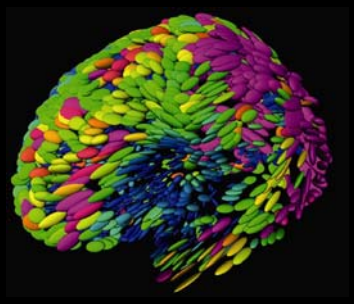
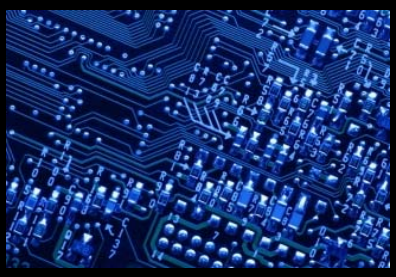
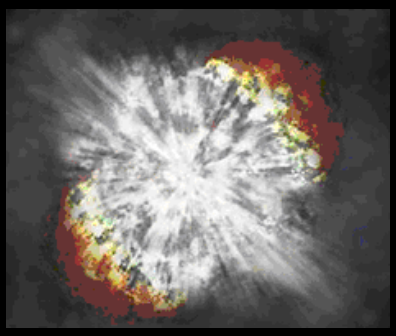
# REPORT OF THE ADVISORY COMMITTEE FOR GPRA PERFORMANCE ASSESSMENT

# FY 2008







**SUBMITTED: JULY 31, 2008**


**DAVID B. SPENCER, SC.D.**

**CHAIR**

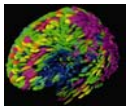
**SHARON DAWES, PH.D.**

**VICE CHAIR**

## Advisory Committee for GPRA Performance Assessment (AC/GPA)

The Advisory Committee for GPRA Performance Assessment (AC/GPA) was established in June 2002 to provide advice and recommendations to the NSF Director regarding the Foundation's performance under the Government Performance and Results Act (GPRA) of 1993. The Committee meets annually to assess the Foundation's overall performance according to the strategic outcome goals in the NSF Strategic Plan for FY 2006 – 2011. The Committee has responsibility for assessing the three strategic outcome goals of Discovery, Learning, and Research Infrastructure. The Committee is comprised of representatives from academia, industry, and government research organizations. This report was compiled by the Chair, David Spencer, and the Vice Chair, Sharon Dawes, from contributions from all Committee members. It features an Executive Summary with conclusions and recommendations, followed by detailed evaluations organized by strategic goal.

## Cover Photo Information and Credits



Composite image of brain MRIs.
*Credit: Image courtesy of Dr. Paul Thompson, National Institute of Biomedical Imaging and Bioengineering, University of California, Los Angeles.*

Jerome Babauta, Washington State University senior, working with Nigerian students in engineering class. Babauta's work in Nigeria is supported by the Office of International Science and Engineering.
*Credit: Van Wie Research Group, Washington State University*

Image of a printed circuit similar to those used in modern electronics. Model checking, a system for checking the accuracy and reliability of computers and software, has made it possible to create more advanced computer-aided devices that we can depend on in our day-to-day lives.
*Credit: Copyright 2008 JupiterImages Corporation*

Illustration of a supernova explosion. Three exceptionally luminous supernovae explosions have been observed in recent years. One was first observed using a robotic telescope at Caltech's Palomar Observatory. Data collected with Palomar's Samuel Oschin Telescope was transmitted from the remote mountain site in southern California to astronomers via the NSF-funded High-Performance Wireless Research and Education Network (HPWREN). The Nearby Supernova Factory research group at the Lawrence Berkeley Laboratory reported the co-discovery of the supernova, known as SN2005gj. Researchers in Canada have analyzed this, along with two other supernovae, and believe that they each may be the signature of the explosive conversion of a neutron star into a quark star.
*Credit: NASA/CXC/M.Weiss*

Melting sea ice in the Arctic Ocean.
*Credit: J. Harbeck, University of Alaska, Fairbanks*

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# Advisory Committee for GPRA Performance Assessment (AC/GPA)
# 2008 Membership List

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# EXECUTIVE SUMMARY

**It is the unanimous judgment of the 2008 Advisory Committee for GPRA Performance Assessment (AC/GPA) that the National Science Foundation successfully met its performance objectives by demonstrating *significant achievement* for each of the following three long-term, qualitative, strategic outcome goals in its 2006-2011 Strategic Plan:**

- **DISCOVERY**: Fostering research that will advance the frontiers of knowledge, emphasizing areas of greatest opportunity and potential benefit and establishing the nation as a global leader in fundamental and transformation science and engineering.
- **LEARNING**: Cultivating a world-class, broadly inclusive science and engineering workforce, and expand the scientific literacy of all citizens.
- **RESEARCH INFRASTRUCTURE**: Building the nation's research capability through critical investments in advanced instrumentation, facilities, cyberinfrastructure and experimental tools.

Further details on the performance evaluation, including several performance or program "highlights" as outstanding examples within the portfolio of projects funded, are presented in subsequent sections of this report. Those sections represent the deliberations of three subgroups organized according to the three goals. Based on the deliberations of each subgroup, and after discussion and evaluation by the Committee as a whole, the performance opinions of each subgroup were supported unanimously by the entire AC/GPA Committee.

The Committee did not form an assessment or opinion of NSF's performance under the fourth goal: *Stewardship*, which is: *to support excellence in science and engineering research and education through a capable and responsive organization*. Performance outcomes under Stewardship are reported using a number of measures and milestones developed internally within NSF.

The Committee's assessments were made during its June 19 and 20, 2008 meetings to consider the activities and achievements of NSF relative to its performance under the Government Performance and Results Act (GPRA). Our charge was to assess NSF's performance with regard to the three long-term strategic outcome goals for FY 2008 using primarily performance highlights prepared by NSF program officers and staff and to provide a report to the NSF Director. We were also charged, at our option, to discuss three additional topics: transformative research, broadening participation and societal benefits of NSF investments.

The 2008 AC/GPA was comprised of 20 members, each of whom had strong academic credentials and substantial experience in academia, government, and/or industry. More than half the AC/GPA members presently serve on advisory committees within the Foundation. As a group, the Committee is familiar with NSF processes and procedures

and, as individuals, the Committee members have personal experience with NSF and a wide range of its programs.

## NSF Response to 2007 AC/GPA Recommendations

A key part of overall performance is following up to be sure the agency has adequately responded to the prior year's recommendations. The recommendations of the 2007 AC/GPA Committee are categorized as follows:
Summary of FY 2007 Recommendations

1. *Development of AC/GPA Evaluation Criteria and a Performance Assessment Framework:* Establish evaluation criteria and a framework within which NSF's overall performance goals could be better assessed and both select and organize program highlights within that framework cutting across all significant activities and investment priorities of the agency.
2. *Enhancing "Broader Impacts" of NSF Research through "Broadening Participation":* Establish initiatives and formalized programs to bring about more emphasis on enhancing participation by minorities and those underrepresented in science, technology, engineering, and mathematics (STEM) fields. This would apply to investigators and universities and would also extend geographic representation.
3. *Transformative Research*: While recognizing that the agency is already focused on conducting *high risk / high reward* programs, the Committee felt that the term "transformative research" lacked adequate definition, and that existing "selection" processes and systems within NSF would need to be modified to further encourage award of these relatively undefined types of programs that have uncertain outcomes.

The Committee is pleased to report that each of these recommendations has been fully addressed, or is being addressed, by NSF staff and NSF management to the satisfaction of the Committee.

Regarding the first recommendation, NSF staff developed specific evaluation criteria within a well structured performance assessment framework. This was surely a difficult and time consuming task, but was necessary in preparation for our 2008 AC/GPA evaluation. The new framework for the 2006-2011 Strategic Plan was utilized this year and utilized successfully. We are pleased to report that the review process went much more smoothly this year as a result. The distribution of program highlights across each of the investment priorities and each of the performance criteria was sufficiently broad to give the Committee the information it needed to arrive at its opinions for each element of the framework, and yet deep enough to evaluate the adequacy of performance within each major goal.

Regarding *broadening participation*, the Chair was of the opinion that the initiatives in place were already quite substantial and over time should result in substantial outcomes and improvements. Because time is needed for these initiatives to take effect and produce results, this topic was not selected as a major topic of discussion for the

Committee this year, although it was included within the context of our overall performance discussions.

Regarding *transformative research*, the same was also true. The recently implemented definitions and transformative research initiatives appear fully responsive to the Committee's recommendations in 2007. All performance highlights included an assessment by program managers of the transformative nature of the research conducted.

## New review process for 2008: Committee of Visitor (COV) Reporting, Review, and Assessment

Every program across the Foundation must undergo an evaluation by a Committee of Visitors (COV) once every three years. Each COV, which is composed of active researchers in the field being reviewed, submits a detailed written report to the appropriate advisory committee. Each COV report generally contains extensive critiques of the division/program's effectiveness with regard to both "process" and "outcomes."

Each year the AC/GPA is provided with COV reports going back several years for its review. However, no formal AC/GPA review process has previously been established to focus on review of the COV reports – which might offer the opportunity for rich insights into agency performance processes and outcomes. Moreover, while program highlights present selected programs as examples of outstanding performance (e.g. "best of the best"), the COV process involves a random selection of program "jackets" for review and might be considered more representative of "average performance." It was hoped that as part of its due diligence efforts, a deep review of COV reports by an AC/GPA subgroup would provide a more representative and deeper understanding of NSF performance as compared to a review of selected performance highlights alone.

## 2008 Recommendations

### 1. Track Future Outcomes from "People" Trained and Supported by the Foundation

It is the Committee's unanimous opinion that the "outcomes" of NSF funding are not only the scientific results that come from the funded research activity, but also the training and commitment of the people involved – the people outcome. People who do the work of funded NSF programs, whether a project is successful or fails, learn from the process and become committed to careers in STEM research and innovation. This often results in a lifetime of future contributions which apparently is not being measured when we assess NSF performance outcomes year to year. These "people contributions" extend not only to the principal investigators, but also to the advisors and professors, particularly junior professors, who oversee the work, as well as to graduate students, staff, and other researchers. We observe that the current performance outcomes do not capture this essential "value added" aspect of NSF investments. We strongly recommend that NSF consider some way of capturing these longer term "development of people" outcomes too, which could well outweigh the technical outcomes or research results from a project.

### 2. Consider Ways to Convey the Long View of NSF Investments in Science and Engineering

Highlights are an excellent way to document and illustrate the breadth of NSF's investment in a wide variety of fields and disciplines at a particular point in time. However, Committee members also expressed interest in finding ways to demonstrate the long-term impacts of NSF support. By seeding new ideas, supporting novel approaches, and encouraging exploration of those ideas over substantial periods of time, NSF has supported both people and discoveries that have had profound impact on science and society. Some examples are biodiversity, nano sciences and engineering, and information and communication technologies. Together with NSF staff, we look forward to discussing ways to tell this deeper, more comprehensive story of scientific advancement supported by NSF funding.

### 3. Reconsider the Format and Value of COV Reports

The COV Subgroup read all 32 COV reports from 2006-2008 in full, discussed the results, and reported key findings to the Committee of the Whole. While the COV Subgroup reviewed Part A of each COV report, which addresses mostly process, it focused its efforts in particular on Part B, which addresses outcomes. In terms of process information reviewed, the Committee recommends that these reports be reviewed on an annual basis at the Director level in order to gain insight into common process issues that may affect performance on an agency-wide basis. In addition, the Committee concluded that Part B of these reports is not very informative and provides little, in fact far less, outcome information than the AC/GPA Committee receives in the performance highlights. Accordingly, the Committee believes that Part B of the COV reports should either be enhanced (which might not be feasible given the typical COV review process) or eliminated.

### 4. Continue to Improve Assessment Processes and Contextual Information Available to the AC/GPA

NSF has continually improved the processes by which the AC/GPA receives and reviews information about performance under the strategic goals. The Committee recommends that the methods and guidelines that program officers use to select and describe highlights be shared with Committee members as part of their preparation for the assessment to reduce time spent at the annual meeting educating new members regarding these processes and procedures. NSF should continue to provide access to other reports that it prepares or commissions, which would give the Committee a broader context in which to consider performance under the strategic goals. In addition, the presence of program officers during the Committee meeting is invaluable to members as they review and discuss the material under review, and this practice should be continued in future years.

## Acknowledgements

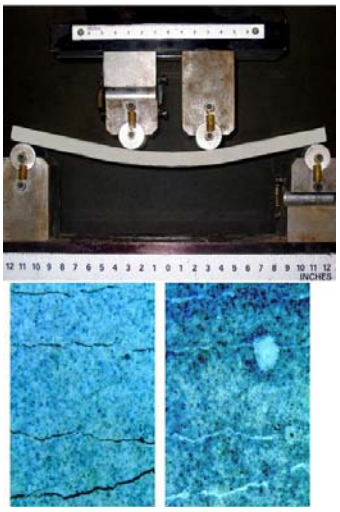
The Committee is most grateful to the NSF staff for the tremendous effort made in preparing the AC/GPA website and providing all the documentation which was assembled for review in advance of the formal meeting. There were many organizational meetings and subcommittee telephone calls needed to prepare our efforts so face to face meeting time could focus on group analysis, collaboration, and consensus building. In particular, we would like to extend our deepest gratitude to Pat Tsuchitani and Jennifer Brostek. They worked diligently to gather data, make arrangements, and help prepare and edit this report. They deserve personal recognition for their contributions to the processes and to the final product. We look forward to working with them again next year. We also thank Michael Sieverts for his insights and advice and presentations during the meeting. Lastly, we thank the NSF program staff for their thoughtful reporting of "highlights," and NSF's senior leadership, Dr. Arden L. Bement, Jr. and Dr. Kathie L. Olsen, for their commitment to this effort and for their insightful remarks at the end of our meeting.

# Reports from AC/GPA Subgroups

## DISCOVERY SUBGROUP

*The Committee concluded that there has been significant achievement for the Discovery outcome goal.*

### Introduction



The Discovery Subgroup of the Advisory Committee for GPRA Performance Assessment was asked to assess activities at the NSF in the area of Discovery. Specifically, it is a goal of the Foundation to "*Foster research that will advance the frontiers of knowledge, emphasizing areas of greatest opportunity and potential benefit and establishing the nation as a global leader in fundamental and transformational science and engineering"* (NSF Strategic Plan FY 2006-2011).

### Process Followed and Criteria Used

A total of 260 highlights, out of 929 highlights submitted by NSF staff, were randomly selected and reviewed by subgroup members. Subgroup members were each assigned 35-40 highlights to review, and were asked to select a few that stood out and demonstrate or exemplify NSF accomplishments under Discovery. In addition, the Chair (D. Apelian) reviewed the 669 highlights that were not selected and concluded that the selected highlights were a representative sample. The Chair also reviewed the highlights cited by Dr. Arden Bement, NSF Director, in his presentation to Congress on the FY2009 Budget (see: http://www.nsf.gov/news/speeches/bement/08/alb080204_budget.jsp).

The Subgroup was asked to review and evaluate the accomplishments against one or more of the following criteria:

**Research Grants** (grants that deal primarily with traditional investigator-initiated research projects):

- *Strengthen fundamental research across the full spectrum of science and engineering through support for NSF's fundamental or core disciplinary programs.*

- *Foster discoveries that have the potential to transform disciplines or fields of science, engineering, or education research.*

- *Promote innovation and partnerships with industries to stimulate the development of new technologies and processes to further U.S. economic competitiveness and benefit the Nation.*

- *Promote international collaboration among U.S. investigators and partners in other countries and regions.*

**Science and Engineering Centers:**

- *Enable academic institutions and their partners to integrate discovery, learning, and innovation on scales that are large enough to transform important science and engineering fields and interdisciplinary areas and stimulate increased innovation.*

Over and beyond the AC/GPA criteria, the Subgroup members felt that, for next year, it would be important to also consider two additional NSF investment priorities that are included in the 2006-2011 Strategic Plan, specifically:

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- *Investigate the human and social dimensions of new knowledge and technology.* NSF will integrate research on ethics, safety considerations, and virtual communities from the outset in new research and in the applications of emerging technologies.

- *Foster research that improves our ability to live sustainably on Earth.* To strengthen our understanding of the links between human behavior and natural processes, research may range from investigations of deep oceans to urban centers and from basic energy science to climate science.

## Results of Analysis

On the basis of the highlights analyzed, the Subgroup concludes that NSF has demonstrated significant achievement in meeting its goals in the area of Discovery. The 260 program highlights that we reviewed clearly demonstrate that NSF fosters research that advances the frontiers of knowledge and helps in establishing our nation as a global leader in fundamental and transformational science and engineering. The Subgroup selected the following highlights as examples of significant achievements in the area of Discovery:

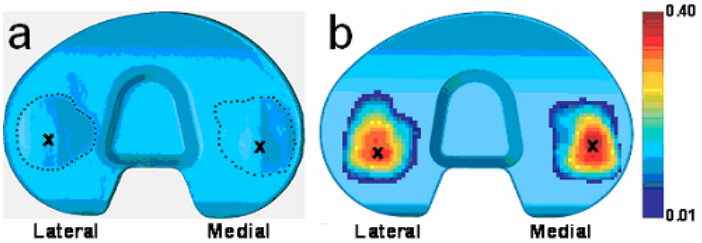
- ***Strengthen fundamental research across the full spectrum of science and engineering through support for NSF's fundamental or core disciplinary programs.***

It has been the conventional scientific wisdom for almost a century that magnetism in a given material opposes conventional superconductivity, such as that found in pure metals. Nobel laureates J. Bardeen, L.N. Cooper, and J.R. Schriefer showed that when superconductivity occurs the electrons in the metal form pairs. However, in

unconventional superconductors, such as high temperature ones, where materials are on the verge of being magnetic, the electrons causing superconductivity take a different collective form than those in conventional superconductors, but the superconducting mechanism is not yet understood. A project titled **Magnetism Meets Superconductivity** *(Highlight 15821; Award Number 0710492)* is a collaborative effort between Zachary Fisk's group at University of California, Irvine and investigators at Los Alamos National Laboratory and Dresden University in Germany, and explores the boundary between superconductivity and magnetism. In crystals of one of these unconventional superconducting materials, consisting of a combination of cerium, cobalt, and indium, both superconductivity and magnetism have been discovered to coexist. This research is an example of fundamental and transformative research that could lead to a completely new understanding of the mechanisms causing superconductivity in high-temperature superconducting materials. $CeCoIn_5$, discovered in this NSF-funded research, has proven to be an ideal material for studying physics at the magnetic/superconducting boundary. These revolutionary findings are a direct result of support for Dr. Fisk that began with NSF-DMR 7504019, when he was a beginning investigator. Long-term NSF support of his research on fundamental condensed-matter physics has led to exciting, important results and to the field of highly correlated electron systems. This result could benefit many electrical applications areas such as power transmission and electronics.

Two other projects that "strengthen fundamental research across the full spectrum of science and engineering" are CAREER (Faculty Early Career Development Program) Awards. Program officers who highlighted these projects indicated that the projects were not only transformative in nature, but also promoted broadening participation, and had societal benefits as well. The first of these projects is titled: **The High Fidelity of Human Image Representation** *(Highlight 16657, Award Number 0546262)*. Dr. Aude Oliva and her team in the Department of Brain and Cognitive Sciences at MIT are currently exploring a novel avenue to explain the feat of human visual understanding, testing human capacity at remembering visual details for a given image. Her work has demonstrated that human visual memory can encode a massive amount of visual details that is an order of magnitude higher than previously believed. These results challenge assumptions about efficient image representations, which is highly relevant to cognitive psychology, neuroscience, and computer vision. This study potentially could lead to much higher-performance artificial vision systems as well as better understanding of human visual processes, which have potential applications to consumer technologies and homeland security and defense. The project affords significant opportunity to examine the ethical and safety dimensions of new technologies that may emerge.

The second CAREER Award selected for this criterion is titled: **Virtual Prototyping of Artificial Knees** *(Highlight 16684, Award Number 0239042)*. Dr. Benjamin Fregly, University of Florida, and his team are addressing a growing need for the aging American population. By one estimate, 40 million Americans will be affected by osteoarthritis in the year 2020. It is felt that this project could lead to an entirely new



approach for designing knee replacements, and testing innovative designs using computer software rather than physical simulator machines. This work is unique because of its ability to predict long-term wear characteristics of knee replacement designs in a matter of minutes or hours using computer simulations. In terms of Broader Impacts, high school students from underrepresented groups have been involved in the knee research, through the University of Florida Summer Science Training Program. In addition, an orthopedic implant company has already enlisted the research team to participate in design of the next generation of knee replacements. Significant ethical and safety issues implicit in this study are ripe for further examination.

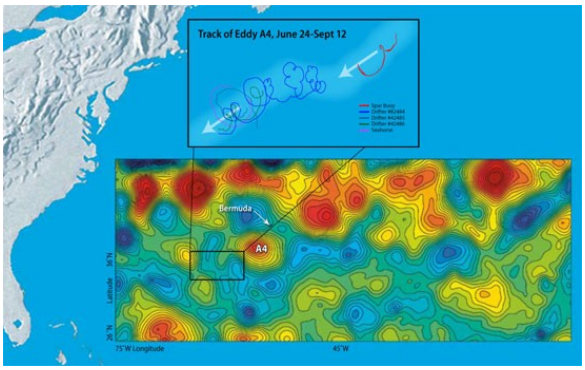
Cross-fertilization of ideas between disciplines can be transformative. Using control theory techniques originally developed for engineering applications, engineers are helping to transform medical treatment of cancer. The project **Control in Genetic Regulatory Networks: An Engineering Approach to Increase the Success Rate in Cancer Therapy** *(Highlight 15041, Award 0355227)* uses control theory from engineering to formulate the process of moving a cell from a diseased state to a disease-free state. The genetic regulatory networks were constructed from experimental data provided by collaborating biologists. The objective was to reduce the activity of certain genes at the tissue level by partitioning the probable outcomes of treatment strategies into good and bad regimes. The theoretically developed control algorithms performed significantly better in simulation studies than alternative approaches currently used. The project strengthens fundamental research in genomics using engineering analysis techniques of signal processing and control, and fosters discoveries whereby an engineering approach may transform medicine. In addition, this work promoted sufficient innovation to win a major follow-up grant from the W. M. Keck Foundation for validation experiments. Finally, it addresses the Strategic Plan goal of investigating the human and social dimensions of new knowledge and technology by transforming medical treatments in cancer.

- ***Foster discoveries that have the potential to transform disciplines or fields of science, engineering, or education research.***

Given the increasing frequency of tornadoes experienced today, new technologies to predict when and where tornadoes and other weather disturbances (floods, severe thunderstorms) will occur are of obvious importance. The NSF Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere (CASA), located at the University of Massachusetts at Amherst, has developed a method of weather sensing that utilizes dense, low-cost radar networks that can sense the lower atmosphere, an important area that is under-sampled by today's technologies *(***New Radar Network Evaluated in National Weather Service Experimental Warning Program**, *Highlight 15599, Award 0313747)*. The finely grained observations of the lower atmosphere obtained by the CASA researchers allowed forecasters to see small meteorological structures that are close to the

ground, such as mini-wind clusters that are embedded in larger storms. During the 2007 tornado season, CASA transmitted real-time data from its first prototype network in Oklahoma to National Weather Service forecasters for evaluation in the Experimental Warning Program. The Center's data will continue to be evaluated in the Experimental Warning Program during the 2008 tornado season. This research is multidisciplinary, requires a complex-systems approach, and involves collaboration between various universities and government agencies at many levels. The research is transformative because it will introduce a new dimension to weather forecasting and sensing, yielding capabilities that do not exist today. This highlight also represents broadening participation in that the faculty and students involved include many women and members of underrepresented minorities.

**Interactions Between the Wind and Oceanic Eddies Stimulate Higher Biological Productivity In Subtropical Ocean Surface Waters** *(Highlight 16578, Awards 0241310, 0241340, 0241023)* is a project led by Dr. Dennis McGillicuddy, Woods Hole Oceanographic Institution, with a team of collaborative investigators from eight different institutions. Oceanographers from these institutions have sampled two different types of eddies over a period of months using a sophisticated approach employing high-tech instrumentation to measure horizontal and vertical dispersion of several water properties. This research contributes to the fundamental knowledge about what factors control biogeochemical cycles and the conversion of carbon dioxide into biomass in the oceans. Their work has demonstrated that episodic eddy-driven upwelling may supply a significant fraction of the nutrients required to sustain primary productivity in the subtropical ocean. The results from this study are changing the view of how biological production and export of carbon to the deep ocean is taking place in the mid-ocean.



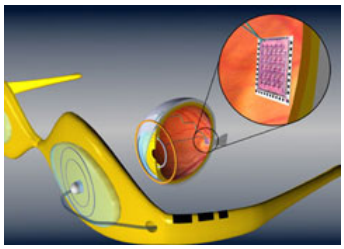

Fundamental research at the atomic level is still alive and well, and established wisdom continues to be challenged. A striking example of this is the preparation of "ultra-heavy" isotopes, magnesium-40 (normally Mg-24), aluminum-42, and aluminum-43 (normally Al-27). These extraordinarily heavy isotopes, created at the National Superconducting Cyclotron Laboratory at Michigan State University *(***Newly Created Forms of Magnesium and Oxygen***, Highlight 16189, Award 0606007)*, defy established theory, which predicts that they should not be stable. The results emerged from careful detection with enhanced techniques that allowed observation of one in one billion particles, an experiment that could not have been carried out without a user facility of this unique type.

A project, **Beware What's Unaware: Deep Impact of Subtle Distractions**, undertaken by Takeo Watanabe, a cognitive neuroscientist at Boston University *(Highlight 15885, Award 0549036)*, fosters discovery into the mechanisms of attention disorders by demonstrating how different regions of the brain interact. He found that participants had

more difficulty suppressing subliminal, low-coherence stimuli (randomly moving dots on a computer screen) when trying to focus on a particular task. This was demonstrated by imaging a particular area of the brain, Middle Temporal, (MT), which perceives motion. The project also simultaneously imaged another area of the brain, the dorsolateral prefrontal cortex (DLPFC), which is responsible for inhibiting responses in the MT. They found that the DLPFC area did not activate when presented with low-coherence stimuli, thereby causing activity in the MT area. They also showed more activity in the MT area with low-coherence stimuli than with high-coherence (coordinated) stimuli. This project has implications for understanding attention disorders in humans (as this research shows that subtler distractions are harder for the brain to screen out) as well as understanding how different regions of the brain interact. It may result in more efficient workplace design. This meets the evaluation criteria of strengthening fundamental research (in understanding better how different regions of the brain interact) and fostering discoveries that could transform cognitive research on attention disorders. Finally, it addresses the Strategic Plan goal of investigating the human and social dimensions of new knowledge and technology.

- ***Promote innovation and partnerships with industries to stimulate the development of new technologies and processes to further U.S. economic competitiveness and benefit the Nation.***

More than 25 million people around the globe, including six million in the United States, are visually affected by genetic retinal diseases. Researchers are working to help patients blinded by Retinitis Pigmentosa; the work involves development of a second generation prosthetic implant (ARGUS II) that will enhance the vision of individuals who have lost sight *(***USC Research May Help Patients Blinded by Retinitis Pigmentosa***, Highlight 15664; Award 0310723).* The new implant was developed by Dr. Mark Humayun's research team at the University of Southern California and Second Sight Medical Products Inc. The ARGUS II consists of a tiny camera and transmitter mounted on eyeglasses, an implanted receiver, and an electrode-studded array that is secured to the retina with a microstack the width of a human hair. A wireless microprocessor and battery pack powers the entire device. Six patients were implanted with earlier prototypes in 2002, and can now perceive light, distinguish between objects, and detect motion. The new implant contains nearly four times as many electrodes as the original (60 vs. 16), each of which is independently controllable, allowing patients to process higher-resolution images. Researchers hope the ARGUS II will be available in a few years and are currently enrolling subjects in clinical trials. This work is transformational in that it represents breakthroughs in microelectronics, image processing, and bio-engineering, which are likely to lead to radically new prosthetic technologies in other areas beside the retina. By 2020, some 50 million patients who have lost their sight due to genetic eye diseases that affect the retina are projected possibly to be able to regain some of their sight using a new retinal implant. The research also satisfies the NSF Strategic Plan's emphasis on broadening participation in that a number of key members of the research team are women. Finally, it demonstrates one of the investment priorities of the Strategic Plan



goal of investigating human and social dimensions of new knowledge and technology by developing products to give some level of sight to patients suffering from Retinitis Pigmentosa.

**Bendable Concrete for Safe, Durable, and Sustainable Infrastructure** *(Highlight 15376, Awards 0223971, 0329416, 0700219)* is a project by investigators at the University of Michigan who have designed a new type of concrete that maintains all the advantages of current concrete but adds ductility, allowing it to bend under stress without fracture. The new type of concrete has 300-500 times the tensile ductility of normal concrete; it can be bent without fracturing when overloaded. The material also exhibits self-healing properties, which further enhances its durability. The work may establish the United States as the global leader in "designer" cement-based composites. It also embodies collaboration among several sectors: government, industry, and academic partners. It has potential consequences in the design of sustainable structures resistant to earthquakes and weather events. This research also exemplifies the NSF Strategic Plan goal of integrating research on ethics, and safety considerations.

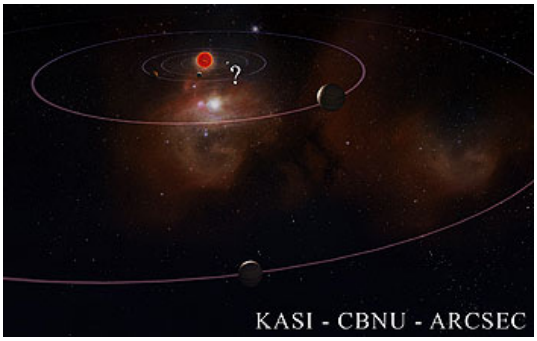
- ***Promote international collaboration among U.S. investigators and partners in other countries and regions.***

**Research and Education Experiences for Students to Examine Earthquake Hazard Mitigation Utilizing the Network for Earthquake Engineering Simulation (NEES)** is an excellent example of international collaboration *(Highlight 16728, Award 0526590).* Professor Richard Christenson and graduate and undergraduate students traveled to Thailand and Japan to conduct research in innovative ways to reduce structural damage arising from natural hazards, such as earthquakes. The visits and collaborative research in the two countries are enabling partnership building between United States, Thai, and Japanese institutions, and scientists who are engaged in the study of ways to create better designed buildings that can withstand strong forces during earthquakes and tsunamis, thus enhancing public safety.

The societal urgency of understanding impacts of global warming on sea level rise requires establishment of innovative observations and partnerships. In the project, **Sea Level Rise from Polar Ice Sheets: Societal Relevance and Broader Impacts** *(Highlight 14730, Awards 0122520, 0407827, 0424589)*, the Center for Remote Sensing of Ice Sheets (CReSIS) serves to join forces between U.S. universities (U. Kansas, Ohio State, Penn State, U. Maine, Elizabeth City State University, and Haskell Indian Nations University) and international collaborators from Denmark, Norway, Australia, the United Kingdom, and Iceland, and the Topeka K-12 school district. This team is transforming science and engineering fields by using satellite-based sensing of the earth with UAV (Unmanned Aerial Vehicle) and traditional airborne-based radar, along with seismic and other measurements with data products, modeling, and analysis to improve on current estimates of sea level rise resulting from global warming. The Nobel-Prize-winning IPCC (Intergovernmental Panel on Climate Change) 2007 estimates, which may under-predict the rate of future sea level rise, are based on traditional modeling of the ice sheets, which ignore rapid changes that may occur due to recently observed mechanisms of bed lubrication and ice shelf stability effects. CReSIS is integrating discovery and learning

via classroom activities developed for K-12 education, which are free and available to all via their website (https://www.cresis.ku.edu/), along with the Summer School for Teachers and PolarTrec, which increase classroom knowledge of climate change. This project has genuine partnerships with minority-serving institutions, which play integral roles in the discoveries and reporting of results. Finally, this work investigates human and social dimensions of new knowledge and technology by integrating discovery (better modeling of sea level rise due to the integration of various observations and data sets) and learning using K-12 classroom activities.

Going from the subatomic to the cosmological, astronomers collaborating from 11 universities have observed a new solar system analogous to ours but smaller in size that contains planets similar to Jupiter and Saturn (**Newly Found Solar System has Jupiter/Saturn Pair Similar to Ours, just scaled down**, *Highlight 16275, Awards 0206189, 0452758, 0708890*). The system was detected by "gravitational microlensing," in which light from another star is magnified by the passing of another body—in this case, the star detected—in front of it. Observations from the 11 different ground-based telescopes provided the sensitivity to observe the planets. The small size of the solar system compared to other exosystems suggests that solar systems like ours may not be rare. The work is an excellent example of an international collaboration, including participation of amateur astronomers.




Research stimulated by the devastation caused by tsunamis has revealed possible origins for their profound impact. Japanese and U.S. scientists (**"Ultrasound" of Earth's Crust Reveals Inner Workings of a Tsunami Factory**, *Highlight 16358, Award 0451790*) examining the seafloor near the southwest coast of Japan, where tsunamis are particularly prevalent, have found a major fault line that can trigger serious earthquakes, which are known to occur in that region. Core drilling also reveals that the fault line appears to have shifted landward over time, and has become shallower and steeper, conditions that are ideal for tsunamis. These multidisciplinary results, carried out through an international partnership, contribute to developing ways for living sustainably on Earth.

# LEARNING SUBGROUP

*The Committee concluded that there has been <u>significant</u> achievement for the Learning outcome goal.*

## Introduction

The Learning Subgroup of the Advisory Committee for GPRA Performance Assessment was asked to assess activities at the NSF in the area of Learning. Specifically, it is a goal of the Foundation to *"cultivate a world-class, broadly inclusive science and engineering workforce, and expand the scientific literacy of all citizens"* (NSF Strategic Plan FY 2006-2011).

## Process Followed and Criteria Used

The Subgroup read and analyzed 159 highlights classified under the Learning outcome goal. Each member of the Subgroup reviewed approximately 53 highlights.

The Subgroup was asked to review and evaluate the accomplishments against one or more of the following criteria:

**<u>Subgroup Members</u>**

Julio de Paula, (Chair)
Lewis & Clark College

Elaine Craft
SC ATE Center of Excellence

Maria Alicia Lopez Freeman
University of California, Los Angeles

Ira Harkavy
University of Pennsylvania

**K-12 Education**

- *Support research to improve science and engineering education, and education research that develops successful models for teaching and learning.*
- *Support active involvement of K-12 teachers in NSF-funded research and workshops to bring fundamental knowledge and technological innovations into their classrooms*
- *Prepare the next generation of STEM professionals and attract and retain more Americans to STEM careers.*

**Undergraduate Education through Postdoctoral Level**

- *Develop creative, new pathways to engage students and researchers at the frontiers of discovery to facilitate their entry into the science and engineering workforce and enhance the skills and knowledge needed to advance their early careers.*
- *Broaden the participation of individuals underrepresented in STEM and diverse institutions throughout the United States in NSF-supported research and education activities and programs.*
- *Support community college faculty in NSF-funded research to bring fundamental knowledge and technological innovation into their classrooms.*
- *Support active research participation by undergraduate students in NSF-funded projects.*

- *Provide opportunities for international research experiences that enhance and strengthen undergraduate and postgraduate education.*
- *Prepare the next generation of STEM professionals and attract and retain more Americans to STEM careers.*

**Public Understanding of STEM and Lifelong Learning**

- *Increase interest, engagement, and understanding of science, engineering, and technology by individuals of all ages and backgrounds and within a variety of different formal and informal educational settings.*
- *Prepare and support the next generation of STEM professionals and attract and retain more Americans to STEM careers.*

## Results of Analysis

The Subgroup selected the following highlights as examples of significant achievements in the area of Learning:

A significant number of projects contributed to creating a pre-school to postdoctoral STEM pathway that engages learners across all levels of schooling, involving learners in hands-on science, broadening participation, and increasing scientific literacy across age groups and backgrounds. Two examples are particularly telling of the cross-cutting nature of some of the initiatives in the portfolio.

**Vast Facility in Appalachia Brings Students, Researchers Together (***Highlight ID 16111, Award 0520928)* describes a facility in Appalachia that studies cosmic ray sources. The project engages high school and college students in scientific research and outreach activities to members of the community. The location of the facility is unique, providing first-time access to advanced instrumentation for populations without a robust tradition of scientific research: students are given opportunities to make genuine and exciting discoveries. In sum, this project integrates successfully education, research, and societal benefit.

Another example is given in **New Flight Simulator Environment Engages Students in Interdisciplinary Research at Historic Tuskegee University** (*Highlight ID 15039, Award 0411464*), which describes a multidisciplinary, collaborative effort at Tuskegee Institute. The Flight Simulator Environment brings together aerospace engineers and psychologists in a quest to understand ways in which pilots make decisions during flight. Research on the topic was conducted by twelve Tuskegee students, and their work has great potential for societal impact, especially in the area of public safety.

In addition to these all-encompassing examples of excellence, the Subgroup also has identified projects that speak specifically to K-12 education, undergraduate education through postdoctoral level, and public understanding of STEM and lifelong learning.

## K-12 Education

The portfolio of highlights provides many examples of work that engages learners across all levels of schooling and prepares K-12 teachers to create and deliver meaningful STEM curricula.

The enrichment of K-12 students through research experiences is an important theme found in the highlights. The work summarized in **Scientists and Students Online: An Oceanographic Expedition to the Indian Ocean** (*Highlight ID 16357*Award 0652315) exemplifies integration of pre-college students in a cutting edge research project through real-time tracking of an oceanographic expedition to the Indian Ocean. This ingenious use of the web resulted in increasing numbers of students tracking and participating in learning activities connected with the expedition. **COSMOS Students Become Rocket Scientists** (*Highlight ID 16417, Award 0602286*) describes a summer residential program at the University of California, San Diego (UCSD) that brings together high school students, undergraduates, graduate students, postdoctoral fellows, and faculty at UCSD with a focus on rockets.

The development of teachers is also an important feature of the portfolio. A Robert Noyce Scholarship program summarized in **Noyce Scholars Prepared to Teach in High-Need Schools** (*Highlight ID 14873, Awards 9852170, 0733849*) addresses the need to attract and retain the next generation of STEM professionals. The program has recruited 63 new math and science teachers to teach in high-need school districts in California, and 65 percent of the scholars have been drawn from underrepresented populations. In another similar example, **Vanderbilt University Biomedical Engineering Research Experience for Teachers** (*Highlight ID 15384, Award 0338092*), 44 teachers participated in a 24-day summer program with academic year follow-up. They completed a research project in a biomedical engineering laboratory, designed instructional units based on that research experience, and implemented them in their high school classrooms.

**Project SEEDBed** (**Stimulating Enthusiasm, Exploration, and Discovery through Biotechnology Education),** *(Highlight ID 14893, Award 0602744*) engages students and teachers from middle and high schools in summer academies at community colleges designed to increase knowledge, stimulate interest in biotechnology among students and teachers, and encourage students to pursue further study, possibly leading to careers as biotechnicians. Teachers are provided with "footlockers" to take back to their classrooms, with all of the equipment necessary to conduct new laboratory activities. Evaluation data indicate significant impact on both students and teachers.

In the project described in **Bringing an Atomic Force Microscope to School** (*Highlight ID 16213, Award 0653346*) high school teachers learn science through serious engagement with University of Wisconsin-Milwaukee faculty, with the science of CD-ROMs and DVDs as the focus. The effective and exciting use of technology in instruction is accomplished through classroom visits by UWM faculty who bring an Atomic Force Microscope to high schools as part of their instruction on the inner workings of CD-ROMs and DVDs. Broadening participation occurs through involvement of high school teachers.

A number of highlights summarize important work that teaches science in cultural context. **BPC-DP: New Voices and New Visions for Engaging Native Americans in Computer Science** (*Highlight ID 16501, Awards 0539982, 0540484*) describes a highly innovative pilot project that integrates Native American culture and experience with computer science. High school and college level students use computing to illustrate and display Native American art and culture to wider publics. By using the computer in culturally affirming ways, students are attracted to computer science and hopefully STEM work in general. The project should result in increasing the participation of Native Americans in computer science. It also illustrates the effective use of the computational sciences as a window for learning about arts and culture, as well as the use of arts and culture as a vehicle for attracting students to computer science. The project, if successful, should be highly replicable across regions and cultures.

**WolfQuest: Learning Science through Game Play** (*Highlight ID 15717, Award 0610427*) is a project that brings wolf behavior and ecology to life through exciting game play and intense social interactions for youth who are not normally attentive to ecological concepts and conservation issues. The WolfQuest game (www.wolfquest.com) represents a new model for informal science learning with practical, cultural, and ethical values embedded in the game's design. With an engaging online forum for learner-generated content, including art, stories, photos, and videos, WolfQuest has created a safe and engaging arena for youth. Removing the formal barriers typically found between scientists and the public, youth can talk directly with the world's leading wolf researchers as scientist role models. Striving to create new forms of science learning, in WolfQuest learners must engage experientially in authentic scientific problem solving using their reasoning skills to figure out complex scenarios regarding wolves and wolf survival without any external guidance. Because of its unique learning strategies, WolfQuest will aggregate data on learners' science content acquisition, attitudinal change, game engagement, and will ultimately yield new guidelines on effective practices for the future development of science education games and appropriate methodologies for evaluating game-based learning.

## Undergraduate Education through Postdoctoral Level

A number of highlights described alternative pedagogical approaches to undergraduate science education. For example, a project summarized in **From Sausages to Skateboards** (*Highlight ID 15221, Award 0431756*), measured the impact of teaching real-life applications in undergraduate mechanical engineering courses. The research demonstrated that the use of applications had a positive impact on final course grades only when the whole course was applications based. Students in the application-based course had significantly higher final course grades than comparison students matched by instructor and course who did not receive application-based teaching or when only two or three applications were used during a course.

In a similar vein, **An Infrastructure for Designing and Conducting Remote Laboratories** *(Highlight ID 16031, Award 0326309*), describes a project consisting of an online laboratory environment that supports experiments based on multi-player computer game engines. This project aims to conceive, design, implement, test, and assess various online laboratory resources for undergraduate engineering and science education based on the use of advanced information technologies and of the rapidly expanding cyberinfrastructure. These online laboratory resources include remote experiments, virtual experiments, and virtual learning environments. Cyberinfrastructure-enabled educational tools such as this online laboratory environment show strong potential for initiating a dramatic shift in the general educational paradigm where the interactions between learners and educational resources as well as between

The portfolio has many examples of programs aimed at populations of students currently underrepresented in STEM disciplines (*Highlight IDs 14876, 15287, 15299, 15304, 15345, 15350, and 15389*). However insufficient data are provided to assess fully the outcomes and broader impacts of these initiatives. That having been said, some examples do stand out. A program at a university in Texas (**Undergraduates Discover the Thrill of Research**, *Highlight ID 15007, Award 0344221*) emphasized learning through discovery rather than by development of specific technical skills. The approach demonstrated success with inquiry-based exposure to scientific research, and the pilot group of 16 students won first place in a college-wide competition. In addition, two students from the group received awards for research presentations at the Louis Stokes Alliances for Minority Participation Program. Likewise, **Flying High in Louisiana** (*Highlight ID 16198, Award 0653423*), describes a curriculum revolving around small balloon science experiments and flight. These activities are designed to attract students from underrepresented groups into STEM programs and develop partnerships between Louisiana State University and local minority serving institutions. The students develop and conduct science experiments involving physics and thermodynamics. They create, launch, and bring to earth balloon

vehicles. The project involves minority youth in creative experiments, exposing them to physics and the process of scientific research.

Project Pathways (**Community College Students Discover Rare Mushroom in Texas**, *Highlight ID 15403, Award 0525536*) is a community college research project that has increased the number of students who obtained associate degrees or transferred to baccalaureate programs in science, technology, engineering, and mathematics (STEM) disciplines. Eastfield College students participate in research projects with various agencies. Some students were placed with U.S. National Park Service researchers and others in collecting data for the All Taxa Biodiversity Inventory of the Big Thicket. These data are used for national strategic planning related to a host of environmental issues. Additionally, the students collect data for their own research projects in biological areas of their choosing including botany, entomology, mycology, and ichthyology. The expedition to the Big Thicket enabled genuine scientific discoveries by students at the community college. Eastfield College is primarily a Hispanic serving institution. The students participating in Project Pathways are mostly first generation college students, women, African-American, Hispanic, or students with disabilities. The program often provides these students with critical first experiences in STEM. This project also illustrates how community colleges enhance infrastructure with major scientific instrumentation to integrate research and innovative teaching that advances discovery and scientific understanding for early undergraduates.

A very good model for global engagement of STEM students is NanoJapan (**Rice University PIRE Program Feated as Best Practice in International Education**, *Highlight ID 15598, Award 0530220*), a program of 12-week research internships in Japan for undergraduate engineering majors that has been awarded the 2008 Andrew Heiskell award for innovation in study abroad by the Institute for International Education. The NanoJapan program sends a diverse group of sixteen first and second year engineering majors from U.S. universities to leading edge nanotechnology laboratories throughout Japan to work with Japanese teams on research projects related to carbon nanotube fabrication. NanoJapan serves as a model for increasing study abroad and for participation of students in science and engineering fields. NanoJapan allows students to gain both experiences. Internships with world-class researchers in state-of-the-art facilities allow students to enhance engineering and research skills while building the cultural understanding, adaptability, and networks necessary to succeed in the global marketplace. This program has strong potential benefits in workforce development. In addition, the exposure of budding engineers to world-class nanotechnology expertise and facilities in Japan can be expected to enhance research and industrial engineering in the United States as participants advance in their careers.

Also noteworthy are the Pan American Advanced Studies Institutes (PASIs), which are jointly funded by the Department of Energy and the NSF (**Better (and More Sustainable) Living with Green Chemistry**, *Highlight ID 15261, Awards 0221274, 0617357*). A Sustainability and Green Chemistry PASI, organized by Dr. Mary Kirchoff of the American Chemical Society, was held in Mexico City, Mexico. Fifty-five graduate and postdoctoral students, nine local participants, and fourteen faculty members representing chemistry, pharmacy, biotechnology, packaging, genetics, nanotechnology,

and chemical, civil, environmental, and geo-environmental engineering participated in interdisciplinary activities and research to advance their knowledge of green chemistry and green engineering. Participants received educational materials and project ideas that could be implemented at their home university and within their local community. This project is an exemplar of interagency collaboration, global engagement, broadening science and engineering knowledge for sustaining the earth, and education extending to the postdoctoral level.

### Public Understanding of STEM and Lifelong Learning

The portfolio is rich in examples of projects that enhance public understanding of science and engineering. Here we focus on three particularly innovative programs that cut across age groups. CYBERCHASE (**NSF-Funded CYBERCHASE Wins Emmy,** *Highlight ID 14955*, *Award* 0638962) is a ground-breaking multi-platform children's program on PBS KIDS GO! that shows the connection between mathematics and the invention process. The content spans the 3rd-5th grade standards of the National Council of Mathematics. The program has been awarded a daytime Emmy and reaches nearly five million viewers each week. It has recorded more than 1.7 billion page views for CYBERCHASE Online (http://pbskids.org/cyberchase/). Importantly, research shows that viewers take away the mathematics content of the episodes they watch and visitors spend more than an hour at the site on the average visit.


**The Coalition on the Public Understanding of Science – COPUS** (*Highlight ID 15556*, *Award* 0628790) is organizing the Year of Science 2009, a national year-long celebration of science to engage the public in science and improve public understanding about the nature and processes of science. COPUS is a growing network with over 180 registered participants that include professional societies, government agencies, business, universities, museums and informal science centers representing all major science disciplines. The network has an active website with information about the organization, national events, resources, and new participant registration. The database allows the public to search for COPUS related activities based on type, location, discipline, and target audience. To better coordinate COPUS activities, the network participants are organizing in regional and thematic hubs that will facilitate the interaction among network participants with common goals.

**sLowlife: A Traveling Exhibit of Plant Science and Art** (*Highlight ID 15586Awards* 0080783, 0416741, 0531641) is a novel multi-media educational/art installation including video, live plants, photographic prints, and interactive environments, originally designed by plant biologist Dr. Roger Hangarter in collaboration with an artist, Dennis Dehart. The exhibit highlights the research of Dr. Hangarter and is designed to convey to a public audience that plants are complex living beings and not just the ornamental inanimate objects many people assume. By combining time-lapse movies with artistic elements that demonstrate various plant movements and growth responses, the exhibit accurately and effectively combines science and art in a way that provides scientists and non-scientists

with a novel way of learning some basic plant biology and an appreciation of the dynamics of plant growth and movement. Contemporary research approaches, including a striking presentation of a genetic screen for tropism mutants in Arabidopsis, use of microarrays to understand plant growth, use of green fluorescent protein (GFP) to visualize the cytoskeleton, and views of chloroplast movement are mixed with classic experimental and educational demonstrations. With written commentary kept to a minimum, the visual impact of plants and experimental data dominates the experience in this novel exhibit.

# RESEARCH INFRASTRUCTURE SUBGROUP

*The Committee concluded that there has been significant achievement for the Research Infrastructure outcome goal.*

## Introduction

The Research Infrastructure Subgroup of the Advisory Committee for GPRA Performance Assessment was asked to assess activities at the NSF in the area of Research Infrastructure. Specifically, it is a goal of the Foundation to *"Build the nation's research capability through critical investments in advanced instrumentation, facilities, cyberinfrastructure and experimental tools"* (NSF Strategic Plan FY 2006-2011).

## Process Followed and Criteria Used

**Subgroup Members**

Mary Ellen Sheridan (Chair)
University of Chicago

Jorge L. Diaz-Herrera
Rochester Institute of Technology

Samuel M. Rankin, III
American Mathematical Society

The Research Infrastructure Subgroup reviewed 115 highlights classified under this goal. Each member of the Subgroup reviewed approximately 35-40 highlights. Highlights selected for inclusion in the report for this strategic outcome goal reflect the broad diversity and functional objectives of investments under Research Infrastructure.

The Subgroup was asked to review and evaluate the accomplishments against one or more of the following criteria:

**Major Multi-user Research Facilities**

- *Promote discoveries at large multi-user research facilities supported by NSF which may be centralized or may consist of distributed installations. These facilities may incorporate large-scale networking or computational infrastructure, multi-user instruments or networks of such instruments; or other infrastructure, instrumentation, and equipment having a major impact on a broad segment of a scientific or engineering discipline. This category includes accelerators, telescopes, research vessels, aircraft, and geographically distributed but networked earthquake engineering simulation equipment.*

**Instrumentation**

- *Provide tools, instruments, and facilities to enable the STEM community to conduct research that could not otherwise be performed without this advanced instrumentation infrastructure.*
- *Expand opportunities for U.S. researchers, educators, and students at all levels to access state-of-the-art science and engineering facilities, laboratory*

*instrumentation and equipment, databases, and advanced computing resources, research networks, and other infrastructure.*

**Cyberinfrastructure**

- *Enable discoveries facilitated by world-class cyberinfrastructure that drives discovery in all fields of science and engineering.*
- *Explore the use of potential cyberinfrastructure in integration of research and education.*

## Results of Analysis

Research Infrastructure encompasses the entire scope and scale of science, mathematics, technology, and education, enabling the conduct of leading-edge research while educating the next generation and future generations of scientists and engineers. Imagine funding the discovery and development of probes that can detect the most singularly quantifiable constituents of the nucleus of an atom or production of an educational video that describes the "life" of a single electron that travels around any nucleus. Research infrastructure has evolved to a point where scientists and engineers can develop and use instrumentation and probes to study phenomena that are smaller than a single strand of hair. At the other end of the spectrum, research infrastructure supports construction, maintenance, and upgrades for telescopes that explore galaxies "far, far away," where distance is measured in millions of light years. While grade school children are using desk top computers and digital hand-held games that have more computing power than mainframe computers of a generation ago, researchers advancing the frontiers of cyberinfrastructure are developing hardware that together with software and communication systems enables petascale computing power. That's one million billion [$10^{15}$] operations per second – virtually an incomprehensible much less imaginable number if the results weren't there to be reckoned with. For example, a million billion seconds would work out to be 32 million years.

The significance of the Research Infrastructure goal is easier to grasp if one thinks of these investments as the critical facilities, tools, and resources that breach the boundaries of yesterday's research and educational programs and enable new and more challenging questions to be answered while enriching educational experiences for graduate students and postdoctoral scholars. NSF's Research Infrastructure investments are on the seas with ships carrying equipment and investigators to and from the Antarctic, and under the seas with submarines that explore the seabed. They are on virtually every continent with telescopes, particle detectors, and cyberinfrastructure collaborations. In addition to petascale computing tools, NSF also supports the preparation of searchable digital libraries and enormous databases that offer better teaching aids for K-12 teachers and students, or facilitate storm prediction or atmospheric modeling for the most challenging research questions. Predominantly undergraduate institutions benefit from Research Infrastructure investments in advanced instrumentation and programs that offer targeted research experiences for high school and college students to attract and train American students in science, technology, engineering, and mathematics (STEM) disciplines. Research-intensive institutions and special subject centers receive funding from NSF to

develop new research tools and to apply unique research capabilities targeted to practical purposes that will benefit the public. NSF's Research Infrastructure portfolio also includes the collection and analysis of data related to STEM for public information and national science policy analysis; NSF's Science and Engineering Indicators 2008, the foremost compendium of quantitative STEM data, is regarded internationally as the gold standard of such reports. The flavor and vast impact of some of these extraordinary "enablers" in each of the programmatic areas is highlighted below. The Subgroup selected the following highlights as examples of significant achievements in the area of Research Infrastructure.

### Major Multi-user Research Facilities

NSF's major multi-user facilities primarily benefit scientific inquiry while providing opportunities for integrating education and research. How safe is a modern-day operating hospital room in a moderate to severe earthquake? Investigator from SUNY at Buffalo (**Hospital Room Shook Up in First Seismic Experiment of Its Kind**, *Highlight 14938*, *Awards 0429331 and 0402490*) used the Buffalo Structural Engineering and Earthquake Simulation Laboratory to explore the impact of shaking on nonstructural elements such as portable equipment, wall-mounted EKGs, ceilings, pipes, and internal walls in a model hospital room. Their findings will help hospitals to anticipate the impact and plan accordingly for the safety of patients and hospital personnel. Researchers at Stanford University (**Holding the San Andreas Fault in our Hands**, *Highlight 14818*, *Award 0323938*) have been amassing data from samples bored into the San Andreas Fault, the most notorious earthquake zone in the United States. Scientists are using these samples to better understand episodic tremors and slips – the little fault line activities that accumulate strain slowly along the Fault plates. For the West Coast residents who live with the San Andreas Fault as a neighbor, improved understanding of fault behavior is practical research with tremendous potential public

"**When Planets Collide**" sounds like a Star Wars movie plot or a GameBoy title. But this is the report of exciting observations by a team from UCLA and the Spitzer Science Center from NSF's Gemini Observatory, which supports telescopes in Hawaii and Chile for observing from both the Northern and Southern hemispheres (*Highlight 15617, Award 0525280*). Astronomers have found the first clear evidence of planet formation through observation of young stony planets which appear to have formed from a collision around one of the stars in the Pleiades clusters. Northern winter sky watchers recognize the Pleiades as one of the most brilliant star clusters.

### Instrumentation

A group of engineers at the National High Magnetic Field Laboratory at Florida State University (**Novel Technique to Study the Structure of Proteins**, *Highlight 16236*,

*Award 0084173)* have developed a novel probe that will permit the use of nuclear magnetic resonance (NMR) for the study of proteins that don't dissolve in water. These new tools are opening up a new frontier in protein structure determination.

**Development of an In-Line Cylinder Bore Inspection System** (*Highlight 15077, Award 0723669*) features an In-line Cylinder Bore Inspection System. This Small Business Innovation Research (SBIR) award to Industrial Optical Measurement Systems supported transformative research that replaces inefficient human visual inspection of cylinders of engine blocks with an automated total inspection of cylinder bore surface finish at the speed of a production line. This novel probe pushes automation and efficiency up a notch in the highly competitive automotive market with a potential to stem the market share loss of domestic producers.

In the midst of all this sophistication, there is also room in the NSF portfolio to explore good old-fashioned slime. For many youngsters, a little "play" with worms could be the pathway to a scientific career. The Nebraska State Museum teamed with a local academic lab to lead some middle schoolers for a romp through parasitology (**The Worms Crawl In, The Worms Crawl Out!**, *Highlight 15805, Award 0646356*). What's not to like about cuddly worms, a fair portion of yuck, lots of curiosity, an admirable "ick" factor, worm humor, and learning. This project demonstrates that attracting young people into scientific careers may begin with a real lab experience on a college campus. These students found out the getting a 'hands-on" worm experience was better than just watching "CSI." NSF continues these enriched experiences for potential STEM careers through programs at minority and primarily undergraduate institutions providing sophisticated research instrumentation and summer research participation programs to allow students to preview scientific and technical opportunities.

## Cyberinfrastructure

NSF's leadership in high performance computing is generating computing capacities and capabilities that approach petascale ranges. Solving problems at a scale that was unimaginable and beyond our reach just a few years ago is now within reach. NSF's investments help anticipate and resolve the real problems and challenges of petascale computing: storage, manipulation, and mining of massive amounts of data that rely on complex hardware architectures, networking of parallel computing power, and heroic software solutions.

**Computer Recognizes Facial Expressions Better Than Humans Can** (*Highlight 16396, Awards 0454233 and 0627822*) describes how researchers at the University of Buffalo and University of California, San Diego have developed the Computer Expression Recognition Toolbox that can be used by social scientists, education researchers, cognitive neuroscientists, and vision researchers. A particularly interesting

finding from their experiments was that automated classifiers were able to differentiate real pain from fake pain significantly better than inexperienced human subjects. Computers were able to detect driver drowsiness with more than 98% accuracy, perhaps telling us that computers can recognize facial expressions better than humans can. Research in these areas will also provide critical information for computer science and engineering efforts to make computers and robots that interact effectively with humans and understand nonverbal behavior.


Digital libraries offer delightful educational "shopping trips" for teachers and budding scientists. With **Chemistry Comes Alive**, (*Highlight 14835, Awards 0632303, 0632247 and 0632269*), a collaborative project between the University of Wisconsin and the American Chemical Society, the curious can observe dangerous chemical reactions and learn about demonstrations or experiments that rivet the attention of young students. Dramatic footage and supplemental educational materials make this a wonderfully attractive and easily accessible resource. This project addresses both the Research Infrastructure and Learning goals by providing teachers and students the opportunity to view a diverse array of chemical reactions that demonstrate concepts in chemistry.

Recent advances in computational linguistics enabled by NSF funding have produced the Sanskrit digital library (**International Digital Sanskrit Library Integration**, *Highlight 16177, Awards 0535207 and 0535038*). This resource challenged the most sophisticated computer scientists – because robust techniques involving recognition factors, selection, and mapping rules made this venture a veritable romp in computational linguistics. The digital Sanskrit tool and infrastructure provide an internationally accessible tool that will replace outmoded grammars, reference books, and other printer materials that will facilitate and broaden participation in linguistics research.

NSF's interest in accumulating massive data bases spans disparate fields, from aggregations of huge volumes of astronomical observations to atmospheric histories that promote challenging modeling and simulation research. Climate modeling has direct relevance for global climate change research and policy issues leading to factual, informed decision making. **Creation of a new satellite-based hurricane database** (*Highlight 15823, Award 0614812*) describes the development of the URSAT dataset which contains 170,000 storm-centered satellite observations in over 2,000 storms worldwide. Researchers at the University of Wisconsin and NOAA's National Climatic Data Center have developed the first global homogeneous record of tropical cyclone intensity estimates from 1978-2006. Hurricanes and tropical storms have a major impact on U.S. and global economy; this database may provide better insight into how increasing temperatures could affect the intensity of hurricanes and cyclones.

# COMMITTEE OF VISITORS (COV) REPORTING SUBGROUP

## Introduction

In an effort to support the outcomes assessment activities of this year's AC/GPA committee, the COV Subgroup was charged with reviewing the Committee of Visitors reports that have been submitted to and accepted by the advisory committees of NSF's various directorates and offices over the past three years. The COV Subgroup was asked to draw from each of the COV reports any information that might provide a meaningful assessment of NSF's effectiveness in achieving its outcome goals pertaining to Discovery, Learning, and Research Infrastructure, especially if the information offered insight that complemented, rather than duplicated, insight gained from the assessment activities of the other three subgroups of our AC/GPA committee. While the COV Subgroup was free to pull information from any portion of these various COV reports, it paid particular attention to Part B (Results of NSF Investments) of each report because the set of questions addressed in this section was more closely aligned with the charge to the AC/GPA committee than was the set of questions addressed in the other major section of each COV report, namely, Part A (Integrity and Efficiency of the Program's Process and Management).

**Subgroup Members**

Joel Tohline (Chair)
Louisiana State University

Pamela O'Neil
Brown University

George Hornberger
University of Virginia

## Process Followed and Criteria Used

The COV Subgroup focused attention on the set of 32 COV reports that spanned the three-year period, 2006-2008. Rather than ask each member of the Subgroup to read through all 32 COV reports, the reports were divided into three groups and each member of the Subgroup was responsible for reviewing one subset. The assignments were made as follows:

Group 1 – Reports from the CISE, MPS, SBE, and OD directorates;

Group 2 – Reports from the BIO and EHR directorates;

Group 3 – Reports from the ENG and GEO directorates.

Following the completion of our individual reading and review assignments, the COV Subgroup met during the AC/GPA committee meeting at NSF to determine its collective findings and then presented those findings to the AC/GPA Committee.

## Results of Analysis

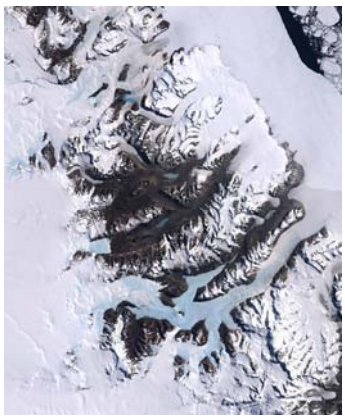
1. The information provided inside Part B of the various COV reports varies greatly from report to report. While a few reports provide insightful comments that are potentially of value to the AC/GPA committee, in general the material given in Part B is too sparse to be of use in our outcomes assessment efforts, or it is composed largely of "nuggets" and "highlights" and therefore duplicates more than complements material being studied by other subgroups. Summary: *Digging into Part B of COV reports provides very little return.*

2. Most COV committees put the majority of their effort into critiquing "Process and Management" issues rather than assessing "Outcomes." If Part B information is to be more useful to the AC/GPA, the NSF should consider offering advice to each COV committee on what would be desirable in such reports. For example, cut-and-paste snippets from highlights provided by Program Officers do not add value. On the other hand, if notable accomplishments gleaned by members of the COV themselves in reading results from previous work sections were reported, this might be useful. Also, the COVs might be in an excellent position to note the awards and honors accrued by people in the field over the previous three years and this information would be useful (see item 4.a below).

3. Future "outcomes" of NSF-funded programs are likely impacted by "process and management" efforts, the main aim of Part A of COV reports. Although some issues will be specific to individual programs, many may transcend even Directorate bounds. In this context, *we recommend that the NSF management regularly conduct an overarching review of the separate COV reports*. The results of such a cross-directorate review could be used by management to effect critical changes that might not be addressed without recognition that they are needed across the Foundation.

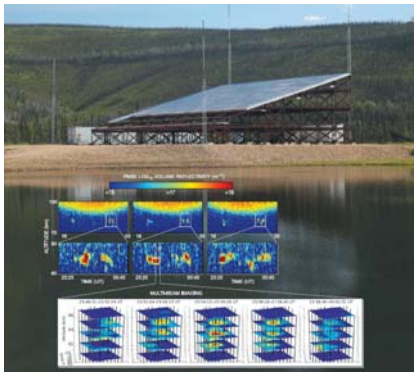
4. Specific "outcomes" issues raised through collective review of various COV reports:

   a. **Discovery**: Each year, it may be useful for the AC/GPA committee to highlight the professional honors and awards that have been received by various scientists and engineers who have been funded through NSF's programs. In particular, it might be instructive to note whether or not NSF funding has contributed to the success of individuals who are awarded a Nobel Prize (or comparably prestigious prize) each year. NOTE: As a step in this direction, a table of recent Nobel Laureates and National Medal of Science Laureates has been attached to this report (Appendix V). It would be useful to highlight which "discoveries" among these awards benefited significantly from past NSF support.



**b. Learning**: There were some interesting comparisons across COV reports in the outcomes section for learning. For example, the Graduate Research Fellowship Program (GRFP) reports that 56 percent of their awards went to women, illustrating that gender diversity in GRFP mirrors the increase in women enrolling in universities. However, core programs in other directorates, for example DEB/BIO, report that the number of proposals from women scientists has not increased and recommends that programs do more to encourage proposals from women and other underrepresented groups. Such comparisons of trends could be useful to the NSF in assessing whether programs designed to increase participation are actually resulting in gains at the highest level of academia. Information drawn from COV reports alone did not provide the comprehensive view necessary to compare across programs. The AC/GPA committee might benefit from examining workforce numbers over a period of years. Perhaps information of this type can be drawn from the PART database and provided to the AC/GPA for review.

**c. Research Infrastructure**: Guidance from NSF to COVs regarding provision of infrastructure outcomes in Part B could also result in useful material for the AC/GPA. An excellent example of useful information along these lines can be found in the COV report for the BIO directorate's Plant Genome Research Program. In their report for B.3, "Outcome Goal for Research Infrastructure," they listed all of the recommendations that the previous COV had made (presumably in Part A) regarding infrastructure needs, and then reported on what had been done in response, i.e., they reported a series of outcomes. If such information were available in all or most COV reports, the AC/GPA would be able not only to evaluate outcomes for a particular period, but would be able to track progress over time.



## Appendix I.

# 2008 Charge

**MEMORANDUM**

DATE: January 15, 2008

TO: Advisory Committee for GPRA Performance Assessment (AC/GPA)

FROM: Thomas Cooley
Chief Financial Officer and Director,
Office of Budget, Finance and Award Management

SUBJECT: Charge for the FY 2007 Advisory Committee for GPRA Performance Assessment

The Advisory Committee for GPRA Performance Assessment (AC/GPA) provides advice and recommendations to the NSF Director on the Foundation's response to the reporting mandate set forth in the Government Performance and Results Act (GPRA) of 1993. The committee focuses on issues related to the Foundation's strategic outcome goals. These outcome goals are defined in the Foundation's Strategic Plan for FY 2006-2011, *Investing in America's Future.*

The AC/GPA charge for FY 2008 is twofold: (1) to assess whether NSF has demonstrated significant achievement for the Discovery, Learning, and Research Infrastructure strategic outcome goals, and (2) to convey its assessment in a report to the NSF Director. As in previous years, a primary resource for this assessment will be program highlights that are made available on the committee website. Other resources, including Committee of Visitors reports, project reports from principal investigators, and other performance information, will also be available for consideration in your assessment. In your report, we ask that you select several program highlights under each outcome goal to demonstrate the most significant accomplishments reported for the agency's portfolio during this past year.

In response to recommendations from the 2007 Committee on improving the Committee's decision-making process, we have made significant improvements in two areas. First, we added specific program categories to the highlights database in order to ensure broad coverage of NSF program accomplishments. Second, we established specific evaluation criteria that you may use in assessing achievement under each strategic outcome goal. We believe that these improvements address the Committee's concerns.

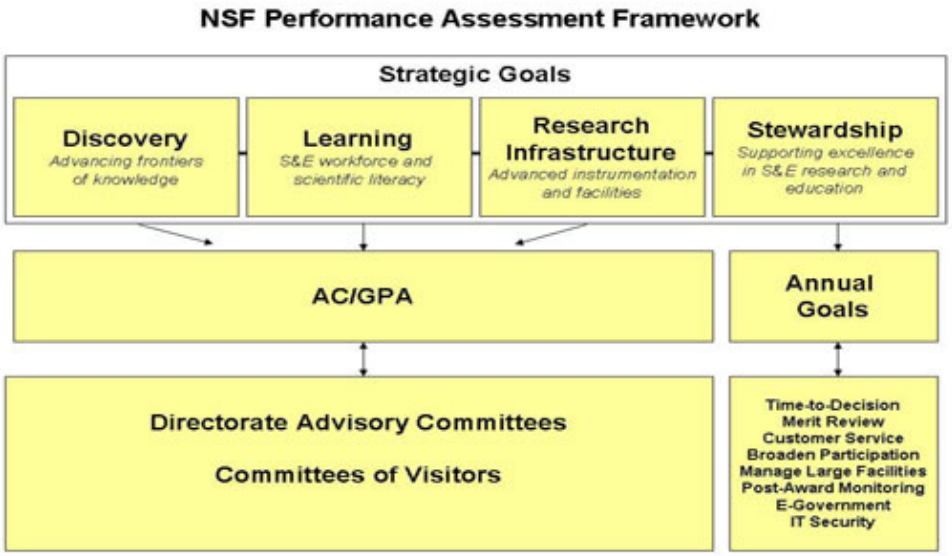
In addition to the formal charge to evaluate NSF's accomplishments under the strategic outcome goals, we request that you discuss three topics at your annual meeting: transformative research, broadening participation, and societal benefit of NSF investments. This year we asked program officers to address these topics in the Highlights, and you will be provided with a set of Highlights that were designated in each area. Collectively these Highlights, as well as other related information, will provide a resource for your discussion at your meeting. We ask that you include a summary of your discussion and conclusions in your report to the Director.

## Appendix II.

# PROCESS OVERVIEW

The Advisory Committee for GPRA Performance Assessment (AC/GPA) was established in June 2002 to provide advice and recommendations to the NSF Director regarding the Foundation's performance under the Government Performance and Results Act (GPRA) of 1993.

The Committee meets annually to assess the Foundation's overall performance according to the strategic outcome goals in the NSF Strategic Plan. The chart below illustrates the Committee's place within the NSF Performance Assessment Framework for FY 2008.




The Committee has responsibility for assessing the three strategic outcome goals of Discovery, Learning, and Research Infrastructure. The Committee did not form an assessment or opinion of NSF's performance under the fourth goal: *Stewardship*, which is: *to support excellence in science and engineering research and education through a capable and responsive organization.* Performance outcomes under Stewardship are reported using a number of measures and milestones developed internally within NSF.

For each outcome goal, the AC/GPA judges NSF's performance successful when, in the aggregate, results reported demonstrate significant achievement. A significant component of the AC/GPA's assessment is based on performance highlights written by NSF program officers. These highlights describe major results achieved and represent outstanding accomplishments from NSF awards. The AC/GPA may also review COV reports, award abstracts, and principal investigator project reports. Based on its review, the Committee submits a report to the Director that is incorporated, at least in part, into the Foundation's annual performance report.

## Appendix III.

# 2008 Evaluation Criteria for Program Highlights

In response to a recommendation by the 2007 AC/GPA, specific evaluation criteria have been established for each of the program categories under the three strategic outcome goals of Discovery, Learning, and Research Infrastructure.

For the highlights you are asked to review, please evaluate the accomplishments against **one or more** of the criteria. It is not necessary to match each highlight against each of the criteria. In the end, the Committee will make a judgment whether the Foundation has demonstrated significant achievement under each of the broad strategic outcome goals and not under each program category.

## DISCOVERY

***Foster research that will advance the frontiers of knowledge, emphasizing areas of greatest opportunity and potential benefit and establishing the nation as a global leader in fundamental and transformational science and engineering. (NSF Strategic Plan FY 2006-2011)***

### RESEARCH GRANTS

This portfolio consists of grants that deal primarily with traditional investigator-initiated research projects. ***Included*** are: Disciplinary & Interdisciplinary Research, International Collaborative Research, the CAREER Program, Evaluation and Research to Improve STEM Education, Discovery Research K-12, and the EPSCoR Program. ***Excluded*** are grants for equipment, education, postdoctoral fellowships, planning and travel grants, and symposia; cooperative agreements for centers and facilities; most of the programs in the Education and Human Resources (EHR) Directorate; and the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.

***Evaluation Criteria***

- Strengthen fundamental research across the full spectrum of science and engineering through support for NSF's fundamental or core disciplinary programs.

- Foster discoveries that have the potential to transform disciplines or fields of science, engineering, or education research.

- Promote innovation and partnerships with industries to stimulate the development of new technologies and processes to further U.S. economic competitiveness and benefit the Nation.

- Promote international collaboration among U.S. investigators and partners in other countries and regions.

### SCIENCE AND ENGINEERING CENTERS

Included in this category are: Centers for Analysis & Synthesis, Centers for Chemical Innovation, Engineering Research Centers, Materials Research Science & Engineering Centers, Nanoscale Science and Engineering Centers, Science and Technology Centers, and Science of Learning Centers.

***Evaluation Criteria***

- Enable academic institutions and their partners to integrate discovery, learning, and innovation on scales that are large enough to transform important science and engineering fields and interdisciplinary areas and stimulate increased innovation.

## LEARNING

***Cultivate a world-class, broadly inclusive science and engineering workforce, and expand the scientific literacy of all citizens. (NSF Strategic Plan FY 2006-2011)***

### K-12 EDUCATION

***Evaluation Criteria***

- Support research to improve science and engineering education, and education research that develops successful models for teaching and learning.

- Support active involvement of K-12 teachers in NSF-funded research and workshops to bring fundamental knowledge and technological innovations into their classrooms

- Prepare the next generation of STEM professionals and attract and retain more Americans to STEM careers.

### UNDERGRADUATE EDUCATION THROUGH POSTDOCTORAL LEVEL

***Evaluation Criteria***

- Develop creative, new pathways to engage students and researchers at the frontiers of discovery to facilitate their entry into the science and engineering

workforce and enhance the skills and knowledge needed to advance their early careers.

- Broaden the participation of individuals underrepresented in STEM and diverse institutions throughout the United States in NSF-supported research and education activities and programs.

- Support community college faculty in NSF-funded research to bring fundamental knowledge and technological innovation into their classrooms

- Support active research participation by undergraduate students in NSF-funded projects.

- Provide opportunities for international research experiences that enhance and strengthen undergraduate and postgraduate education.

- Prepare the next generation of STEM professionals and attract and retain more Americans to STEM careers.

### PUBLIC UNDERSTANDING OF STEM AND LIFELONG LEARNING

***Evaluation Criteria***

- Increase interest, engagement, and understanding of science, engineering, and technology by individuals of all ages and backgrounds and within a variety of different formal and informal educational settings.

- Prepare and support the next generation of STEM professionals and attract and retain more Americans to STEM careers.

## RESEARCH INFRASTRUCTURE

***Build the nation's research capability through critical investments in advanced instrumentation, facilities, cyberinfrastructure and experimental tools. (NSF Strategic Plan FY 2006-2011)***

### MAJOR MULTI-USER RESEARCH FACILITIES

***Evaluation Criteria***

- Promote discoveries at large multi-user research facilities supported by NSF, which may be centralized or may consist of distributed installations. These facilities may incorporate large-scale networking or computational infrastructure; multi-user instruments or networks of such instruments; or other infrastructure, instrumentation, and equipment having a major impact on a broad segment of a scientific or engineering discipline. This category includes accelerators,

telescopes, research vessels, aircraft, and geographically distributed but networked earthquake engineering simulation equipment.

## INSTRUMENTATION

### *Evaluation Criteria*

- Provide tools, instruments, and facilities to enable the STEM community to conduct research that could not be performed without this advanced instrumentation infrastructure.

- Expand opportunities for U.S. researchers, educators, and students at all levels to access state-of-the-art science and engineering facilities, laboratory instrumentation and equipment, databases, and advanced computing resources, research networks, and other infrastructure.

## CYBERINFRASTRUCTURE

### *Evaluation Criteria*

- Enable discoveries facilitated by world-class cyberinfrastructure that drives discovery in all fields of science and engineering.

- Explore the use of potential cyberinfrastructure in integration of research and education.

# Appendix IV.

## Committee of Visitor Reports Reviewed by AC/GPA

**BIO**

2007 DBI: Division of Biological Infrastructure
DBI–PGR: DBI Planet Genome Research Program

2006 DEB: Division of Environmental Biology
EF: Emerging Frontiers

**CISE**

2006 CCF: Division of Computer and Communications Foundations
CNS: Division of Computer & Network Systems
IIS: Division of Information and Intelligent Systems

**EHR:**

2007 DRL: Division on Learning in Formal and Informal Settings-Teacher Professional Continuum Program
DUE: Division of Undergraduate Education – Federal Cyber Scholarships for Service Program

2006 DUE: Division of Undergraduate Education
- Advanced Technological Education
- Course, Curriculum, and Laboratory Improvement
- Science, Technology, Engineering, and Mathematics Talent Expansion

DGE: Division of Graduate Education
HRD: Division of Human Resource Development
- Research on Gender in Science and Engineering
- Research in Disabilities Education

**ENG**

2008 EEC: Engineering Education and Centers

2007 IIP: Industrial Innovation & Partnership (SBIR/STTR)

2006 CTS: Division of Chemical and Transport Systems
DMI: Division of Design and Manufacturing Innovation

**GEO**

2007 ATM: Division of Atmospheric Sciences
EAR: Division of Earth Sciences Research
ED: Education and Diversity Programs

2006 ATM: Division of Atmospheric Sciences
OCE: Division of Ocean Sciences

**MPS**

2008 AST: Division of Astronomical Sciences
DMR: Division of Materials Research

2007 CHE: Division of Chemistry
DMS: Division of Mathematical Sciences

2006 PHY: Division of Physics

**SBE**

2007 SES: Division of Social and Economic Sciences

2006 BCS: Division of Behavioral and Cognitive Sciences
SRS: Division of Science Resource Statistics

**OD**

2008 Office of Cyberinfrastructure

## Appendix V.

# Nobel Prize & Award Winners supported by NSF

## Nobel Prize Winners

| Chemistry | Year | Institution |
|---|---|---|
| **Roderick MacKinnon** | 2003 | Rockefeller University |
| **Peter Agre** | 2003 | Johns Hopkins School of Medicine |
| **Robert H. Grubbs** | 2005 | California Institute of Technology |
| **Richard R. Schrock** | 2005 | Massachusetts Institute of Technology |
| Physics | | |
| **Anthony J. Leggett** | 2003 | University of Illinois |
| **David J. Gross** | 2004 | University of California |
| **H. David Politzer** | 2004 | California Institute of Technology |
| **Frank Wilczek** | 2004 | Massachusetts Institute of Technology |
| **Roy J. Glauber** | 2005 | Harvard University |
| **John L. Hall** | 2005 | University of Colorado |
| **Theodor W. Hänsch** (Germany) | 2005 | Ludwig Maximilian University |
| **George F. Smoot** | 2006 | University of California |
| Economics | | |
| **Robert F. Engle III** | 2003 | New York University |
| **Clive W.J. Granger** | 2003 | University of California |
| **Finn E. Kydland** | 2004 | Carnegie Mellon University<br>University of California |
| **Edward C. Prescott** | 2004 | Arizona State University<br>Federal State Reserve Bank |
| **Robert J. Aumann** | 2005 | University of Jerusalem |
| **Thomas C. Schelling** | 2005 | University of Maryland |
| **Edmund S. Phelps** | 2006 | Columbia University |
| **Leonid Hurwicz** | 2007 | University of Minnesota |
| **Eric S. Maskin** | 2007 | Princeton University<br>- Institute for Advanced Study |
| **Roger B. Myerson** | 2007 | University of Chicago |
| Medicine | | |
| **Paul C. Lauterber** | 2003 | University of Illinois |
| **Richard Axel** | 2004 | Columbia University |
| **Mario R. Capecchi** | 2005 | University of Utah<br>Howard Hughes Medical Institute |

# Awards

## National Medal of Science Laureates 2006

| | Institution |
|---|---|
| **Hyman Bass** | University of Michigan |
| **Marvin H. Caruthers** | University of Colorado |
| **Rita A. Colwell** | University of Maryland |
| **Peter B. Dervan** | California Institute of Technology |
| **Nina V. Fedoroff** | Pennsylvania State University |
| **Daniel Kleppner** | Massachusetts Institute of Technology |
| **Robert S. Langer** | Massachusetts Institute of Technology |
| **Lubert Stryer** | Stanford University |

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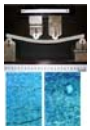
## National Medal of Science Laureates 2005

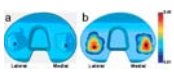
| | |
|---|---|
| **Jan D. Achenbach** | Northwestern University |
| **Ralph A. Alpher** | The Dudley Observatory |
| **Gordon H. Bower** | Stanford University |
| **Bradley Efron** | Stanford University |
| **Anthony S. Fauci** | National Institutes of Health |
| **Tobin J. Marks** | Northwestern University |
| **Lonnie G. Thompson** | Ohio State University |
| **Torsten N. Wiesel** | The Rockefeller University |

## Appendix VI.

## Photo Information and Credits

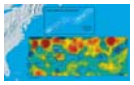


Page 6 – These images show the unique properties of Engineered Cementitious Composites in both its high ductility and ability to self-heal after fracture.
*Credit: Victor Li, University of Michigan*



Page 8 – Comparison of experimental (a) and simulated (b) wear regions for a total knee replacement design after 5 million cycles of walking performed in a knee simulator machine. X's indicate locations of maximum wear. Dotted lines in (a) indicate boundaries of experimental wear regions. Color bar in (b) indicates depth in millimeters of simulated wear regions.
*Credit: B.J. Fregly, University of Florida*

Page 9 – Damage from an EF1 tornado. CASA graduate student Patrick Marsh (University of Oklahoma) conducted a damage survey to verify the EF1 tornado identified in CASA data.
*Credit: CASA*



Page 10 – Data from satellite altimeters (lower inset), which measure sea surface heights, show depressions (blue) and bumps (red) that mark cold- and warm-water eddies in the ocean on June 17, 2005. Researchers tracked the southwestward motion of eddy A4 (light-blue in the upper inset) by ship from June 24 to Sept. 12. They released several drifters and a buoy (colored tracks) to capture the swirling motion of the eddy's currents.
*Credit: This figure was drafted by Jim Canavan and provided as a courtesy by Dennis McGillicuddy, WHOI, and the Colorado Center for Astrodynamics Research.*

Page 11 – The retinal prosthesis consists of a camera and transmitter mounted in eyeglasses, an implanted receiver, and a microelectrode array attached to the retina.
*Credit: Biomimetic MicroElectronic Systems Engineering Research Center (BMES)*

Page 13 – Astronomers have discovered a solar system analogous to ours containing scaled-down versions of Saturn and Jupiter. The two planets were revealed when the star they orbit crossed in front of a more distant star as seen from Earth. For a two-week period from late March through April 2006, the nearer star magnified the light shining from the farther star. Their finding suggests that our galaxy hosts many star systems like our own.
*Credit: Korea Astronomy and Space Science Institute (KASI), Chungbuk National University (CBNU), and Astrophysical Research Center for the Structure and Evolution of the Cosmos (ARCSEC)*

Page 14 – BirdSleuth students are citizen scientists, collecting data on birds and sharing their observations through the Cornell Lab of Ornithology.
*Credit: Diane Tessaglia-Hymes, Cornell Lab of Ornithology*

Page 15 – View of the Flight Simulator Environment setup at Tuskegee University
*Credit: Tuskegee University*

Page 16 – Two SEEDBEd high school students use micropipettes to move enzyme digested DNA into an electrophoresis gel.
*Credit: Cindy Barton, Tulsa Community College*

Page 17– Virtual wolves on the prowl.
*Credit: Grant Spickelmier, Minnesota Zoo*

Page 18 – Middle school teachers building models of fullerenes (above) and running an experiment.
*Credit: Andrew Greenberg, University of Wisconsin, Madison*

Page 20 – Middle school teachers building models of fullerenes (above) and running an experiment
*Credit: Sandra Sheppard*

Page 22 – Propagation of the Gemini laser guide star during commissioning in July 2006. Exposure duration is approximately one minute.
*Credit: Gemini Observatory*

Page 24 – Artist's rendering of what the environment around HD 23514 might look like as two Earth-sized bodies collide.
*Credit: Gemini Observatory/Lynette Cook*

Page 25– Student practice combing for ectoparasites.
*Credit: Dr. Scott Gardner, University of Nebraska*

Page 26 - Chemistry Comes Alive! website received the 2006 Pirelli *Internet*ional Award "for the effectiveness of this collection of multimedia tools that are designed to enhance chemistry education in schools and universities".
*Credit: Journal of Chemical Education Software, a publication of the Division of Chemical Education, Inc. of the American Chemical Society*

Page 27 - A woman entrepreneur in the Philippines.
*Credit: Dean Karlan and Innovations for Poverty Action*

Page 28 – This image shows the McMurdo Dry Valleys, a major research focus for the U.S. Antarctic Program. The region host the largest ice free areas of Antarctica.
*Credit: Landsat Image Mosaic of Antarctica (LIMA) Project*

Page 29 - An image from the Saturday outreach program to K-8 schoolchildren by the NIRT PIs in Bullock County, Alabama.
*Credit: Tamara Floyd, Tuskegee University*

Page 29 - The Poker Flat Incoherent Scatter Radar. Insets show radar backscatter from Polar Mesospheric Summer Echoes between 80 and 90 km altitude. The middle row focuses in on a region of interest. In the bottom, 25 beams (black lines) have been used to create the first three-dimensional images of these structures in the middle atmosphere.
*Credit: Reproduced by permission of American Geophysical Union*