. Here, unfortunately, we face major challenges. As documented in a 2002 NSF report, 70% of Americans do not have a basic understanding of the scientific process, and most do not feel that they are well informed about S&T issues. (Most Americans, Canadians, and Europeans gave the wrong answer [true] to the statement: “Ordinary tomatoes do not contain genes, while genetically modified tomatoes do.”) Improving the overall science literacy of the average American becomes increasingly important as new technologies that are based on complex scientific discover-

ies, such as nanotechnology and biotechnology, are incorporated into the marketplace and become the subject of social or political debates.

### Attracting and Retaining Talent

Since 1998, when total number of PhDs reached an all-time high, a significant decline in science and engineering doctorates has returned the total number of PhDs to pre-1994 levels. The decline in interest in S&T careers, which is evident at all levels, is particularly an issue for women and underrepresented minorities. Women are 46% of the total labor force but only 23% of the science and engineering labor force. At the 9th-grade level, young women indicate interest in S&T careers at rates nearly as high as their male counterparts but have a much lower retention rate. African Americans, Hispanics, and Native Americans are 24% of the US population but only 7% of the science and engineering labor force. Their retention rates in S&T programs are also significantly lower than those of their White or Asian counterparts. Neither women nor minorities are being recruited into and supported in S&T academic programs in numbers large enough to address these imbalances.

To address the recruitment and retention problem, universities and colleges should be encouraged to reward faculty for educational activities as well as for research and to recruit and support a diverse faculty to mentor and encourage a diverse student body. In



Cylinder seal from San Adrés Tabasco, Mexico, showing the glyphs, including three Ajaw, the name of a day in the 260-day Mesoamerican calendar.

### Understanding language and learning

Breakthroughs of language and learning span ancient times to the present. NSF-funded scientists have uncovered evidence of what is believed to be the earliest form of writing ever found in the New World. This find indicates that the form of written communication used by the Olmecs, the “mother civilization” of Mexico (1200 BC–600 AD), led into what became forms of writing for several other cultures. Understanding the historical development of written language is one tool in understanding the learning process.



Neural electromagnetic measurements for the non-invasive characterization of neural function.

Other research uses modern experimental techniques such as the brain imaging studies funded by DOE and NIH. Such studies, combined with theory-driven cognitive studies, all inform education policy by furthering our understanding of how people acquire and organize new knowledge or skills. ■

CHRISTOPHER VON NAGY

DOE, LOS ALAMOS NATIONAL LABORATORY – HUMAN BRAIN PROJECT

addition, Federal agencies should continue to ensure that their programs improve training for the technical workforce as well as undergraduate and graduate science and engineering education, and provide research-mentoring opportunities.

Additionally, we must maintain a vital international exchange of scientists and students to promote a productive, international scientific community and enhance global cooperation. The talents of visiting scientists and students greatly enrich the US scientific enterprise. Although we must adopt adequate national and homeland security measures and protect uniquely available or sensitive knowledge, we must ensure that these measures do not prevent the global partnerships in scientific research that benefit us all. This ongoing challenge requires continued attention.

### **Coordinating Education Programs**

Some examples of Federal agency actions to improve coordination in education programs, workforce issues, and scientific exchange follow

- Agencies have worked through the new NSTC Subcommittee on Education and Workforce Development to ensure that their programs to support various levels of education research are coordinated and aligned with community needs. Through this subcommittee, the agencies, working with the Department of Education (ED), are

coordinating research programs implemented in line with the No Child Left Behind Act of 2001. The subcommittee also has tackled the question of future S&T workforce requirement projections, including projected growth in specific fields (e.g., nanotechnology). To provide the subcommittee with additional information, OSTP sponsored a workshop to identify and determine how to fill the data gaps that could allow researchers and industry to better agree on future demands and improve planning for investments in education and training. The workshop brought together economists who study the scientific workforce, representatives of the Federal research agencies, and the people who collect workforce data and develop the requirements projections.

Complementing K–12 educational initiatives and programs targeting undergraduate and graduate education, such as the Presidential Math and Science Scholars Fund, the President’s Jobs for the 21st Century Initiative would provide more than \$500 million in 2005 to better prepare high school students and workers for the higher-skilled, higher-paying jobs of the future. It includes a \$250 million initiative for community colleges to train workers for industries creating the most new jobs, which builds on the Administration’s High-Growth Job Training Initiative.

- The Aerospace Workforce Interagency Task Force of the Department of Labor’s Employment and Training Administration is addressing the major science and engineering challenges of the aerospace sector. The participating agencies include the Departments of Commerce, Defense, Education, Labor, and Transportation, along with NSF, NASA, OMB, and OSTP. The President’s Commission on the Future of the United States Aerospace Industry recommended the establishment of an interagency task force to develop a national strategy that will attract public attention to the importance and opportunities within the aerospace industry and ensure appropriate coordination and resource sharing within the participating agencies. The task force will catalyze the development of replicable model solutions and ensure appropriate buy-in from key education, training, economic development, and industry constituencies regarding aerospace workforce issues. These partners will also bring political, technical, and subject matter expertise that will help develop the aerospace workforce and meet industry demand.
- After the attacks of September 11, 2001, OSTP and the Homeland Security Council agreed to co-lead an interagency group to review policies for visiting students and scientists and advise the President



on the best ways to enhance homeland security without blocking legitimate, international scientific exchange. The discussions resulted in an interagency policy of case-by-case review to ensure that international students do not gain access to uniquely available knowledge or to training that could subsequently enable terrorist attacks against the United States or its allies. Best practices from the interagency discussions were disseminated and security procedures to screen international visitors were put in place. The agencies have continued in this collaboration as part of a broader framework to support continued scientific exchange and ease travel restrictions for the majority of students and scientists who pose no threat to US national or homeland security.

- The Federal agencies collaborate through OSTP on numerous events and awards that enhance the visibility and communicate the importance of math, science, and technology education and careers. In 2001, OSTP launched and directed a science and technology outreach campaign, Global Science and Technology week, which has become an annual event now called Excellence in Science Technology and Mathematics Education week. The event brings together science agencies, science museums, professional societies, and educational associations to host events for



APPALACHIAN MATH SCIENCE PARTNERSHIP

### **Math and science partnerships**

The Math and Science Partnership (MSP) program addresses the President's challenge—enunciated in the No Child Left Behind Act of 2001—to strengthen K–12 science and mathematics education. MSP supports partnerships that unite local school districts with college and university faculty in mathematics, science, and engineering. In 2003, MSP awards directly affected at least 2.85 million students nationwide and in Puerto Rico—children who learn in urban, rural, suburban, and tribal nation schools.

MSP, funded within the Department of Education and NSF, has three main components: comprehensive and targeted projects; research, evalua-

### **Redesigned "Math for Teachers" course sequence engages college students more fully in the mathematics content they will teach.**

tion, and technical assistance; and teacher participation in Teacher Institutes for the 21st Century to provide intellectual leadership in their schools and districts. Many MSP-funded projects contribute to the MSP Learning Network, a network of researchers and practitioners studying and evaluating promising strategies to improve K–12 student achievement and other student outcomes in mathematics and science. ■



COURTESY OF M. DIAZ, NIH

**Marilyn Diaz, NIH, National Institute of Environmental Health Sciences. Winner of a 2002 Presidential Early Career Award for Scientists and Engineers.**

teachers and students. Three highly prestigious awards that are coordinated among the agencies and recognize the importance of mentors, teachers, and early achievers are the Presidential Award for Excellence in Science, Math, and Engineering Mentoring, the Presidential Award for Excellence in Math and Science Teaching, and the Presidential Early Career Award for Scientists and Engineers.

### **Training Tomorrow's Scientists**

The Federal agencies are partnering with the educational community to improve S&T programs and develop the next generation of the S&T workforce and education professionals

- The new DHS Scholars and Fellows Program supports graduate and undergraduate students in an effort to produce more US scholars with expertise related to security issues. DHS provides scholarships for undergraduate and fellowships for graduate students pursuing degrees in fields relevant to its security mission such as engineering, information technology, computer science and mathematics, the social and economic sciences, life sciences, and physical sciences. The students receive professional mentoring and are given a summer internship opportunity to help them connect their academic pursuits with homeland security national objectives and initiatives.

Fifty scholars and 50 fellows are nearing completion of their first academic year. A second class of 100 scholars and fellows will receive awards beginning in September 2004.

- The VA Office of Research and Development supports more than 200 scientists in the early stages of their research careers. The Career Development Program provides salary and research support for investigators to conduct studies or receive specific training while working with experienced mentors. Career development awards help attract the highly talented researchers who are essential to maintaining and building the capacity and vitality of the research enterprise. The awards are offered in all four major areas of VA research biomedical, clinical, rehabilitation, and health services.
- DOD has joined with NSF to enhance its successful program, Research Experiences for Undergraduates (REU), by providing additional support for disciplines important to national defense. REU provides students with early hands-on exposure to the research process, bringing their coursework to life with the excitement of discovery science.
- DOE Office of Science's Laboratory Science Teachers Professional Development Program is designed to create a cadre of outstanding

science and math teachers to serve as leaders and agents of positive change in their local and regional teaching communities. This three-year program will use the wealth of mentoring talent at the DOE National Laboratories to guide and enrich the teachers' understanding of the scientific and technological world. Through this program, teachers will establish long-term relationships with their mentor scientists and teaching colleagues, who will continue to support the educational efforts of the teachers when they have returned to their classrooms.

### Impact

An adequate education in math and science is increasingly important for all our citizens. The highly skilled scientific and technical workforce of the future will need strong preparatory programs, must draw on the talents of the full diversity of our nation's population, and will be enlivened by international collaboration and exchange. Through these and other education and workforce activities, the Federal research agencies are actively engaged in ensuring our continued world leadership in research and development and the national benefits that result from a highly skilled workforce and an engaged citizenry.



NASA

### Bringing science to life

Since June 2003, students, administrators, and teachers from 50 diverse, underserved schools have joined with NASA in a three-year partnership to promote science, mathematics, technology applications, and career explorations. The NASA Explorer Schools (NES) program provides the opportunity for teachers and education administrators who serve grades 4–9 to participate in professional development and educational activities using NASA's unique content, experts, and resources. During the partnership, the school teams receive grant funds to support the integration of technologies that increase student engagement in science and mathematics. In May 2004, one teacher and

Students from NASA Explorer Schools work with NASA education specialists.



two students representing every NES school team presented findings from their science or mathematics investigations during the program's first year at the NES Student Symposium held at NASA's Kennedy Space Center. ■





# A SHARED VISION

We have outlined four broad Federal science responsibilities: ensuring a diverse portfolio of fundamental research, science to support society's pressing challenges, the translation of science into concrete benefits, and the education of the next generation in math and science. We have discussed the policies that are in place to address these responsibilities and presented an array of accomplishments and ongoing activities that, together, define a Federal agenda for science in the 21st century. It is important to have this clear agenda, because science is a critical element of the larger enterprise that will ensure our future security, prosperity, health, and quality of life.

Clouds and sun glint over the Indian Ocean from space.

### A National Priority

Science has always been a national priority. The Federal research enterprise has enjoyed non-partisan support since the Second World War, and the benefits of this scientific research are well recognized. Although we have never been able to foretell specific outcomes when we engage in discovery science, we have seen that it consistently leads to valuable results. We also engage in science that is directed to addressing specific national challenges and pursue methods to accelerate the translation of science into products and applications. Federal research programs provide educational opportunities and inspiration for the young scientists and educators who will help shape our future.

Currently, the enormous potential for discovery at the intersection of disciplines and the demand for large-scale investments place a high premium on developing a shared commitment to our common priorities. The Federal science enterprise, augmented by partnerships with our great national resources in academia and industry,



JAMES GATHANY, CDC

**A CDC biologist works with an electron microscope at the National Center for Infectious Diseases.**

represents a huge reservoir of information, capability, and infrastructure. Collaborative planning, the fostering of existing partnerships, and the forming of new partnerships, both nationally and internationally, must be ongoing priorities.



HUNTSVILLE CONVENTION & VISITORS BUREAU

**Children at Space Camp contemplate future careers in science and technology.**

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### **Our Challenge for the Future**

The challenges and opportunities we face are in some ways indicative of our age and in other ways, timeless. Our strategies evolve as we learn from our successes and mistakes and improve on our processes. In the 21st century, as in the past, we convene the best minds in the scientific community to look at the challenges, consider our capabilities, evaluate the opportunities, and chart an optimal course. As we move into the future, international and intergovernmental cooperation and exchanges will be increasingly important. The responsibilities, policies, and programs mentioned in this report are elements of this continuing process to keep the Federal science enterprise aligned with scientific opportunity and global realities.

We have stated our critical responsibilities as Federal research agencies and detailed our processes to meet these responsibilities. We now challenge ourselves to advance the frontiers of science in all disciplines and to vigorously pursue science that can be employed to address societal challenges. We trust that this vision for the nation's scientific enterprise will stimulate us to continue to yield a very high rate of return for the public investment in science as we engage with the community of scientists, business leaders, policy makers, and the broader public in addressing the critical issues, collective aspirations, and the dreams of the 21st century. ■



## List of Agency Abbreviations and Acronyms

CDC	Centers for Disease Control and Prevention
CIA	Central Intelligence Agency
DHS	Department of Homeland Security
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOJ	Department of Justice
DOL	Department of Labor
DOT	Department of Transportation
ED	Department of Education
EPA	Environmental Protection Agency
FBI	Federal Bureau of Investigation
FDA	Food and Drug Administration
FCC	Federal Communications Commission
HHS	Department of Health and Human Services
NASA	National Aeronautics and Space Administration
NGA	National Geospatial-Intelligence Agency
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NSTC	National Science and Technology Council
OMB	Office of Management and Budget
OSTP	Office of Science and Technology Policy
PCAST	President's Council of Advisors on Science and Technology
USDA	US Department of Agriculture
USGS	US Geological Survey
VA	Department of Veterans Affairs

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