# REPORT OF THE ADVISORY COMMITTEE FOR

# GPRA PERFORMANCE ASSESSMENT

# FY 2006

**SUBMITTED: JULY 25, 2006**
**GLORIA M. ROGERS, PHD**
**CHAIRMAN**

# Table of Contents

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

***LIST OF COMMITTEE MEMBERS***

* Absent on June 22-23, 2006

**Gloria M. Rogers (Chair)**
Assoc. Exec. Director, Professional Services
ABET
Baltimore, MD

**Jack Fellows (Vice Chair)**
Vice President of Corporate Affairs and Director, Office of Programs
University Corporation for Atmospheric Research
Boulder, CO

**Dawn Adrian Adams***
President and Founder
Tapestry Institute
Harrison, NE

**W. Richards (Rick) Adrion (CISE AC)**
Professor of Computer Science
University of Massachusetts Amherst
Amherst, MA

**Todd R. Allen**
Manager, Intl. Internship Program, Global University Team
Johnson & Johnson
New Brunswick, NJ

**Lisa Alvarez-Cohen (ENG AC)**
Department of Civil & Environmental Engineering
University of California, Berkeley
Berkeley, CA

**Shenda Baker (MPS AC)***
Professor
Department of Chemistry
Harvey Mudd College
Claremont, CA

**Cecilia Conrad (SBE AC)**
Stedman-Sumner Professor of Economics
Department of Economics
Pomona College
Claremont, CA

**Elaine L. Craft**
Director, SC ATE Center of Excellence
Florence-Darlington Technical College
Florence, SC

**Larry R. Dalton (MPS AC)**
Dept. of Chemistry
University of Washington
Seattle, WA

**Julio C. de Paula (OISE AC)**
Dean of the College of Arts and Sciences
Lewis & Clark College
Portland, OR

**Howard A. Gordon**
Associate Chair
Physics Department
Brookhaven National Laboratory
Upton, NY

**Robert C. Harriss (GEO AC)**
President & CEO
Houston Advanced Research Center
The Woodlands, TX

**John K. Haynes**
David Packard Professor and Dean
Division of Science & Mathematics
Morehouse College
Atlanta, GA

**Glake Hill**
Assistant Professor, Department of Chemistry
Jackson State University
Jackson, MS

**Lynn Jelinski (BIO AC)**
President
Sunshine Consultants, International
Green Cove Springs, FL

**Robert L. Lichter (CEOSE**)
Principal, Merrimack Consultants, LLC
Great Barrington, MA

**Sally K. Mason (EHR AC)**
Provost
Purdue University
West Lafayette, IN

**Thomas H. McGovern (OPP AC)**
Director, Bioarchaeology Lab
Department of Anthropology
Hunter College
City University of New York
New York, NY

**Samuel M. Rankin, III**
Associate Executive Director
American Mathematical Society
Washington, DC

**Eric Sheppard**
Dean, School of Engineering
Hampton University
Hampton, VA

**Finbarr C. Sloane**
Associate Professor of Mathematics Education and
Senior Research Scientist CRESMET
College of Education
Arizona State University
Tempe, AZ

**David Spencer (SBIR AC)**
Chief Executive Officer
wTe Corporation
Bedford, MA

**E. Jennings Taylor**
CTO and Intellectual Property Director
Faraday Technology, Inc.
Clayton, OH

**Gordon E. Uno**
David Ross Boyd Professor of Botany and
Chair, Department of Botany and Microbiology
University of Oklahoma
Norman, OK

**Ben R. Ware**
Vice President for Research and Dean of the Graduate School
Syracuse University
Syracuse, NY

# AC/GPA FY 2006 Report

## *I. EXECUTIVE SUMMARY*

**Committee.** The 2006 National Science Foundation Advisory Committee for GRPA Performance Assessment (AC/GPA) consists of 26 members from the engineering, science and education communities, drawn from both the public and private sectors. Twelve of the committee members served on the AC/GPA for two or more years and 14 were new appointees. Eleven committee members also serve on other NSF Advisory Committees and brought a broad spectrum of experiences to the deliberations of the committee.

**Charge.** The AC/GPA was charged by NSF for FY2006 to provide a report that included:

1) an assessment on significant achievement for indicators associated with the IDEAS, TOOLS, PEOPLE, and ORGANIZATIONAL EXCELLENCE strategic goals,
2) comments on the quality and relevance of the achievements; and
3) comments on the Committee's future operation under the proposed 2006-2011 Strategic Plan, particularly with regard to the processes involved for that activity.

In addition, the report was expected to contain performance highlights or examples identified as among the most significant accomplishments reported for the agency's portfolio.

**Process.** To determine significant achievement and the quality and relevance of the achievement of NSF's performance on the four strategic goals of the 2003-2008 Strategic Plan, the AC/GPA reviewed a substantial amount of documentation that included performance highlights (nuggets), Committee of Visitor reports, project reports, and Advisory Committee reports. The Committee also had the benefit of the expertise of NSF staff who provided information and responded to Committee questions throughout the process. The Committee met on June 22-23, 2006 to determine its findings and develop recommendations. The work of the Committee was completed both in small groups representing each of the NSF strategic goal areas and as a Committee of the whole. There was a substantial amount of work done prior to the June meeting that allowed the Committee's meeting discussion to be focused at a very high level.

**2003-2008 Strategic Plan Goal Areas.** (Strategic Outcome Goals and Indicators are provided in Appendix A).

- **IDEAS:** discovery across the frontier of science and engineering, connected to learning, innovation, and service to society
- **TOOLS**: broadly accessible, state-of-the-art S&E facilities, tools and other infrastructure that enable discovery, learning and innovation
- **PEOPLE**: a diverse, competitive, and globally-engaged U.S. workforce of scientists, engineers, technologists and well-prepared citizens
- **ORGANIZATIONAL EXCELLENCE**: agile, innovative organization that fulfills its mission through leadership in state-of-the-art business practices

**Conclusions**

The Committee found that NSF demonstrated **significant achievement** in all of its performance indicators related to the four strategic goals of the 2003-2008 Strategic Plan. Quality and relevance are also demonstrated for the achievement of each indicator of Ideas, Tools, and People. For each of the Organizational Excellence indicators, NSF also demonstrated quality (the evaluation criterion "relevance" is not applicable to Organizational Excellence). The challenge that AC/GPA faces in the coming years is efficient assessment of achievement, quality and relevance against the proposed 2006-2011 Strategic Plan. The Committee identified information that would be needed to make its assessment efficient but there is some concern about the how the two objectives in the new plan will be used in the evaluation process.

Based on the overall review, the Committee generated twelve recommendations in three areas: (1) how to improve the performance assessment effort (e.g., data collection, analysis, guidance, etc), (2) some recommendations on how to improve the AC/GPA process, and (3) general recommendations on NSF priorities.

**2006 AC/GPA Recommendations (listed in order of priority).**

1. **New Strategic Plan Objectives.** There was considerable discussion about exactly what significant achievement toward the two new Strategic Plan objectives would mean. The definitions under each of the new objectives are basically further definitions of the new four goal areas and includes 14 sub-objectives. It was not clear how these objectives will be used in the evaluation process. NSF is encouraged to give more thought on how best to use the new objectives as evaluation tools.

2. **Nuggets.** Nuggets should include more than, for example, just the number of or fact that minority students were included, but also, the specific activities and outcomes that are desired. The selection process should allow the designation of "primary nuggets" to cross goal areas (e.g., People and Ideas). When available, nuggets should include measures of effectiveness and data on who has been affected and how. Program Officers (POs) should be encouraged to write nuggets as they evaluate annual reports (versus once-a-year for the AC/GPA process).

3. **Baselines.** NSF should develop analysis on research and education trends with baselines indicating how NSF efforts are contributing to change. Currently, it is not clear what research and education baselines we are using to assess performance and how NSF's role relates to the broader federal research and education efforts.

4. **Stimulate Education Research.** NSF is encouraged to do more to stimulate new and more in-depth research in teaching and learning, particularly in engineering education, implementing and disseminating potential best practices as they are identified.

5. **Reports.** The Committee will continue to need relevant Advisory Committee, technical, and site visit reports, but the reports will need to reflect the new strategic plan goals, objectives, and priorities. NSF should continue to improve the quantitative measures in COV reports so that they can be compared across programs.

6. **Broadening Participation.** The Committee would like to see data on all aspects of "broadening participation." Specifically:
   - More conclusive evidence is needed on whether NSF has indeed increased opportunities for underrepresented individuals and institutions.
   - NSF should explore creative mechanisms to bring industry and academia together to achieve this goal.
   - NSF should increase the number of non-EHR programs in the Committee information that have indicators showing diversity and inclusive workforces.

7. **Merit Review.** NSF should establish supplemental guidelines and factors to consider in evaluating the Broader Impacts Criterion. These should be made readily available to PIs to ensure that both criteria are clearly understood. The Reviewer Management System (database of reviewers) needs to be improved to enhance the diversity and overall quality of the review pool.

8. **Alignment of Goals, Outcomes, and Budgets**. The Committee would like to see information that links goals, objectives, and priorities to budgets and outcomes across the NSF. This should also include aligning the research and educational initiatives within NSF with the priorities indicated in the National Academies report Rising Above the Gathering Storm, particularly where the priorities outlined in the report and those of NSF overlap.

9. **Innovation.** NSF should provide a report on the most important innovations across the NSF directorates and embrace innovation as a fundamental element of its mission. The Committee would like to see how the NSF balances its risk portfolio to include: (1) high risk, transformative research, (2) important, lower-risk research, and (3) innovative research that may enhance near-term national competitiveness. The first two are converting dollars into knowledge and the third converting knowledge into dollars.

10. **Facilities.** NSF needs to improve the management of large projects and consider the maintenance and sustainability of these for the long-term.

11. **Workload/Workforce.** NSF should examine ways to reduce workload (e.g., reduce inspections of inspections, increase intervals between COVs, etc). The Committee continues to be concerned about the workload that program officers continue to face. One thing to consider would be to discontinue the use of paper jackets that summarize the award decisions and make this process more electronic and transparent. The Committee also recommends that all new POs attend the Program Manager Seminar ("bootcamp") and NSF should provide periodic updates for permanent POs. From previous Committee reports and given rising stress in the reviewer pool, the NSF needs to include the "reviewers" in its agency workforce analysis (i.e., how to increase the numbers and diversity in the pool,)

12. **Process.** The Committee recommends the following related to the AC/GPA process:
    - Committee members should have three-year terms that are staggered, with one-third rotating off each year. The terms of the Chair and Vice-Chair might be extended 1-2 years so they can both serve on the committee and be in a position to become an informed and effective committee leader.
    - This year's orientation and pre-meeting materials and work enhanced the quality of the on-site discussion and should be continued.
    - The Committee needs to provide each subgroup a reporting template so that the subgroup reports are uniform. That would substantial reduce the editing needed in the final production of this report.
    - A decadal assessment to explore performance trends across the years at the Foundation level should be considered.

## *II. FOUNDATION-LEVEL ASSESSMENT SUMMARY OF FY 2006 INVESTMENTS*

**Introduction and Summary**
The Committee met on June 22-23, 2006. For FY 2006, the charge to the NSF AC/GPA was to provide a report that included an assessment of significant achievement for indicators associated with the IDEAS, TOOLS, PEOPLE, and ORGANIZATIONAL EXCELLENCE strategic goals, comments on the quality and relevance of the achievements, and comments on consideration of the Committee's operation under the proposed 2006-2011 Strategic Plan, particularly with regard to the processes involved for that activity.

In addition, the report was expected to contain performance highlights or examples identified as among the most significant accomplishments reported for the agency's portfolio.

Based on the extensive review of numerous materials provided by the NSF, **the Committee was unanimous in its conclusion that NSF has demonstrated significant achievement for all indicators in the Ideas, Tools, and People goals and as well as the indicators of the Organizational Excellence goal. There was also agreement that NSF has demonstrated quality and relevance on Ideas, Tools, and People. The Committee also found demonstrated quality in all indicators of the Organizational Excellence goal (the evaluation criterion "relevance" is not applicable to Organizational Excellence).**

The NSF portfolio is deep and rich in IDEAS. From novel discoveries in the basic sciences and engineering to educational advancements across the STEM disciplines, the NSF has demonstrated continued commitment to its basic goals of pursuing the highest quality research, in novel and transformative ways, while broadening the participation in science and engineering of people from all parts of society. The R&D programs under the TOOLS performance indicator are important investments and appropriate and deemed to be of high quality. Many of the projects reviewed related to the PEOPLE performance indicators have high relevance to the development of a strong workforce and to public understanding of science. Projects were found to include goals and accomplishments considered to be bold and at the frontiers of science, engineering, and education. The ORGANIZATIONAL EXCELLENCE review found the merit review system to be highly effective, trusted, and respected by participants within the science community. The process is thorough and has well-designed contingencies for handling non-procedural issues and allows for continuous improvement.

**Methodologies Used**

The 2006 AC/GPA consisted of 26 members from the engineering, science and education communities, drawn from both the public and private sectors. Twelve of the committee members served on the AC/GPA for two or more years and 14 were new appointees. Eleven committee members also serve on other NSF Advisory Committees and brought a broad spectrum of experiences to the deliberations of the Committee.

The AC/GPA committee began its work in the spring of 2006 with teleconferences designed to review the committee's charge, review resources available, and discuss processes and timelines. The committee was divided into four working groups representing the strategic goal areas of IDEAS, TOOLS, PEOPLE, and ORGANIZATIONAL EXCELLENCE. These subgroups were chaired by AC/GPA members who served as a valuable resource to the other committee members and facilitated the work of the group. Subgroups reviewed the performance highlights (nuggets) and made preliminary selection of those that they believed supported their overall assessment of the portfolio.

The AC/GPA met at NSF on June 22 and 23. The assessment of NSF performance toward the achievement of the strategic goals was done in both subgroups and as a committee of the whole. Each subgroup deliberated concerning its assessment and brought its findings and conclusions to the committee of the whole for discussion. The discussion of future work of AC/GPA under the proposed 2006-2011 strategic plan was also done in subgroups divided by the four strategic goals in the new plan:

1) 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 transformative science and engineering.
2) Learning – Cultivate a world-class science and engineering workforce, and expand the scientific literacy of all citizens.
3) Research Infrastructure – Build the nation's research capability through critical investments in advanced instrumentation, facilities, cyberinfrastructure, and experimental tools.
4) Stewardship – Support excellence in science and engineering research and education through a capable and responsive organization.

Each subgroup considered what resources would be needed to assess NSF achievement related to the assigned goal and how the work of the AC/GPA would be impacted by the new plan. Each subgroup reported its findings to the committee of the whole for discussion and final recommendations.

The primary source of information for the committee was the AC/GPA secure website that was prepared by NSF to facilitate the work of the committee. The website was invaluable to the committee in its work. The NSF staff is to be congratulated on the improvements to the website that enabled the committee members to work more efficiently. The committee members had access to numerous reports and summaries including Committee of Visitor Reports, Advisory Committee reports, Project reports, Nuggets, Strategic Plan, as well as numerous additional NSF and other reports that were relevant to the work of the committee. The performance indicators were critical to the work of the subgroups for IDEAS, TOOLS, and PEOPLE. NSF Program Officers (POs) identified more than 970 primary indicators (mutually exclusive) and almost 1400 secondary indicators (not mutually exclusive) related to the 16 performance indicators. In addition, they identified 227 projects as transformative and 531 as multidisciplinary. The ORGANIZATIONAL EXCELLENCE (OE) subgroup reviewed materials from the Advisory Committee for Business and Operations (AC/B&O) which assesses three of the strategic objectives that make up OE: utilizes new technologies; diverse, capable staff; and performance assessment. The OE subgroup reviewed numerous materials related to the AC/B&O findings as well as other relevant reports. The Merit Review strategic objective assessment utilized reports and compilations from Committees of Visitors, reports to the National Science Board, and materials provided by AC/B&O.

**R& D Investment Criteria**

The Committee was charged with providing comments on the quality and relevance of the achievements. Based upon the materials reviewed and the personal expertise and experience of the committee members, **it was the assessment of the Committee that the NSF portfolio related to IDEAS, TOOLS, and PEOPLE was high in quality and relevance. It was found**

**<u>that the quality of ORGANIZATIONAL EXCELLENCE was also high</u>**. The NSF portfolio was found to have both breadth and depth of research topics which were both cutting edge and fundamental discoveries advancing science and engineering. The commitment of NSF to the highest quality research while, at the same time, broadening the participation in science and engineering to populations from all parts of society was evident in the review. NSF continues to support state-of-the-art facilities, tools and databases as well as other infrastructure which enable investigators to carry out significant research in a variety of STEM areas. These investments are critical in providing the scientific underpinnings for future scientific advancements. Current investments targeted to increase the diversity of the workforce and education of our citizenry is central to ensuring our nation's high quality of life and security. The Committee also recognized the critical role that organizational excellence plays in support of the other goals. The merit review process continues to be critical to ensure a balanced process that reaches across the full spectrum of science and engineering interests.

Table 1 summarizes the Committee's findings. Even though the NSF has received significant achievement, quality and relevance in all performance indicators, the Committee believes there are always opportunities for improvement and challenges that can be overcome to enhance performance. These areas for enhanced performance are set forth in the following sections of the report.

**Table 1. Assessment Summary**

| GOAL | INDICATOR | Significant Achievement | Quality | Relevance |
|---|---|---|---|---|
| IDEAS | I1: (Contributions) Enable people who work at the forefront of discovery to make important and significant contributions to science and engineering knowledge. | ✓ | ✓ | ✓ |
| | I2**:** (Collaborations) Encourage collaborative research and education efforts across organizations, disciplines, sectors and international boundaries. | ✓ | ✓ | ✓ |
| | I3: (Connections) Foster connections between discoveries and their use in the service of society | ✓ | ✓ | ✓ |
| | I4**:** (Underrepresented individuals and institutions) Increase opportunities for underrepresented individuals and institutions to conduct high quality, competitive research and education activities. | ✓ | ✓ | ✓ |
| | I5**:** (Identifying new opportunities) Provide leadership in identifying and developing new research and education opportunities within and across S&E fields. | ✓ | ✓ | ✓ |
| | I6: (Cross-disciplinary) Accelerate progress in selected S&E areas of high priority by creating new integrative and cross-disciplinary knowledge and tools, and by providing people with new skills and perspectives | ✓ | ✓ | ✓ |
| | I7: (Identifying new opportunities) Support innovative research on learning and teaching that provides a scientific basis for improving science, technology, engineering and mathematics education at all levels. | ✓ | ✓ | ✓ |
| TOOLS | T1**:** (Expand access) Expand opportunities for U.S. researchers, educators, and students at all levels to access state-of the-art S&E facilities, tools, databases, and other infrastructure. | ✓ | ✓ | ✓ |
| | T2: (Next generation facilities and platforms) Provide leadership in the development, construction, and operation of major, next-generation facilities and other large research and education platforms. | ✓ | ✓ | ✓ |
| | T3: **(**Cyberinfrastructure) Develop and deploy an advanced cyberinfrastructure to enable all fields of science and engineering to fully utilize state-of-the-art computation. | ✓ | ✓ | ✓ |
| | T4: (Data collection/analysis**)** Provide for the collection and analysis of the scientific and technical resources of the U.S. and other nations to inform policy formulation and resource allocation | ✓ | ✓ | ✓ |
| | T5: **(**Instrument technology) Support research that advances instrument technology and leads to the development of next-generation research and education tools. | ✓ | ✓ | ✓ |

| GOAL | INDICATOR | Significant Achievement | Quality | Relevance |
|---|---|---|---|---|
| PEOPLE | P1: (Greater diversity) Promote greater diversity in the science and engineering workforce through increased participation of underrepresented and institutions in all NSF programs and activities. | ✓ | ✓ | ✓ |
| | P2: (Global S&E workforce) Support programs that attract and prepare U.S. students to be highly qualified members of the members of the global S&E workforce, including providing opportunities for international study, collaborations and partnerships. | ✓ | ✓ | ✓ |
| | P3: (Continuous learning) Develop the Nation's capability to provide K-12 and higher education faculty with opportunities for continuous learning and career development in science, technology, engineering, and mathematics. | ✓ | ✓ | ✓ |
| | P4: (Public understanding of science) Promote public understanding and appreciation of science, technology, engineering, and mathematics, and build bridges between formal and informal science education. | ✓ | ✓ | ✓ |
| Organizational Excellence | OE1: Human Capital Management--develop a diverse, capable, motivated staff that operates with efficiency and integrity. | ✓ | ✓ | |
| | OE2: Technology-enabled Business Process--utilize and sustain broad access to new and emerging technologies for business application. | ✓ | ✓ | |
| | OE3: Performance Assessment--develop and use performance assessment tools and measures to provide an environment of continuous improvement in NSF's intellectual investments as well as its management effectiveness. | ✓ | ✓ | |
| | OE4: Merit Review--operate a credible, efficient merit review system. | ✓ | ✓ | |

DETAILED ASSESSMENTS OF OUTCOME GOALS

## A. IDEAS OUTCOME GOAL

The NSF portfolio is deep and rich in ideas. From novel discoveries in the basic sciences and engineering to educational advancements across the STEM disciplines, NSF has demonstrated continued commitment to its basic goals of pursuing the highest quality research, in novel and transformative ways, while broadening the participation in science and engineering of people from all parts of society.

Each of the indicators under the IDEAS goal has been met in a variety of ways as demonstrated by the discussion of evidence. The breadth and depth of research topics supported by the NSF spans a vast array from cutting edge climate research in remote regions of our planet to fundamental discoveries in the engineering of nanoscale materials and biologicals. Across the vast array of examples provided, it is clear that the various directorates of the Foundation are supporting high quality research at a variety of institutions, from a diverse group of investigators, and of a potentially transformative nature in a significant number of cases.

The reach of the Foundation cuts across all disciplines, all educational sectors, and extends significantly across international boundaries as evidenced by the large-scale interdisciplinary and internationally focused projects that have been funded. The global impact of the Foundation's reach is readily apparent from the portfolio of funded projects available to the advisory committee.

The relevance of NSF-sponsored research to societal needs is dramatic and direct as evidenced by the many examples of applications from identifying terrorism targets, to producing more energy-efficient, environmentally sound materials, to assessing and reducing costs associated with structures built to withstand earthquakes. From the many examples available for review, it is clear that impact will be local, national, and potentially global from the various types of research projects that are underway.

There is good evidence that many sectors of the Foundation can demonstrate progress in the goal of broadening participation. There is also evidence that some directorates are not demonstrating clear commitment to this goal in ways that can be tangibly measured. We urge that more uniformity be applied across directorates with regard to reporting on this goal.

NSF appears to be leading the effort to identify and develop new research and educational opportunities that cut across various science and engineering fields. Examples of large-scale, cross-cutting projects indicate a high level of commitment by the Foundation to novel, sometimes high-risk, research and dissemination efforts.

New tools, new perspectives and integration across the disciplines have been demonstrated in a variety of projects from information technology to biotechnology. Combinations of approaches from the different disciplines are providing novel opportunities to solve large-scale problems.

And finally, the impact of projects designed to improve STEM education at all levels is manifested in a variety of projects that take full advantage of the scientific method as a means of engaging students at all levels in the excitement of scientific inquiry. Making science and mathematics accessible and interesting to students of all ages is a goal of a number of projects sponsored by NSF. Indeed this will position NSF well for responding to the National Academies report *Rising Above the Gathering Storm*, and we look forward to even more creative programming efforts on the part of the Foundation with regard to STEM education. In particular, efforts to address similar challenges in engineering education need to be enhanced significantly. We believe the NSF has the opportunity to be a significant driver in the improvement and enhancement of STEM education generally and engineering education most particularly.

Issues identified include:

- A need to acquire more comprehensive data (see, for example, the most recent CEOSE report) on whether NSF has indeed increased opportunities for underrepresented individuals and institutions; nuggets cannot provide the kind of "rich" data to truly assess how well and how deep broadening participation has extended, nor do we know with confidence what really is or is not working.
- A need to draw more obvious connections between the educational aspects of many of the research projects that are represented within the portfolio, especially because it can be difficult to distinguish connections between what appears to be a human resource (people) issue versus what may fundamentally be a research issue.
- A need to grow the portfolio of information on teaching and learning in engineering education.

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IDEAS GOAL -- Indicator I1: Enable people who work at the forefront of discovery to make important and significant contributions to science and engineering knowledge.

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NSF has supported a broad range of fields and topics that are at the forefront of science and engineering, providing the basis for technology of the future through the fundamental discoveries and innovations of today. There are literally hundreds of examples of high-quality and relevant projects that reflect both current cutting-edge research and research that has the potential to be truly transformative. A subset of this vast and impressive number of examples is presented below:

As the primary source of ground-based astronomy in the US, NSF has provided the basis for our understanding of our universe. For example, the project entitled "A Galaxy with Atomic Hydrogen Gas, Dark Matter and no Stars?" (9809484) shows our explorations into dark galaxies, vast clouds of hydrogen through which no visible light emerges, suggesting the presence of dark matter, the "missing mass" that must provide the gravitational attraction to hold the gas together. Carried out at a national observatory, NSF supported the development of the people who use and develop innovative instrumentation enabling new discoveries of how our universe is constructed.

NSF also has primary responsibility for leading our understanding of the Antarctic, through its Office of Polar Programs. Through a project on "Antarctic Temperature Changes, 1958-2002," we, for the first time, have used advanced statistical techniques to observe and model the surface temperatures from the "International Geophysical Year" to now. Using a vast network of manned observation sites, automated weather stations, and ship reports from the neighboring oceans, researchers have determined the average temperature variations in significant portions of the southern hemisphere.

NSF also plays a fundamental role in enabling forefront contributions in fundamental biology. Researchers have had astonishing insight into the central nervous system (0237956) by examining a simpler model than the human brain (with >100 billion neurons) "Architecture of Neurons for Brain Function." Project leaders have established links to the genetic factors associated with neuronal activity in nematodes, which also have a well-developed database of bioinformatics. This scientific genomic history provides for a powerful basis for understanding cellular mechanisms in neurobiology and cell development. In addition, scientists have found the first gene that encodes for pigmentation in both zebra fish and humans (9604923) "Discovering a New Gene Linked to Human and Fish Pigmentation." This type of genetic analysis and correspondence to expression contributes to our understanding of cell differentiation and mutation, which has tremendous implications in cancer treatments and in developmental biology.

Many forefront discoveries require collaborations across disciplines. In a project entitled "How do Proteins Organize Themselves within Cells," researchers show how cells create higher order structure internally by conversion of chemical energy to mechanical energy on a molecular level. This connection between the physical and biological sciences enabled a subcellular understanding of the organization of cell structure. Furthermore, a number of very fundamental studies in biology are leading the way to advances in medicine, agriculture and our understanding of the tools of genomics. For example "Plants Sacrifice Cells to Fight Viral Infections," (0077510, 0211872) shows that genes can be silenced in plants, a new technique developed by a new researcher to demonstrate programmed cell death that prevents the spread of a virus to neighboring cells. This type of mechanism enabled major discoveries in plant biology. In a related way, "Small RNA's: Small Molecules with a Big Responsibility," (0439186) show that small pieces of RNA can play huge roles in silencing, activating, and controlling gene expression. This rapid development of this forefront discovery continues to provide insight into genomics and its translation into proteomics at the fundamental, molecular level.

Nanotechnology continues to cut through nearly all of the NSF directorates. Scientists and engineers are examining the "Ingredients for Making Nanoscale Wires that Last" (0312028 ) and have developed a remarkable way to determine and control the stability of nanowires, connecting the fundamental theories of condensed matter physics with the practical applications of conducting wires. In addition, the ability to manipulate matter on the nano or micro length scale is being increased by research such as "Weaving and Bedazzling on a Microscopic Scale with Holographic Hands" (0451589) has demonstrated the ability to control the position of very small colloidal particles in order to understand their behavior on that scale and to create manufacturable materials such as photonic crystals that may be the fast communication devices of the future. As society moves into the nano-age, NSF also contributes cutting edge insight into how we as humans deal with that length scale through funding of programs on "nano-ethics". One program, "From Laboratory to Society: Developing an Informed Approach to Nanoscale" (0304448) is developing new models to understand both the conventional and disruptive technologies that are emerging with the human enhancements enabled by nanotechnology. For example, nanosensors on the human body could make one aware of all physiological conditions and health status, but how should access to that information be controlled? Effective communications between scientists, engineers, and policymakers is a key component of the developing models.

Some problems in mathematics have been unsolved for centuries. NSF supported research into "Partitions of Natural Numbers" (0196355), which lead to the successful description of how a number can be divided into a sum of natural numbers. The problem was solved with many of the same techniques used to prove "Fermat's last theorem" and contributes to our understanding of statistics and mathematical techniques through fundamental and inquiry-based science. The implications can be seen in the powerful innovations in algorithms and computational power which lean heavily on mathematics as a partner in development. For example, in “Efficient Numerical Methods for Viscous Incompressible Flows,” (0512176) researchers have developed tools for very challenging modeling of unpredictable and turbulent flow at length scales that verge on the molecular scale in three dimensions. Using computational power that will be developed even more to capture science that can be enabled by truly integrated cyberinfrastructure, these developments should be able to be further developed for very complicated systems: magneto-hydrodynamics, polymers, geodynamics, and climate modeling.

And finally, NSF has enabled our understanding of the human world, that is, our social and our physical interactions within our surroundings. In one exciting example, “Is Infants' Understanding of Spatial Concepts Guided by Universal Processes or Language-Specific Experiences” (0349183), researchers examine how different language speakers address spatial concepts. Differently trained speakers from different countries can group words and concepts differently, although many of the initial language relationships to spatial orientation are constant. Moreover, after a certain preconditioning, certain learned behaviors persist and cannot be retained back to a more universal interpretation.

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IDEAS GOAL -- Indicator I2: Encourage collaborative research and education efforts across organizations, disciplines, sectors and international boundaries.

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NSF is a unique source of support for international, interdisciplinary collaboration in research and education. In the past two decades, NSF has made major investments in collaborative research projects that cut across disciplinary and organizational barriers to achieve high quality results. Major commitments made to cross directorate initiatives like “Biocomplexity in the Environment (BE)” have attracted hundreds of high quality integrative proposals. As the 2004 BE COV noted, NSF has been, in fact, “leading the charge” in promoting interdisciplinary collaboration on major research questions of broad social and scientific relevance that are not well addressed by single-discipline approaches. Without NSF encouragement, the dynamics of most campus promotion and tenure processes all too often tend to discourage cross-disciplinary or multi-investigator approaches, reducing both quality and relevance of scholarly research for national goals. Internationally NSF is one of the few national funding agencies open to participation by foreign collaborators, actively encouraging the formation of international research teams and exchange of students and scholars. This openness provides clear benefits to US science and provides students with practical experience in international cooperation, which will become increasingly important in the future.

One example of synergistic results from a large-scale, multiple-investigator effort, cross cutting across multiple organizations is the program, “A Large Group of Investigators for a Common Goal: Assembling the Tree of Life: AToL,” program (0502081). One of the most profound ideas to emerge from biological research over the last decade is the realization that all life, from the smallest microorganism to the largest vertebrate, is connected through evolutionary relationships to form a single, vast evolutionary tree, the Tree of Life. The Tree of Life provides the framework for much of our modern understanding of biology because it reveals the diversity of life as well as the historical basis for similarity and differences among organisms. A meeting of all investigators on AToL grants was held November 2004, at NSF. The then 22 funded projects, reported that they were making fast progress and were producing data on an unimaginable scale. The interactions of the researchers at this workshop demonstrated that the field of biological systematics is changing: the field has been transformed by these large groups of collaborating workers pooling their efforts to advance toward a common goal. All of the projects contain substantial training and education components at all levels from undergraduates through post-docs, and many incorporate educational programs for K-12 schools and the public. The AToL program represents the synergy possible by large scale integration of scientific effort around a common set of research goals.

Another project reflecting NSF sponsorship of multi-investigator, multi-disciplinary collaboration on a coherent research topic of major societal importance is **"**Data Assimilation for Geophysical Systems" (0112069 , 9810282 , 0355474). This project brought together geoscientists, engineers, mathematicians, and statisticians and sought to encourage new interdisciplinary work on the problem of effectively processing and synthesizing diverse climatological and geophysical data sets used for weather prediction and short term climate modeling such as hurricane forecasting. Collaboration of multiple investigators drawing upon different disciplines allows for the assimilation (in timely manner) of diverse observations of diverse types into a common and usable framework. This project is a good example of new predictive and modeling tools with immediate societal benefits coming out of a combined multi-investigator, multi-disciplinary effort that would have been unlikely without NSF support.

NSF has taken the lead in sponsoring creative combinations of research and education through a number of programs and initiatives. The project, **"**Dissertations Initiative for the Advancement of Climate Change Research (DISCCRS)," (0435728, 0435728 ) is an example of a focused educational project addressing major barriers to high quality education and interdisciplinary collaboration. DISCCRS fosters cross-disciplinary interactions across the natural and social sciences and facilitates early-career development for Ph.D. graduates embarking on interdisciplinary, socially relevant careers dedicated to understanding and mitigating climate change and its impacts. A critical need for interdisciplinary research is to provide incentives and mentoring for younger investigators. There are still many structural intra-disciplinary forces which will tend to penalize extra-disciplinary activities and act to prevent younger un-tenured faculty from taking on the risks of an interdisciplinary collaboration such as those needed to understand climate change/climate impacts. It is hard to make the early career inter- personal contacts necessary for effective cross disciplinary collaborations that allow younger investigators to initiate larger scale projects. Support and collaboration networks need to be fostered early in science careers, and this program will provide a massive jump start to new investigators and senior students. DISCCRS establishes a sense of community by notifying participants of climate change news and events and, more importantly, encourages networking across disciplines and institutions that could otherwise take years. This is a good example of an innovative and well designed NSF educational program focused upon a key problem for the enhancement and development of US interdisciplinary science.

NSF has taken the lead in large-scale, logistics-heavy programs in the polar regions through the Office of Polar Programs. The ITASE (International Trans Antarctic Scientific Expedition) **"**A Basis for Understanding Past, Present, and Future Climate Change Over Antarctica and Adjacent Southern Ocean. The International Trans Antarctic Scientific Expedition" (0435728) is a 20-nation over-snow traverse consortium that is developing a continent-wide array of annually resolved, instrumentally calibrated records of past climate (temperature, net mass balance, atmospheric circulation, chemistry of the atmosphere, and forcing) covering the last 200-1000 years. ITASE provides an example of large-scale, international, expeditionary science at its most dramatic, and a good example of the impressive logistic capabilities of NSF's OPP. US science has a high international profile due in part to NSF's willingness to support such major undertakings, and to involve non-US co-PI's in big projects. The US Antarctic program has supported a vast range of projects ranging from paleontology to astronomy, and the trans-Antarctic expedition brings together many disciplines while continuing some of the "heroic age" traditions of polar science. It also provides a rich source of outreach materials, which has been well developed by NSF as a means of inspiring and attracting the public to the more dramatic aspects of scientific research.

Less dramatic but equally typical of highly effective long term NSF support for international cooperation in education is "Research Experiences for Undergraduates in Japan in Advanced Technology (REUJAT) (0243809). Since 2002 the REUJAT program has taken a few of America's top undergraduate students abroad to participate in a summer research appointment at some of Japan's finest universities and research institutions. The REUJAT program creates a unique opportunity for its participants to work closely with renowned Japanese researchers as their mentors in innovative technological research. This is a relatively small, but long lasting REU program in engineering which has a solid record of international collaboration. In this case, the link is bi-national (US-Japan) rather than multi-national, but the depth of the connection and the strong commitment on both sides has produced solid results in strengthening international connections in science and providing life-changing experiences to undergraduate students. The small-group mentoring approach has long characterized the NSF REU approach, and this approach works well in many international settings. The combination of educational impact and technology transfer make this program a very cost-effective NSF contribution to the long term health of US high-tech engineering and to maintaining close US-Japanese scientific connections.

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IDEAS GOAL -- Indicator I3: Foster connections between discoveries and their use in the service of society.

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Clearly, the entire portfolio of NSF awards will have long-range, broader impacts on society, but there are more than 250 examples across all of the directorates of recent projects that have direct and immediate benefit to society. Interestingly, many of these projects not only have near-term benefit, but from a research perspective are transformative, i.e., either associated with major breakthroughs or shifts in research paradigms. Each of these projects represents innovative and high quality fundamental research. While there are many good examples, the Foundation could do more. Often program directors play a central or key role in encouraging and connecting academic researchers with industry and/or other agencies to address societal problems. SF should continue to encourage program managers to play a role in facilitating such connections.

Post 9-11, the NSF worked closely with the Department of Homeland Security (DHS) and other agencies to connect NSF researchers with "real-world" problems that would help ensure security and protect the homeland. In one example (0322146), the Social and Behavioral Sciences Directorate funded researchers to develop an Adaptive Two-Player Hierarchical Holographic game, which is a scenario-based method for identifying and prioritizing security vulnerabilities related to critical infrastructure. In collaboration with DHS, the researchers advanced, improved and tested this innovative risk-analysis method by applying it to actual terrorism-assessment problems, simultaneously advancing their science and helping with an important national need.

Also related to critical infrastructures, the Engineering directorate through its National Network for Earthquake Engineering Simulation (NEES) activity (0402490 , 0217293) enabled academic researchers to collaborate with a consortium of California engineering and design companies to simulate the impact of an earthquake on an actual seven-story, 275-ton building, They used the large outdoor shake table at the University of California, San Diego, for the first test ever of an artifact of this size under motion replicating the ground motion recorded during the devastating January 17, 1994, Northridge, CA, earthquake. This test was part of a series of tests to evaluate potential new reinforced concrete building designs to improve both the seismic design and reduce the construction cost of residential structures in the densely populated and active seismic regions of Los Angeles and southern California. The result of this testing has a high likelihood of influencing future building codes. The testing also demonstrated that an alternative strategy of constructing lighter, cheaper buildings with precisely positioned reinforcement can provide structures more resilient in earthquakes.

NSF has also funded a number of projects with direct impact on the environment. For example, the impact of rainforests (and the loss thereof) on the carbon cycle is a very important issue. A research team (0213585, 0107270, 9815912) undertook an extensive geochemical survey of the Amazon basin using a dual-isotope method to trace carbon molecules in river water back to geological (inorganic) or biological (organic) sources. The scientists established that the source of carbon dioxide outgassing from the Amazon, and perhaps other medium or larger tropical rivers, is primarily from young plant-derived carbon rather than older geologically-derived organic and inorganic carbon. This research provides to ecosystem science a conceptual framework for the role of streams and rivers in tropical carbon budgets as a basis for future carbon cycle studies and as an important component of climate change modeling.

In another project (0234860) related to the environment, the Chemistry Division supported a group of chemists who pioneered the use of well-defined metal catalysts for converting the inexpensive gas carbon dioxide ($CO_2$) and a class of molecules called epoxides into thermoplastics (polycarbonates). Existing methods of preparing thermoplastics in the market today, like eyeglass lenses, CDs and DVDs, shatterproof glass, and baby bottles, are prepared by existing methods that generally require petroleum. This work is notable because it is an earth-friendly discovery that utilizes a greenhouse gas, carbon dioxide, in the development of a common, everyday material.

NSF's Biocomplexity in the Environment Program funded research (0119976) on the complex interactions of over-fishing and coral reef health, mediated through predator fish, grazing fish, and marine protected areas. With increased attention in the fisheries management arena toward ecosystems-based management approaches, this is a rare piece of fundamental research on complex coral reef systems that shows how one ecosystem-based approach, no-take marine reserves, may achieve the desired results both through direct enhancement of target fish species, but also by improving overall ecosystem health and the enhancement of non-target fish populations.

As DNA testing becomes increasingly used for identifying and diagnosing diseases, NSF supported a project (0506529) that developed a new method to identify DNA mutations that could possibly replace the Polymerase Chain Reaction (PCR) technique for DNA detection, and eventually result in small, portable, electronic devices for the rapid screening and identification of DNA sequences, PCR is an important method for amplifying small quantities of DNA, but it is relatively slow. This work is notable because this method may provide a faster, simpler means for the rapid screening and identification of DNA sequences. The method may have application in the diagnosis and treatment of genetic diseases.

The millions of Americans who use software applications are ending up as "end-user" programmers who have all the same needs as professional software engineers to make sure their programs are correct and reliable. A NSF project (0325273, 0324861, 0324770) is bringing Software Engineering capabilities to the end-user programmer – improving the dependability of the software end users create by applying Software Engineering knowledge and tools. The project studies not only how to bring technical programming support to the end-user but also studies the human factors involved. The project has an extensive educational component, which includes helping teachers redesign their mathematics curriculum to include the project software as a teaching tool.

In the area of education, a suite of four studies (0231826) on the use of directed instruction of perceptual learning of multiple representations show dramatic gains in students' understanding of mathematics and science. The studies were on graphing data, algebra problems, fractional problems, and incorporating perceptual learning into the classroom. The results of this project could lead to improved instruction across all disciplines of mathematics and science

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IDEAS GOAL – Indicator I4: Increase opportunities for underrepresented individuals and institutions to conduct high quality, competitive research and education activities.

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A critical analysis of the extent to which NSF is increasing opportunities for underrepresented individuals (women, underrepresented minorities and the disabled) and institutions to conduct high quality, competitive research and education activities would require data on the percentage of P.I.'s and students from each underrepresented group participating in NSF grants. Related to the above numbers is the percentage of underrepresented persons who served as grant reviewers, and the extent to which the Broader Impact criteria was addressed by both grant applicants and reviewers. A review of a number of COV reports indicates that there is a continuing need for better reporting and disaggregation of the data, as was recommended in the ten year report (2004) of the Committee on Equal Opportunities in Science and Engineering (CEOSE), the congressionally-mandated advisory committee to NSF. Yet, a number of the COV's reported that progress had been made. Several quotes are provided below from COV reports that make the case for both better reporting and that progress has been made. With regard to the query, "Does the Division Portfolio have the Appropriate Participation of Underrepresented Groups", the 2005 CISE COV stated that "Minority status had no visible impact on acceptance, though the data are sparse". On the other hand, the 2005 Integrative Organismal Biology COV stated that the representation was appropriate, and that the Committee was "heartened by the increasing number of proposals submitted by minority PIs and also by the striking increase in the number with minority participants, as reported in the Self Study". Yet the Integrative Organismal Biology COV recommended that "Better tools for tracking the Division's ability to support outstanding science and education are needed". And further, that it was "especially important to better document those persons from underrepresented groups in the science enterprise".

The review of nuggets below must be viewed in the context of the above discussion. Highlights of the review include: 1) The focus on integrating computer science and mathematics with other science disciplines in several new HBCU-UP grants; 2) The continuing research productivity of faculty members and students at Minority Serving Institutions which have CREST grant awards; 3) Significant scientific contributions being made by junior women scientists, in which NSF support played a major role; and 4) NSF support of projects that have the potential to significantly increase the entry of disabled persons into science careers.

Several projects support the case that NSF programs are impacting positively the representation of underrepresented minorities in science through programs that combine opportunities for high-level research with enhanced education. Examples include six (6) new HBCU-UP awards to Historically Black Colleges (0505872, 0506062, 0506155) that focus on the integration of computer science and mathematics with other disciplines in the sciences at the undergraduate level. We have entered an era where analysis of large amounts of data, particularly in Biology, is necessary to answer the major questions. Skills in computer science and mathematics are clearly necessary for success. Moreover, as graduate education and science research become increasingly more interdisciplinary, they provide the country with an opportunity to increase the interest of underrerepresented minority students in pursuing research careers by bringing together students from different disciplines to work on interdisciplinary problems. NSF's continued support of programs of this nature is essential to ensure that students who attend minority serving institutions are well prepared for the new emphasis on interdisciplinary research in graduate school.

Several CREST projects (9805529, 0317772, 9805465, 0318519, 0206028, and 9706268) make the case that infusion of significant support over a period of time can result in true institutional transformation. CEA-CREST (9805529) involves a collaboration between students and faculty in California State University Los Angeles' Center for Environmental Analysis and faculty at the University of Arizona's SAHRA Science and Technology Center to study the surface water and groundwater systems along the city of El Paso/Ciudad Juarez international metroplex. This project has resulted in new knowledge about groundwater, and has brought together a broad spectrum of underrepresented minority students with world-class research scientists. Jackson State University CREST has hosted for the past 5 years a conference entitled, "Current Trends in Computational Chemistry." In 2004, approximately 200 persons participated from 20 different countries, and 130 Jackson State students presented posters during the two-day conference. During 2004-05, the Center published 46 research papers in peer-reviewed journals and 2 book chapters. Another notable example is Tennessee State University CREST (0206028) which is using a telescope that it developed in 2003 as part of the CREST award to observe about 580 stars. In July, 2005, TSU CREST researchers were part of an international team that was the first to observe a planet with a solid core outside the earth's solar system. Since its inception in 2002, this Center has published more than 140 research papers.

While women participate proportionally to a greater extent in science than underrepresented minorities, it was surprising that there was only one program among the nuggets that specifically aimed at increasing representation of women in the science workforce. Yet, in light of the low representation of women in the field of computer science, a grant to the Computing Research Association' Committee on the Status of Women in Computing Research (CRA-W) is a notable grant (0434310, 0328587, 0124641). CRA-W has organized a network that allows them to implement a pipeline approach from undergraduate to senior academic leadership. This particular grant is for a distributed mentoring program which provides an opportunity for undergraduate women to engage in mentored research. The involvement of a professional society in a multifaceted approach to addressing underrepresentation of women in computer science could have a substantial future impact on this profession. Projects of this nature should be encouraged from other professional scientific societies.

Several grants are noteworthy in providing opportunities for the disabled to do research (0227992, 0406128). The project, entitled "Accessible Microscopy at Purdue," (0227992) aimed at constructing an integrated accessible microscopic workstation that would allow students with disabilities to independently perform various microscopic procedures. All of the participating disabled students were able to use the microscope successfully. In the second grant, entitled "Research Internships for Deaf Students", Dr. Peggy Cebe and three colleagues at Tufts University served as summer research mentors in the area of Polymer-Based Nanocomposites for four deaf students, three from Galludet University and the other from the National Technical Institute for the Deaf at Rochester Institute of Technology. One of the students presented the results of her research at the annual meeting of the American Chemical Society, took several additional courses in polymer science at her home institution, and will participate this summer in a program on polymer interfaces at the NSF Materials Research Science and Engineering Center at Stanford University. This latter project is a pioneering effort that needs to be replicated at other sites. A third study (0346951) shows that deaf children learn mathematics progressively well over the school years and almost as well as their hearing siblings. This study corrects previous misconceptions on the progress that deaf children make in learning mathematics, and may change how schools treat deaf children. Taken together, these three studies suggest that NSF is funding work with high potential impact in increasing the representation of disabled persons in the science workforce.

While not targeted to female scientists, several NSF grant awards to junior level female scientists have resulted in notable findings which could catapult these young professionals into very successful careers. Christina Marchetti (0305407) is using physics to study how the cytoskeleton is organized in cells. She is an emerging leader at the interface between biology and physics. Isabela Sziufarska (0427188, 0512228) made a significant contribution to our understanding of deformation processes in materials (published in Science) while a postdoctoral fellow and supported by an NSF –Information Technology Research Award. In 2005, she received her own grant from NSF to determine the properties of nanostructured ceramic materials. This grant is helping to launch her career in the University of Wisconsin's Materials Sciences and Engineering Department. Renata Wentzcovitch (0428774) and her colleagues are using advanced computers to predict the properties of materials in order to understand how planets, like earth, acquire geology, atmosphere and other distinctive features. Much of this work was published in Science. This work is also supported by an NSF Information Technology Research award. Finally, Duana Fullwiley (0208100), an anthropologist and recipient of a minority postdoctoral fellowship award, has conducted one of the first ethnographies aimed at understanding uses of race in medical genetics in the U.S. The above examples suggest that young women scientists are benefiting from NSF support.

Native Americans are the most marginalized group in the scientific workforce. In its 2004 report, CEOSE recommended that NSF enhance research opportunities at tribal colleges. While there were no nuggets related to tribal colleges, two nuggets (0328234, 0440614) describe projects involving major universities and Native Americans in Alaska. The P.I. of one project, Deanna Kingston, is a faculty member at Oregon State University and a member of the Inuipat (Eskimo) tribe in Alaska. The project was planned in conjunction with members of the tribe (community-based research) and involves a team of researchers from Oregon State (anthropologists, biologists, archaeologists, geographers, and linguists) along with 30 members of the Kings Island diaspora, who have returned to the island to participate in the project. The purpose of the project is to gather as much information about the cultural bio-geography of Kings Island, before it is lost with the passing of the oldest members of the tribe. This work will immerse younger members of the tribe in scientific research, and represents a significant research effort by the female P.I. who is a member of the Inuipat diaspora. A second project (0440614) is a GK-12 grant to the University of Alaska Fairbanks which involves six faculty members, 12 GK-12 graduate fellows and 22 elementary school teachers at 13 schools within three school districts, where 28% of the student population in made up of underrepresented students. The purpose of the project is to teach computer and cyber skills to elementary school children, directed towards increasing their participation in science. This project has impacted 550 elementary school children. This project has the potential to transform science education at the elementary schools involved, thereby increasing the number of Native Americans who pursue careers in science

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IDEAS GOAL – Indicator I5: Provide leadership in identifying and developing new research and education opportunities within and across S&E fields.

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Many projects supported by the NSF provide leadership in identifying new research and education opportunities within and across S&E fields. These projects have direct societal benefit and some will have future economic impact.

For example, the NSF funded project, "Adaptive Signaling and MIMO Precoding for Rapidly Time-Varying Fading Channels" (0312294), improves capacity and user quality of service in wireless communications. Growth and demand for wireless communications capacity has created a need for significant improvement in performance by more efficiently adjusting transmitted signal-to-fading conditions. Novel approaches with adaptive optimization techniques have led Professor Alexandra Duel-Hallen and her collaborators to the development and implementation of more reliable wireless transmission. This work involves collaboration with industry and thus, enhances the education of the graduate students working on the project.

Large-scale engineering design is a necessary and high-cost component of product development and improvement. Computer-aided design (CAD) systems are essential to the modern product development cycle. Geometric design is fundamental to CAD systems. The NSF-supported projects "Signal Processing for Surfaces" (0093390) and "Subdivision-based Algorithms for Surface Modeling" (9988528), by Professor Denis Zorin, of the Courant Institute of Mathematical Sciences, has identified and developed new techniques that significantly improve the underlying theory of geometric design. Furthermore, results of this work have been incorporated into a well-known commercial CAD system used by manufacturers world-wide. The improved CAD system has allowed for the design of more complicated models along with reduced costs. The insertion of these new techniques into the CAD system required collaboration between theoretical computer scientists, engineers, and management.

A coordinated investment by NSF in long-term, high-risk, multidisciplinary research, has led to a prototype of the first ever retinal prosthesis. The contributions of individuals from different research fields, over more than a decade, show promise of a major breakthrough in the treatment of blindness. A prosthetic device that enables previously blind people to perceive light and patterns has been developed through the work at the Engineering Research Center for Biomimetic Microelectronic Systems (0310723), led by Dr. Mark Humayun. The use of an implantable prosthetic device to send visual imagery information through the optic nerve to the brain is a new paradigm in the treatment of blindness. Researchers from the fields of biomedical engineering, electrical engineering, computer science, and medicine contributed to the discovery.

Image or signal reconstruction is an important technology that concerns recovery of an object – a digital signal or image – from incomplete measurements. This technology is used today in repairing old films and tapes, in biomedical imaging, as well as in military applications of satellite pictures. Professor Emmanuel Candes of the California Institute of Technology, through his NSF funded projected, "Signal Recovery from Highly Incomplete Data" (0515362) has recently developed a new sampling theory, called Compressive Sampling (CS) that enables the reconstruction of images or signals from a number of samples, which is much smaller than the desired resolution of the image or signal, for example the number of pixels in the image. This means that by collecting a relatively small number of measurements rather than pixel values, an image can be reconstructed that has essentially the same resolution as if all the pixels were measured. CS will have considerable impact in many fields of science and technology. Professor Candes has recently been selected to receive the National Science Board's prestigious Alan T. Waterman Award for his pioneering work.

The research of Anselmo Lastra, NSF project "Fifth Generation Graphics Hardware" (0306478), contributes to the need for more energy-efficient computation to extend limited battery life. The use of portable multimedia devices has increased tremendously over the last several years and has revolutionized how society deals with information. Applications of these portable devices, range from consumer use to professional and military uses, such as exploration, search and rescue, and communications. High power consumption is a critical limitation to mobile device technology. Professor Lastra has developed a new computing paradigm that allows computing speed to be traded off for power. With this new architecture, computation proceeds as fast as possible, given possible power constraints, and only consumes significant power when a task is to be done. This work has produced dramatic improvements in energy usage.

The development of fabrication techniques that bridge the gap between the micron scale and the molecular scale is a major goal of nanoscience and nanotechnology. A key problem is how molecular scale structures can be selectively attached and interconnected with micron scale structures. A Project led by Thomas LaBean of Duke University, "Novel DNA Nanostructures for Targeted Molecular Scale to Micron Scale Interconnects" (0218376), has achieved a significant step toward this goal using self-assembling DNA nanostructures. The project also provides training for minority high school students, and undergraduate, graduate, and post-doctoral students. Nanotechnology is an important field of the future, and training students at all levels will help ensure we have the needed expertise in this field in the future.

John E. Hobbie and Erik A. Hobbie have transformed the way ecologists measure the importance of material flux between plants and mycorrhizal fungi, as well as presenting alternative interpretations of other existing ecological data sets. It is known that an important beneficial relationship exists between soil fungi and certain plants. When nitrogen is limited, the fungi transport soil nitrogen to plant roots and receive plant sugars in return. In the past, efforts to measure the importance of this process have been questioned, since the techniques involved were either disruptive or manipulative and could be argued not to be representative of the natural environment. The Hobbies' work in Toollik Lake, Alaska, "The Response of Carbon Cycling in Arctic Ecosystems to Global Change: Regional and Pan-Artic Assessments" (9732281) and "Aquatic Ecosystem Responses to Changes in the Environment of an Arctic Drainage Basin" (9911278), should help interpret ecological observations at many other research sites and have applications for improved farming practices. Using products of natural processes to obtain measures of important ecological rates were unavailable earlier to the ecological community.

IDEAS GOAL – Indicator I6: Accelerate progress in selected S&E areas of high priority by creating new integrative and cross-disciplinary knowledge and tools, and by providing people with new skills and perspectives

NSF has made investments in projects that have brought together scientists from multiple disciplines to develop new tools and new integrative knowledge. In some cases, these investments have already resulted in important scientific advances. In other cases, these investments have created the infrastructure to foster significant advances in the future. NSF's cross cutting programs have "generated a large number of innovative ideas to increase the number of women in science and to improve their environment" (ADVANCE COV Report, 2005) and have "fostered an important area of multidisciplinary research addressing challenging environmental questions, including the explicit role of humans" (Biocomplexity and the Environment Competition COV Report, 2004). NSF's portfolio of investments meets the standards of relevance, quality and performance.

Several examples of NSF funded projects demonstrate how tools from one discipline may be usefully applied to the management and analysis of information and data collected in another so as to develop new integrative techniques. For example, Gutti Babu (0434234) organized a "Summer School in Statistics for Astronomers" to train physical scientists to use advanced statistical methods as a means for extracting physical insights from their data. The thirty-four graduate students and young researchers who attended the summer school uniformly rated it as a positive experience. At Brown University, artists, computer scientists, biologists, and physicists have collaborated to develop an innovative technique to visualize and analyze both experimental and computational data describing bat locomotion (0427374). The team, led by David Laidlaw, has developed custom artistic tools for iterative design and refinement of visualizations in virtual reality and these tools are being disseminated through an award-winning multidisciplinary course taught at Brown and the Rhode Island Institute of Design. Through the synergy of computer science, geoscience and applied mathematics, researchers at the University of Pennsylvania are developing new ways to collect data about archaeological structures thereby reducing the cost of excavation (0431070). This project not only develops a new technique for archaeologists, but also has resulted in the development of a new algorithm to use ground penetrating radar, electric resistivity, electromagnetic inductivity, and on surface laser scanning data to produce annotated volumes and slices. These three projects engage researchers from different disciplines to develop new integrative approaches to process and understand data.

Multidisciplinary teams of NSF funded scholars are developing new techniques that could revolutionize biomedicine. Researchers at the Biotechnology Process Engineering Research Center have developed the "liver chip," a living model of the liver that allows researchers to grow what is essentially a small liver and perform tests on it without risking a person's life or health (9843342). The technique that they have developed allows for small-scale simulations of body organs to be grown from the cells of individual donors, eliminating the use of lab animals and permitting more individually tailored therapies. The Engineering Research Center for Biomimetic MicroElectronic Systems at the University of Southern California is developing a new genre of microelectronic devices that can be implanted into the human body to replace missing or damaged neuronal functions (0310723). This center has developed a break-through device for the treatment of blindness with a retinal prosthesis (0310723). Both centers bring together engineers from multiple disciplines to develop new science. Both also serve as sites for undergraduate research and hence provide future scientists with new skills and perspectives.

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IDEAS GOAL -- Indicator I7: Support innovative research on learning and teaching that provides a scientific basis for improving science, technology, engineering and mathematics education at all levels.

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The nuggets provided to the Advisory Committee revealed three major relevant areas of intense activity and high performance in NSF-funded initiatives that go toward fulfilling the goal to "support innovative research on learning and teaching that provides a scientific basis for improving science, technology, engineering, and mathematics education at all levels:"

- Enhancement of K-12 education in mathematics and science, with a special focus on reaching underrepresented groups.
- Efforts to point undergraduates toward careers in mathematics, science, and engineering and to understand why fewer and fewer students choose such careers.
- Development of better and more effective venues for presenting mathematics, science, and engineering to the public at large.

In the area of K-12 education, several grants of high quality have performed well in addressing the essential need to reform the curriculum. Integrating the development of language and quantitative skills, long thought to be critical in the pedagogy of science, is addressed in "Improving Mathematics Achievement Through English Language Development" (0096609). Research on learning and teaching is also being advanced along productive lines by identifying new approaches to explaining complex topics in science and mathematics. The "NRC Study Highlights the Importance of Spatial Thinking in the Development of K-12 Curricula" (0076284), finds that spatial thinking, which helps students understand geometry, molecular structure, geology, astronomy, and a host of other disciplines, is not taught systematically in American schools. In "Understanding Science Through Models and Simulations" (0115699), new tools are described that help students conceptualize biological, chemical, and physical phenomena.

It is heartening to observe that many of the funded projects advance the notion that science should be taught by using the scientific method directly. For example, "Thinking Like a Scientist Helps Underrepresented Youth Use Science in Real-World Contexts" (0126555), "Bringing Playful Invention and Exploration to Families" (12021), "Dominican-American Students Learn about Evolution and Ecology" (0238908), "High School Students are Practicing to be Scientists" (0402648), and "Northern Science Education" (0234383) give students hands-on experience with scientific exploration and discovery, both in traditional classroom settings and in research environments. Many of these projects address the need to bring the excitement of science and engineering to students from underrepresented groups. The last project also gives students a global perspective on science, which also needs to be introduced in the curriculum as we prepare scientists and engineers to operate in a global economy and marketplace of ideas.

Simply introducing new pedagogical tools into the curriculum will not accomplish the goal of improving mathematics and science education unless these tools are adopted by schools and significant progress is detected. Efforts directed at formal assessment of curricular reform initiatives are particularly relevant to NSF's goal to support innovation in research on teaching and learning. In "The impact of Comprehensive School Reform" (0411796) and "Teacher adoption of Classroom Reform Practices" (0231981), researchers are asking which, how, and why new pedagogical methods are incorporated into the curriculum. They are also studying which strategies for curricular reform work and why. In "Assessing Teachers' Knowledge of the Mathematics and Science Needed for Teaching K-12" (0335411, 0335328, 0227057 ), tools are described that could help organizations assess the extent to which teachers are acquiring, through professional development activities, the skills and knowledge required to deliver a strong curriculum.

In the area of developing interest in science and engineering careers among undergraduates and graduate students, three nuggets summarize particularly relevant and effective efforts by grantees. The work summarized in "Bringing Authentic Science to the Undergraduate Lab Experience" (0513525) demonstrates a growing trend in undergraduate education to integrate research and education across all levels of the curriculum. By blurring the lines between learning concepts and applying them to the discovery of new phenomena, students can become excited by the prospect of conducting scientific research as a career. The work described in "Who Goes to Graduate School" (0310268) is a good first step toward describing the factors that play into choices made by college graduates contemplating graduate studies. Family income, academic performance, and quality of the undergraduate institution attended by the student were the key determining factors identified in this study. Amplification to include more potential determinants will be useful. To that end, the work described in "Women's Mathematical Interest and performance" (0217251) sheds light on possible strategies to increase representation of women in the higher professional ranks of mathematics, science, and engineering disciplines.

Many of the initiatives described above will benefit from parallel efforts to make concepts of mathematics, science, and engineering more accessible to the public at large. Representative of these efforts is the work described in "Molecularium" (0117792), a film about molecules adapted for dome theaters such as those found in planetaria, and "Understanding the Natural World" (0096613, 0229294, 0337243), a collection of web sites and museum exhibits that explains evolution.

In summary, the National Science Foundation's grant portfolio does a good job of addressing the need for continuing research on learning and teaching in mathematics and science. Among the nuggets supplied to the Advisory Committee, relatively few addressed efforts to meet these challenges in the field of engineering. Yet, the steady decrease in the graduation rate of engineers is a significant threat to further technological development in the United States. To the extent that it is able, the Foundation should energize the engineering community, through outreach, workshops facilitated by successful grantees, and perhaps special grants programs, to become engaged in high-quality and high-performance efforts to enhance research on teaching and learning in all areas of engineering.

### B. TOOLS OUTCOME GOAL

To accomplish NSF's mission, the foundation must not only invest in people and ideas, but it must also invest in the necessary TOOLS to support those people and ideas -- so the overall job can be accomplished both efficiently and effectively.

The Committee's assessment for the TOOLS performance indicator is that NSF has attained "significant achievement" in "*all*" sub-indicators T1 through T5 of the TOOLS strategic outcome goal. The Committee also concluded that the projects contained in the TOOLS portfolio for 2005 (FY 2006 Report) exhibited both high quality and high relevance.

Based upon the Committee's findings, and as supported by the nuggets from various new and on-going projects funded by NSF during FY 2005, and review of the many documents and resources made available to the Committee during the term of its review of NSF performance the TOOLS subgroup has unanimously concluded that NSF has demonstrated both relevance and quality. The R&D programs under the TOOLS performance indicator are important investments and appropriate and deemed to be of very high quality. Based on evidence provided directly to the Committee, it was not possible to independently gauge overall "performance" because we were only provided with a sample of the best nuggets, not a representative sample of all work performed. However, our review of the COV reports, which evaluated representative samples of all projects, indicates that performance was also excellent across the board. Our concerns in sub-indicator T-2 are discussed more fully under that topic below.

The current NSF strategic plan for FY2005 (2003 – 2008) dated September 30, 2003, is in place and includes a "GPRA Goal Structure" aimed at balancing expenditures for IDEAS, TOOLS, PEOPLE, and ORGANIZATIONAL EXCELLENCE. The amount budgeted for TOOLS, when compared to the needs for the other performance indicators set forth in the strategic plan, was 25% of the total NSF budget. During 2005, of the total NSF budget, which amounted to $5.4 billion, TOOLS equaled $1.375 billion. Thus, if expenditures can be used as a rough measure of performance, assuming expenditures were appropriately controlled, and we are confident they were, TOOLS expenditures met the performance goal in terms of allocation of resources. Alignment between strategic plan goal structure and FY 2005 expenditures was therefore achieved from a budget and expenditure standpoint.

**Recommendations for 2006 and Follow-up to 2005**

<u>Encourage More Focus on Innovative / High-Risk Bold Research</u>. The subgroup's 2005 recommendation that use of the Small Grants for Exploratory Research (SGERs) program should be expanded seems to have been addressed by the agency, but overall utilization remains low compared to the availability of such funding and thus more work needs to be done going forward.

<u>Fund more innovation (in addition to basic research) to balance the agency portfolio and enhance national competitiveness.</u> The subgroup saw little evidence that this recommendation was addressed after the 2005 recommendation. Further, there is some concern that the policy may not be appropriately aimed at balancing innovation (converting knowledge into dollars) against basic research (converting dollars into knowledge). The subgroup believes that there needs to be a balance within the agency between expenditures for transformative research and knowledge creation having long range impacts, with innovation, which has a nearer term impact on economic competitiveness. The subgroup believes the goal of supporting paradigm-shifting leading edge research, invention, and knowledge creation can remain a key part of the portfolio. However, the subgroup recommends balancing the research portfolio to include more emphasis on innovation.

**Supporting Information and Examples of Performance**

In support of the opinion regarding *substantial* accomplishment of all the goals for TOOLS, various Committee members conducted evaluations of work accomplished during 2005 in each of the TOOLS subcategories T-1 through T-5.

TOOLS GOAL – Indicator T1: Expand opportunities for U.S. researchers, educators, and students at all levels to access state-of the-art S&E facilities, tools, databases, and other infrastructure.

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NSF supports state-of-the-art facilities, tools, databases and other infrastructure that enable investigators to carry out significant research in a variety of STEM areas. Following NSF's interests in the intellectual merit of projects as well as broadening their impact, many projects extend access to researchers, educators, students, and, in some cases, the general public. From digital libraries to access to critical databases in the social sciences, to remote access to equipment such as microscopes and telescopes, NSF has demonstrated relevance to its mission, high quality and significant achievement in the performance indicator T1. A selection of examples follows.

NSF is using its National Science, Technology, Engineering, and Mathematics (STEM) Education Digital Library (NSDL) program to stoke the interest of underrepresented groups by sponsoring a project that has developed a comprehensive STEM career development digital library targeted toward engaging middle school students in STEM education and careers. "The Fun Works" (0333426) resources, user services, and interface are intended to place particular emphasis on the needs and interests of currently underrepresented populations in STEM education and careers, including females, students of color, and youth with disabilities. The project designed and launched the collection in May 2005. WebTrends activity for the preceding months indicates steadily growing web traffic. Statistics for successful hits to the site show that hits have grown from 95,000 in June 2005, to 228,000 in October 2005.

The National Nanotechnology Infrastructure Network (NNIN) (0335765) is an integrated national network of 13 university user facilities based at Cornell University that provides researchers open access, both on-site and remotely, to resources, instrumentation, and expertise in all domains of nanoscale science, engineering, and technology. The broad scope of NNIN coverage includes areas of physics, chemistry, materials, mechanical systems, geosciences, biology, medical and life sciences, electronics, and optics, among others. NNIN's impact in FY 2005 is represented by 4290 users, including 570 from small companies and 3200 graduate students, and by the nearly 200 new users per month being trained to utilize the facility resources. More than 1000 PhD awards every year are enabled by NNIN, representing a leverage of over $400 millions of national research investment. The network also has a substantial national and local effort in support of education, public outreach, safety, and examination of the societal and ethical implications of nanotechnology. Major scientific discoveries resulting from use of NNIN's resources have been highlighted on the cover of prestigious research journals such as Science and Nature.

In collaboration with colleagues in the National Center for Electron Microscopy (NCEM) at Lawrence Berkeley National Laboratory (LBNL) a group at the University of California-Davis (0335364) is developing the ability to control the transmission electron microscope (TEM) through a remote access control panel across the internet. The aim of the remote access is to allow students and faculty to perform the highest resolution experiments without having to travel to the microscope facility. The remote access microscopy facilities are similar to those being set up at other places throughout the US. The difference in the program that is being developed involving the UC-D group and NCEM is that the aim is to be able to perform the highest resolution analysis remotely. Typically only the basic operation of the microscope can be obtained from a remote site. Through internet accessibility to extra functionality and resolution, a higher degree of experimentation and teaching can be obtained.

NSF funding sometimes creates access to tools by enabling teams of researchers to work together. The California Array for Research in Millimeter Astronomy (0228955, 0228953, 0228963) -- CARMA -- combines telescopes from two NSF-supported observatories to form one new array of 15 millimeter-wave radio telescopes. CARMA will investigate a wide range of science topics, including forming solar systems around other stars, molecular clouds in the Milky Way, mapping of nearby external galaxies in molecules such as carbon monoxide, and detection of very distant forming galaxies. With all antennas under computer control, CARMA is ready for the first science observations and the data archive is about to be activated. This important new astronomy tool is the result of a collaboration of the California Institute of Technology (0228955), the University of Illinois Urbana-Champaign (0228953), and the University of California, Berkeley (0228963).

Alzheimer's disease, Parkinson's disease, and Lou Gehrig's disease are progressive neurological disorders involving the loss of neural cells in different regions of the central nervous system (CNS). Visualizing changes in the CNS is crucial to understanding and following the progression of these diseases, as well as researching the effectiveness of new treatments. Researchers using the 750MHz imaging magnet at the National High Magnetic Field Laboratory at Florida State University (0084173) studied brain and spinal cord changes in a mouse model of Alzheimer's and Parkinson's diseases. This study shows that high field magnetic resonance microscopy is sufficiently sensitive to measure small volume changes in early stages of a progressive neurological disease. The technique provides structural images with high definition corresponding to an isotropic resolution of just 41 micro-meters. The work illustrates the unique magnetic resonance imaging capability at the National High Magnetic Field Laboratory. The tool is available to the US scientific, community for research, and education and training in condensed matter, materials research, chemistry, biology, health sciences and the geosciences.

Finally, innovations supported by NSF are providing access to graphical images in science, mathematics and engineering for blind students. Graphical images, such as line or bar graphs, diagrams, and illustrations, are prevalent in math, science and engineering textbooks at all educational levels. But while studies have shown that tactual perception is the best way for people who are visually impaired to comprehend graphical images, those found in textbooks typically aren't available in this format. This impedes learning, development and success in areas in which individuals with disabilities are under-represented. A project from the University of Washington (0415273) has designed and developed the Tactile Graphics Assistant (TGA), a set of plug-ins for Photoshop and Illustrator, which support, as automatically and intelligently as possible, the transformation of graphical images into high quality tactual forms.

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TOOLS GOAL -- Indicator T2: Provide leadership in the development, construction, and operation of major, next-generation facilities and other large research and education platforms.

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There are ample examples, and several nuggets, which demonstrate significant achievement in performance indicator T2. However, the NSF has had a history of challenges with large projects. Just in the last year the Rare Symmetry Violating Processes (RSVP) MREFC was cancelled due to cost overruns and the ALMA project was re-baselined at a 45% cost increase of $155M. The life cycle of large projects listed in the indicator: development, construction and operation present difficult situations which the NSF is now addressing. We are pleased to see the progress in the oversight of large projects however; the new oversight methodology should be monitored closely by all. Information should flow freely between the Program Officers and the Director as well as all levels in between.

On Nov. 22, 2005 the NSF published "Guidelines for Planning and Managing the Major Research and Facilities Construction (MREFC) Account." This comprehensive methodology describes what should be done at the various stages of a MREFC: Conceptual Design, Preliminary Design, Final Design, Construction, Commissioning, Operations and Renewal/Termination. The Guidelines are well thought out and are now being implemented for all MREFCs. In the development of large projects, the NSF must insure that there is enough design and engineering support to obtain a realistic cost estimate. In addition, a Report by the Facilities Subcommittee of the NSF Business and Operations Advisory Committee dated May 16, 2006 gives many constructive recommendations to help the NSF be more effective in the oversight of operations of large facilities.

Below are three nuggets, each chosen to represent one of these three life cycle phases: Funding Initiated for the Design and Development of The Large Synoptic Survey Telescope (0244680) which is in the early stages of design and development; IceCube High Energy Neutrino Observatory (0236449) which is in construction; and Laser Interferometer Gravitational Laboratory (LIGO) Comes of Age (0107417) which is in operation. These nuggets represent three different life cycle stages in a major project and proper support and oversight of these phases can insure success. Each of these projects is a bold advance from any such existing tools anywhere in the world and therefore the NSF is to be commended for their support.

The Large Synoptic Survey Telescope (LSST) is a world class 8.4 meter telescope designed to survey the sky to search for exploding supernovae, potentially hazardous near-Earth asteroids, and distant Kuiper Belt Objects. The superb images from the LSST will also be used to trace the apparent distortions in the shapes of remote galaxies produced by lumps of Dark Matter, providing multiple tests of the mysterious Dark Energy. The nugget describes the NSF support for advances needed to make LSST successful in large scale optics fabrication, data management and a 3 billion pixel digital camera – the largest ever created. The LSST data will be open to the public and scientists around the world - thus serving educational as well as scientific missions. However, not to repeat some of the mistakes in RSVP, LSST is to be funded jointly by DOE and NSF and some of the lessons from the COV report above should be taken into account. Specifically there should be sufficient funding to perform the engineering needed to make an accurate cost estimate and there should be excellent coordination between NSF and DOE.

The IceCube High Energy Neutrino Observatory is aimed at doing neutrino astronomy – because neutrinos have no electric charge, they are not affected by the magnetic fields in the universe and so would point back to their source. In order to detect such energetic neutrinos which are very weakly interacting, IceCube uses about a kilometer cube of ice under the South Pole instrumented by 80 strings of 60 photomultipliers. A considerable amount of logistics is involved with drilling the holes in the ice, developing reliable strings of photomultipliers, developing the software to extract, calibrate and analyze the data. The first nine strings have been deployed as of early 2006 and are working well. Construction is scheduled to continue through 2010. This is an international project involving the U.S. with mainly NSF support and Belgium, Germany and Sweden.

While the construction of IceCube is going well now, there needs to be plans for the operation of the detector. Funding for operations is difficult within the NSF system, since any such funding competes with other projects. We suggest that the NSF consider budgeting operations of MREFCs in the same way as for the construction – namely with multiyear projections in a separate account which does not threaten smaller grants.

The third nugget selected to illustrate the excellent performance of the NSF is the Laser Interferometer Gravitational Laboratory (LIGO) which went into operation in 2005. This tool is located partly in the state of Washington and partly in the state of Louisiana and is designed to detect gravitational waves generated in cataclysmic events involving compact objects in the universe, such as the orbital decay and collision of black hole and neutron star binary pairs. Gravitational waves are distortions in the fabric of space-time produced by the rapid motion of massive objects; though predicted by Einstein's general theory of relativity and identified as the cause of the decaying orbits of neutron star binaries, they have not yet been directly observed. The interferometers are sensitive to gravitational waves since the length of one of the arms would change. The incredible sensitivity is smaller than one-thousandth of the diameter of a proton. The support of the operation of LIGO after the successful construction supported by the NSF is an exemplar of how the NSF needs to support large tools such as the previous two nuggets.

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TOOLS GOAL – Indicator T3: Develop and deploy an advanced cyberinfrastructure to enable all fields of science and engineering to fully utilize state-of-the-art computation.

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A review of the documents associated with performance indicator T3 indicated significant achievement in performance. As cyberinfrastructure evolves and new projects are added to the cyberinfrastructure portfolio, the portfolio should be assessed and monitored for alignment with national priorities. Finally, the definition of cyberinfrastructure itself is evolving.

At the recent Engineering Advisory Committee meeting held at NSF on May 3-4, 2006, the Subcommittee on Cyberinfrastructure characterized cyberinfrastructure as resources (computers, data storage, networks, scientific instruments, experts, etc.) plus “glue” (integrating software, systems, and organizations). As such, cyberinfrastructure constitutes the research environments that make advanced computation, data acquisition, and collaborative services available through high-speed networks. The activities addressing the goal of cyberinfrastructure fall into two categories[1]: Development of new tools to extend the bounds of cyberinfrastructure, and applications of the current cyberinfrastructure.

In 2002, the NSF convened a “Blue Ribbon” advisory committee to assess the challenges and opportunities associated with developing and deploying cyberinfrastructure. The report identified the following national and global priorities associated with applications of cyberinfrastructure:

- Global climate change
- Protecting the natural environment
- Applying genomics and proteomics to human health
- Maintaining national security
- Mastering the world of nanotechnology
- Protecting against natural and human disasters

[1] N. E. Noonan (Chair) “Report of the Advisory Committee for GPRA Performance Assessment” July 20, 2005.

- Addressing fundamental intellectual questions such as the formation of the universe and the fundamental character of matter

Another important application of cyberinfrastructure evident in the performance highlights was in teacher training and K-12 education as well as undergraduate education at Historically Black Colleges and Universities and Minority Serving Institutions. Although not specifically cited in the "Blue-Ribbon" panel report, this application of cyberinfrastructure aligns with the National Science Foundation strategic goal of "Learning", as identified in the current FY 2003 – 2008 NSF Strategic Plan:

> Cultivate a world-class science and engineering workforce, and expand the scientific literacy of all citizens.

As evidenced below, significant progress continues to be made towards the goal of cyberinfrastructure. The major challenges related to cyberinfrastructure are maintaining a balance between funding the development of new tools extending the bounds of cyberinfrastructure versus applications of existing cyberinfrastructure. In addition, the national and global priorities identified by the "Blue-Ribbon" panel should be re-verified and balance and alignment within the portfolio of applications maintained. Finally, as cyberinfrastructure becomes more prevalent, a growing concern continues to be stable funding and management of cyberinfrastructure resources and data storage, curation, accessibility and preservation.

Applications Aligned with "Blue Ribbon" Panel Priorities:

A review of the performance highlights associated with the cyberinfrastructure goal indicated a broad distribution of activities. The application "global climate change" included 4% of the cyberinfrastructure performance highlights. An example in this category is "GLORIAD: Advanced Science Internet Network" (0441102). GLORIAD is an optical ring carrying millions of bits of information every second allowing the transmission of entire libraries of information in minutes or permitting hundreds of simultaneous video-conferences or shared seminars. GLORIAD allows scientists and engineers in China, Russia, Korea, Canada, the Netherlands and the United States to exchange data and share sophisticated scientific instrumentation distributed across thousands of miles.

"The application "protecting the environment" included the largest percentage, 26%, of the cyberinfrastructure performance highlights. An example in this category is "Model Adaptivity for Porous Media; Unpolluted Water" (0511190). The computational techniques developed in this work facilitate the modeling of water flow through complex geological formations.

The application "applying genomics and proteomics to human health" included 11% of cyberinfrastructure performance highlights. An example in this category is "Genomics Collaboration Compares an Unprecedented Eight Species Using Evolution Highway Software" (0504064). By exploring the complete genome at once, multiple chromosomes across multiple species, these researchers found that "reuse" breakpoints were more common than previously thought. These reuse breakpoints were correlated to cancer by a mechanism similar to the breakpoints associated with cancer.

The application "maintaining national security" included 7% of the performance highlights. An example in this category is "Detection and Forensic Analysis of Database Tampering" (0415101). This work is aligned with recent legislation such as the Health Insurance Portability and Accountability Act and Sarbanes-Oxley Act, which mandate computerized audit information to prevent/detect database tampering.

The application "Mastering the World of Nanotechnology" included 6% of the cybernfrastructure performance highlights. An example in this category is "Walking Molecule Provides a Key to 'Molecular Memory'" (0438741). In this project a molecule was designed that can move across a surface in a straight line by simulating human walking. `This finding can have huge implications for nano-scale manufacturing.

The application "protecting against natural and human disasters" included 9% of the cyberinfrastructure performance highlights. An example in this category is "Forecasting Severe Storms" (0456541). In this collaborative effort between academic researchers and NOAA scientists, simulations were used to accurately predict the details of thunderstorms twenty-four hours in advance. Forecasts were run daily across the continental U.S. at a grid spacing of two kilometers, with five times finer resolution than previously attempted.

The application "addressing fundamental intellectual questions such as the formation of the universe and the fundamental character of matter" included a large percentage, 20%, of cyberinfrastructure performance highlights. An example in this category is "A Star is Born: Alternative Star Formation Theory Debunked" (0438741). In this work, astrophysicists at the University of California, Berkley collaborated with researchers at the San Diego Supercomputer Center (SDSC) to conduct simulations regarding star formation. These simulations advocated one of two competing theories of star formation.

Teacher Training and Education:

Several additional examples aligned with the strategic goal "Learning" from the current NSF Strategic Plan FY 2003 - 2008 are noted. "CENsei Project Leverages Real-World Scientific Data" (0352572) is developing curricular materials to enable middle school students to explore authentic scientific data collected from Southern California ecosystems. This work offers a peek at the potential for cyberinfrastructure to transform K-12 education by providing students access to real scientific data by facilitating scientific inquiry.

"Computational Science Workshop for Underrepresented Groups" (0427188, 0427177, 0427540) is enabling undergraduate students and faculty from Historically Black Colleges and Universities and Minority Serving Institutions to apply advanced computing and visualization to scientific problems. "Creating Cyber-savvy Teachers" (0520036, 0520146) is teaching K-12 teachers to learn how to teach state-of-the-art cyberinfrastructure to their students.

Finally, "GLORIAD: Advanced Science Internet Network," cited above, encompasses the "development of new tools to extend the bounds of cyberinfrastructure."

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Tools Goal – Indicator T4: Provide for the collection and analysis of the scientific and technical resources of the U.S. and other nations to inform policy formulation and resource allocation

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Examination of this year's nuggets and the many resources on the NSF web site leads to the conclusion that NSF has demonstrated significant achievement in the collection, analysis, and dissemination of technical resources that can effectively inform policy formulation and resource allocation. Many of the databases compiled by NSF and derived from NSF-funded research can be found on the web site of the Division of Science Resource Statistics (www.nsf.gov/statistics). These databases are found to be rich, varied, and widely applicable to a variety of important issues. NSF-funded work in some instances is addressed directly to the collection, analysis, and interpretation of complex data expressly for the purpose of policy formulation. In other cases the fundamental research funded by NSF produces new information that is pertinent to important policy and resource allocation decisions. Examples are given of both types of research.

In recognition of the need for better data on the international dimensions of U.S. industrial R&D, NSF's Division of Science Resources Statistics proposed and funded a feasibility study to determine whether an integrated data set on U.S. R&D performance and funding could be created by linking NSF/Census Bureau data on the R&D activity of all U.S. companies with Department of Commerce/Bureau of Economic Analyses (BEA) data on the R&D activity of U.S. and foreign multinational companies (11984). The project both demonstrated the feasibility of linking the Census Bureau and BEA survey data and resulted in a richer data set on the domestic and international dimensions of U.S. R&D activity. Among the new information generated by the project are data on the R&D activities of U.S. and foreign multinational companies, including details by character of work (basic research, applied research, development). This project reflects methodological enhancements for capturing information on the globalization of industrial research and development and also provides new information that can be the basis for policy formulation in the international arena.

The Scientists and Engineers Statistical Data System (SESTAT) provides the most comprehensive picture available in the United States of the highly skilled science and engineering workforce (0420325, 0214279). The 2003 cycle SESTAT, released in 2005, combines the National Survey of College Graduates (NSCG), the National Survey of Recent College Graduates (NSRCG) and the Survey of Doctorate Recipients (SDR) to provide a detailed analysis of the employment, educational, and demographic characteristics of those trained or working in science and engineering occupations. This data release provides a substantial improvement in our understanding of such issues as size and composition of workforce in various science and engineering fields, patterns of immigration among scientists and engineers, and patterns of employment among under-represented groups.

NSF is providing support for pioneering research to develop international computing networks, or 'grids', that will enable broad collaborations in research and the analysis of massive data sets (0122557, 0086044). Examples include the nationwide Grid Physics Network (GriPhyN) to manage the data from two detectors at the Large Hadron Collider at CERN, the Laser Interferometer Gravitational Wave Observatory, and the Sloan Digital Sky Survey. Grid computing expands access to both computing power and rich data sets to enable participation by virtually any interested scientist or student in any discipline. The grid approach is fundamentally a concept for efficient computing resource allocation that provides opportunities for multidisciplinary and international collaborations.

The Inoperability Input-Output Model (IIM) is a new approach funded by NSF to estimate the economic impact of heightened Homeland Security Alert System (HSAS) threat levels, including the impacts of the length of implementation period and regional scope of alert (0301553). The model was applied to input-output data sets for the Greater New York Metropolitan Region. National IIM analysis was also implemented to estimate the psychological response of the general public to HSAS alert modifications. The team used IIM for modeling and analyzing transportation interdependencies, which includes road network structure, flow, capacity, as well as the type of economic activities they support. A specific case study was conducted for the Virginia Department of Transportation (VDOT) to illustrate how a terrorist attack (or disruption) on a highway system element can propagate to other physical and economic sectors within Virginia and also its contiguous region, so that management policies can be implemented to reduce the consequences of the event.

Adaptive On-Board Data Processing (AODP) is a key foundation technology for autonomous internetworking capabilities to support situational awareness by sensors and their on-board processors (0434117). The AODP technology is a software agent approach to detecting and integrating input from multiple sensors, which may be in many different situations and at many different locations. The outcome of this research will include a framework to enable sensor networks that are autonomous, intelligent and applicable to a wide range of environments; data analysis and mining components that can be utilized in intelligent sensor networks; an agent based processing system capable of adaptable workflow execution within the sensor network; and a sensor network test bed for continued research and development functionality. Deployment of this technology will enable rapid decision-making and resource deployment in a wide range of challenging situations.

The Comparative Study of Electoral Systems (CSES) is a 50-nation collaborative effort among 200 scholars to gather data to study the effects of various electoral systems and other democratic institutions on citizens' choices and political perspectives (0112029, 0451598). This multinational approach allows researchers to address questions of governance and perception across a spectrum of different political systems. Studies have included analysis of presidential versus parliamentary systems, structure of federal systems, and the impact of various electoral rules in different systems of democracy. To facilitate the utilization of the results in policy formulation, all data and study details are publicly available at www.cses.org.

Ozone depletion in the upper atmosphere is a serious issue for the future of life on this planet. The impact of chlorine compounds on ozone depletion has been studied in a project funded by NSF (9732909). Chlorine monoxide (ClO), reactive nitrogen gases (NOx), aerosol particle surface area, and water near the tropopause at high northern latitudes were measured from a DC-8 aircraft during an extensive series of measurements in the upper atmosphere in the years 1999 and 2000. These measurements suggest that enhancements of the active chlorine in this region of the atmosphere can result from exposure of air to particles containing water and nitric acid at low temperatures (<208 K). The daytime behavior of ClO is consistent with a mechanism in which activation of chlorine on particle surfaces dominates in regions of the atmosphere that are particle-rich, and deactivation by nitrogen oxides prevails in regions that are particle-poor. Knowledge of the major sources for ozone depletion is an important factor in the understanding of global climate change and in the formulation of policies regarding release of chemical compounds into the atmosphere.

For more than twenty years, there has been uncertainty about the energy, security, and environmental benefits of ethanol in the face of inconsistent and apparently contradictory studies. This uncertainty has now been greatly reduced by NSF-funded researchers who have examined the existing biofuels analyses to identify the sources of variation in the various analyses, areas of commonality, and important directions for further research (0345798). Using six representative recent studies, the researchers deconstructed the assumptions and data in each, and reassembled these into a common framework. Their analysis led to the definitive conclusion that the derivation of ethanol from corn requires much less petroleum per unit of energy than gasoline and produces a positive net return on the fossil fuel energy invested. The methodology employed is now freely available on the web (http://rael.berkeley.edu/EBAMM/) for others to utilize, and the results of this study contribute meaningfully to the national policy on biofuels and the allocation of resources for energy production.

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TOOLS GOAL – Indicator T5: Support research that advances instrument technology and leads to the development of next-generation research and education tools.

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NSF-supported research is providing the scientific underpinnings for future advances in instrument technology. The advisory committee found that NSF has demonstrated significant achievement in the T5 performance indicator. Specifically, the nuggets described below illustrate that the applications of new instrument technology will have significant societal impact. These applications include homeland security, alternative energy, drug development, the next generation of nanoelectronic devices, and improved observations of other solar systems.

For example, NSF-supported John L. Hall (0096822) shared the 2005 Nobel Prize in Physics for the development of laser-based precision spectroscopy, including the technique known as an optical frequency comb. The comb can be thought of as a precision ruler made of light, which can be used to measure, very accurately, very small changes in time. A potential application includes the development of more accurate Global Positioning Systems.

“Catalytic activity of nitrogen-containing functional groups supported on carbon structures for cathodic oxygen reaction for PEM fuel cells”, (0437451) deals with basic research supporting the next generation of fuel cells. Commercial feasibility of the hydrogen economy requires that a material or catalyst be found that can activate oxygen at low temperatures and still withstand the harsh chemical environment inside the fuel cell. Ideally, it should be non-metallic. The researchers are investigating nanostructured carbon doped with nitrogen, which shows activity equivalent to a commercial 20 wt% platinum catalyst.

“ME: Combinatorial, in Vitro Manipulation of a Polyketide Synthase Pathway on a Microscale” (0118820, 0414887) has demonstrated the synthesis of an antibiotic, a complex natural product, on a biochip. The biochip contains microfluidic chambers, causing the synthesis reaction to proceed more quickly and more stably than if it were carried out in a flask. This breakthrough, which resulted in two patent applications, provides the ability to generate novel metabolic pathways for drug discovery.

Molecular electronics --- building circuit components out of single molecules --- will require instrumentation to “see” the structure and function of these devices as they are fabricated. ” Electron Transport in Nanostructures and Single Molecules” (0244713) is using an electron-beam microscope, and has shown that it can improve the reproducibility of wiring single molecules into electronic circuits. For the first time, researchers have been able to optimize the working parameters to place, reproducibly, a molecule in the molecular sized gap formed by breaking a gold wire.

Adaptive optics, the use of mirrors that deform many times a second to match changes in the atmosphere and refocus incoming light, can enhance the capabilities of existing telescopes. These systems remove the blurring effects caused by turbulence in Earth’s atmosphere. Several adaptive optics systems have been installed. Implemented at the Gemini North telescope, Gemini Operations and Maintenance (0233706) produced near-infrared images of the stars that rival the resolution of those obtained from space. The Dunn Solar Telescope

(0244679) has obtained intriguing images inside sunspots, details of which suggest that there are features remaining to be discovered in solar activity. A highly unprecedented combination of adaptive systems, quantum optics and astronomy was the subject of a high-risk SGER grant, The Next Step in Low Cost, High Resolution Astronomy: Informationally Synthesized Optics (9813589). The approach, which was highly successful, substituted computational intelligence for hardware. It could result in an order-of-magnitude reduction in the cost of searching for spectral signatures of life in other solar systems and it led to a $2M follow-on grant from NASA.

## C. PEOPLE OUTCOME GOAL

The NSF PEOPLE Strategic Outcome Goal, which is to create "a diverse, competitive and globally-engaged U.S. workforce of scientists, engineers, technologists and well-prepared citizens," is central to ensuring that our nation continues to enjoy the high quality of life and security that this and previous generations worked so hard to create.

The Committee assessing the PEOPLE Strategic Outcome Goal found significant achievement for each indicator established for the assessment. Based on the review of project accomplishments (nuggets), COV reports, and other relevant materials, the quality of projects and programs was determined to be high and relevant to the PEOPLE Strategic Outcome Goal. Many of the projects reviewed have high relevance to the development of a strong workforce and to public understanding of science. Projects contributing to the PEOPLE goal were found to include goals and accomplishments considered to be bold and at the frontiers of science, engineering, and education.

The PEOPLE subgroup is concerned that focused investment in people occurs primarily in the Education and Human Resources Directorate (EHR). Our preliminary analysis indicates that programs in the science and engineering directorates specifically targeted at creating a diverse competitive and globally-engaged U.S. workforce of scientists, engineers, technologists and well-prepared citizens ranges from ~2 to 14% of the total budget. We would recommend that every directorate explore the potential for additional opportunities to contribute to NSF's workforce-for-the-21$^{st}$-century goals.

Looking to the future, the subgroup expressed concerned about the direction of the workforce development that must be the cornerstone of the growth of science within the nation. NSF has been admirable in establishing a culture within which a growing number of underrepresented groups are included in the future of science. There is concern, however, that this inclusion often is limited to the first layer of response, namely, the mere number of people from these groups. As the need for a well developed workforce increases, greater efforts must be made to ensure true inclusion of all people and institutions. Partnerships with minority-serving institutions must be infrastructure and science partnerships, not solely external student research opportunities. Student training must be the right balance between rigor and exposure. Funding must have the appearance of a true meritocracy, where the ideas are more important than the institution in which one resides. Innovative science teaching models must not only be discussed and developed, but implemented. The mission of NSF clearly establishes the goals of a diverse workforce in science. While we applaud NSF commitment to this goal and are very pleased in the programs established, we look forward in anticipation to the innovative and proactive solutions for which NSF is known, so that in the near future the need for specific diverse workforce programs will be eliminated.

We are heartened that NSF continues to recognize the importance of strengthening the STEM workforce by striving to attract more US citizens into STEM fields. Many youngsters have the impression, however, that they can earn better salaries in other fields, such as medicine, law, or business. We suggest that NSF collaborate with experts in marketing to mount or support more-aggressive campaigns that demonstrate not only the excitement of these careers but also the opportunity to earn lucrative salaries and advance into other careers as well.

In this context, we recommend strongly that NSF intensify efforts to identify, nurture and develop the next generation of leaders of the STEM workforce, those who will provide the vision and set the agenda for the Nation's future scientific, technological, and hence economic leadership, and the benefits to humankind that these will afford. Without leadership, the enterprise cannot go forward.

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PEOPLE GOAL – Indicator P1: Promote greater diversity in the science and engineering workforce through increased participation of underrepresented and institutions in all NSF programs and activities.

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The National Science Foundation has historically been a significant contributor to the development of a diverse science and engineering workforce in the United States. A number of these programs have yielded significant contributions and should be strongly encouraged to continue. The focuses of these programs have been on three areas: (1) high school student development, (2) undergraduate and graduate student development, and (3) institutional and faculty development. The Foundation continues to build on past programmatic successes with innovative approaches and significant results.

The development of pre-college students is an important component of the Foundation's plan to improve diversity. Focusing on elementary and high school teachers and students (0094095, 0402648, 0353331,0089231,9725525,0096609,0556062, 0509123), these programs have given students that traditionally do not have access to cutting edge science the ability to see and understand interesting science. A Carnegie-Mellon University program (0338760) provides an example of an innovative collaboration between high school and elementary teachers, researchers, students and corporate partners. This collaboration has resulted in not only success within the program, but the development of software and procedures that translate methods in a usable form to teachers and students. The program has also stimulated collaborations and knowledge transfer, (0227709) that adapt tools developed in this program for use in other programs. This is an example of the extraordinary power that the Foundation can have in the development of partnerships that excel in increasing the workforce pool.

Enhancing diversity in undergraduate programs is especially vital to the development of the skilled workforce that is required by the competitive global economy. LS-AMP is a leading program in this arena (0000305). LS-AMP has supported the participation of tens of thousands of minority students in STEM fields in a large number of universities across the nation.

At the graduate level, one of the most innovative efforts is the GK-12 program (0231998, 0338326, 0231832) that affords graduate students opportunities to work with urban public school students to prepare them for STEM careers. The program exploits the notion that graduate students from similar backgrounds have insight into the needs and concerns of the students with whom they are working. This program not only educates graduate students in science but also in the development teaching skills as they learn teaching skills from experienced teachers.

Enhancing diversity in the faculty ranks of universities and colleges is also a priority for the Foundation and the nation. Programs increasing the number of women faculty (0452821, 0139528, 9619670 ) and minority faculty (0454533, 0109206, 0432398 ) are excellent examples of important steps towards a more inclusive faculty workforce in STEM fields. The development of minority institutions is also crucial to the education and professional development of minority students (0427188, 0427177, 0427540 , 0433819, 0114343, 9909038). The CREST program at Tennessee State University is an example of how Foundation funds can support minority institution programmatic goals (0206028, 9706268). This program provides funding for faculty to become more engaged in research, and students with role models in important STEM areas with a critical need for enhanced minority participation.

The inclusion of minorities and underrepresented students is crucial to workforce development. Deaf students, who have received inadequate attention, are being nurtured in proper and challenging environments (0349070, 0435627). Programs inclusive of people with disabilities are instrumental in creating a society that both appreciates and encourages diversity in the next generation of scientists (0234383).

Finally, a nugget is highlighted that illustrates the potential for rapid change in schools with low performance on meeting educational testing standards. The work of New Mexico State University and the Gadsden Independent School District (0096674) is truly extraordinary. The improvement of the poor minority population from sub-par scores in math and science to average and above average scores in five years was a success that was unmatched in other programs reviewed. This is a testament to the potential that the Foundation has in developing a diverse workforce that is inclusive of the best minds our nation has to offer.

Evaluation is crucial to understanding the societal benefits of NSF investments. Questions to be addressed include: how effective have these programs been in enhancing the participation of underrepresented groups and institutions in all NSF programs, and what do the results of a particular program imply for future research needs and goals? The efficacy of programs should be measured using a number of instruments. The American Economic Association program utilized statistical and survey methods to examine a number of NSF programs (0452821 ). The project identified important strengths and concerns in programmatic results.

There were notable absences in the reports. Most of the diversity nuggets originated from the EHR and CAREER programs. Notably absent are highlighted accomplishments from programs supported by other STEM divisions within the Foundation. While there is no doubt that there are important diversity successes across the NSF, the lack of information causes concern. The Foundation must be as proactive in its other Divisions and Directorates in these areas.

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PEOPLE GOAL – Indicator P2: Support programs that attract and prepare U.S. students to be highly qualified members of the members of the global S&E workforce, including providing opportunities for international study, collaborations and partnerships.

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The development of a US citizenry that is ready to partake of and lead in a new globally based S&E workforce is critical to the continued power of the US economy and to the development of new scientific frontiers. Given the evidence provided, the Committee lauds the National Science

Foundation for its continued tradition of S&E leadership in meeting this particularly crucial goal for the nation.

The workforce of the future will draw on today's K-12 student body, two- and four-year college students, and graduate students. The documents from the Foundation list 67 nuggets as primary indicators that fulfill this critical national goal. Based on the variety and quality of research awards that these nuggets represent, it is clear that the NSF investment supports tremendous breadth and depth. These include, among many others, nanotechnology and education, glass science research, robotics (and autonomous underwater robotics), the simulation of magnetic devices, materials development. In this summary three examples are highlighted. These are chosen to capture the depth and breadth of the Foundation's reach. We focus on depth to acknowledge the raw numbers of students involved and the grade levels at which that involvement occurs. We focus on breadth because it encompasses the quality and variety of the science involved, as well as the existence of international collaboration.

In graduate programs one of the more innovative examples can be seen in Electronic Device Fabrication Based on Conducting Polymer Nanofibers: Motivating Undergraduate Students towards Research in Materials Science, (0402766) where researchers at NYU bring an interdisciplinary focus to the study of magnetic devices. As device scale changes (here decreases) the relevant sciences also changes. For example, defects, spatial disorder and thermal fluctuations take on new meaning at nano-scales. The possibility for modeling, simulation, analysis and design, while mathematical in nature, raise fundamental questions for mathematics and physics. An interdisciplinary team of researchers at NYU has graduated five PhD's in mathematics and one PhD in Physics. Further, two post-doctoral fellows were involved in this research. These graduates have taken postdoctoral and faculty positions at Courant, Harvard, University of Warwick, UC Berkeley, Arizona, and Michigan State University (see also Nuggets: 0334176 and 0110253).,

Undergraduate programs are critical to the production of the S&E workforce. In the past four years more than 150 students have participated in Glass science at Coe College (0502051, 0089510 ). This work has built on a number of collaborative research opportunities in University of Manitoba, Canada; University of Warwick, UK; and Fudan and Sojo University, Japan. The research faculty has published 100 papers with their undergraduate students as joint authors, and, students have given presentations nationally and abroad. The work has focused on the atomic arrangements and other properties of oxide gases, and the rapid cooling of gases. About 75% of these students have moved on to graduate school in the sciences. Other examples of high quality programs of work are included in nuggets: 0402766, 0244097, 0409588, 0434108, & 0414102.

The GK-12 program described above extends the reach of the NSF to minority and disadvantaged children throughout the nation. In addition, a number of Graduate Research Fellows have occupied themselves with similar problems and issues. However, the highlighted nugget(s) look at protein modeling. " Macromolecular Structure Database" (0312718) looks at a high school challenge in structural biology, while Protein Data Bank (0312718) looks at protein modeling. Both utilize state level science Olympiads as a focal point in their respective K-12 systems. Unlike many other funded projects the former project here was used to leverage the success of the latter project. Eight high school student teams in New Jersey developed a written analysis of a TAT-binding protein (1PSV) and then used Rasmol and the Protein Data Bank coordinate file to construct a structure model. Efforts like this one encourage students to link biophysics, chemistry, computer science, and structural biology. These settings provide rich opportunities for learning science and allow students to experience the excitement and challenges that such opportunities generate.

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PEOPLE GOAL – Indicator P3: Develop the Nation's capability to provide K-12 and higher education faculty with opportunities for continuous learning and career development in science, technology, engineering, and mathematics.

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Development opportunities that implement Indicator P3 are funded over a wide rage of programs. Outcomes reported by projects funded in FY 2006 provide evidence of achievement and demonstrate a variety of approaches to engage teachers and faculty in quality development experiences across STEM disciplines. Examples include research to guide educators in effectively teaching scientific thinking and analysis, professional development that teaches system design, hands-on teacher development activities that are linked to state K-12 curriculum standards and coupled with mentoring to build teacher confidence, targeted activities to address shortages in science teachers in specific school districts, and opportunities for educators to explore newer fields and applications such as computational topology and nanotechnology. The number of people impacted by projects varies considerably and often reflects the nature of the activity. Some projects are designed for breadth of exposure and increased awareness, whereas others seek to achieve depth of understanding. Thus the portfolio of NSF projects represents a spectrum of continuous learning opportunities for educators. NSF project outcomes clearly demonstrate that the impact on involved educators is often quite extraordinary; and will, in turn, impact the larger number of students they teach.

Robotics are being incorporated into classrooms to teach real-time imbedded system design (0227709), with LEGO tutorials that address state educational standards for elementary and middle schools students (9731677), and to demonstrate the connection between mathematics, science, and technology (0202202). Teacher and administrator interest is being enhanced by linking STEM professional development to specific state needs and educational standards. Examples include the LEGO tutorials project mentioned above and the TRUST program that is answering New York City's need for certified earth science teachers via a museum-based summer earth and space science institute for educators; new geosciences content courses for educators; and a focus on NYC certification requirements in space and earth science (0243467).

Increasing the capability of the nations STEM teachers involves both expanding content knowledge and effecting continuous improvement of a teacher's ability to develop capable mathematicians, scientists, and engineers for the future. Examples of projects that are addressing growth in content knowledge include an NSF Summer Institute on Nano Mechanics and Materials that emphasizes recently developed techniques and theories not available in texts or standard university courses (0318907); and New Directions Visiting Professorships and the Institute for Mathematics and its Applications that focus on enhancing mid-career mathematical scientists in the field of computational topology (0307274). Both the Nano Mechanics and Materials and Computational Topology learning experiences are highly multidisciplinary. To date, 370 professors, post doctorals, and others have participated in the Institute on Nano Mechanics and Materials. In a more traditional field of study, enhanced science curricula for the study of sustainable resources has been developed and provided to 452 two- and four-year colleges for the benefit of more than 6000 students. In addition, a community-based approach to teaching sustainable resource science has been incorporated in more than 160 high schools nationally (0101498, 04455446).

“Thinking like a Scientist” is an example of expanding the nation’s ability to teach in STEM areas. This project is helping show STEM educators how to move students away from learning science as a memorization task. The focus is on using scientific thinking and investigation to solve socially relevant problems in a student’s daily life (0126555). Meeting the learning styles of today’s students is being demonstrated by “One to One Learning Opportunities across the Web” (0113317). By using web-based games that teach, more than 25,000 students and teachers in 50 states have been engaged in learning games that are collaborative and encourage the learner to contact a friend to log on and play a learning game. The “Connecting Math, Science, and Technology” project provides faculty development workshops for community college and high school teachers, and 130 teachers in the great lakes region have learned to help students make connections across STEM discipline through the use of calculator-based robots and other low-cost equipment (0202202). These teachers, in turn, teach 25,000 students annually.

Minority and disadvantaged youth are benefiting from multiple GK-12 Fellows projects (0231998, 0338326, 0231832). More than 1000 students with disabilities in New Mexico and Texas have benefited from the RASEM-Squared project that engages disabled youth as mentors and provides mentors with internships that often lead to jobs (0124198). A guide produced by the ADVANCE Program outlines best practices for attracting and recruiting a broadly representative pool of talent for the nation’s universities. This guide, which is available on the web, is already having a positive impact on the number of new hires of color and on the number of female science and engineering faculty at the University of California-Irvine (0123682). If widely used, the guide’s clear and easily applied set of informed practices have the potential of providing diverse role models for students and more career opportunities for those traditionally underrepresented in STEM.

PEOPLE GOAL – Indicator P4: Promote public understanding and appreciation of science, technology, engineering, and mathematics, and build bridges between formal and informal science education.

A wide variety of successful informal learning projects demonstrate the high level of excellence with which the Foundation has met its goal to promote public understanding and appreciation of science and mathematics. A large portfolio of outstanding projects includes mass media, exhibits, hands-on explorations, and web-based interactive elements -- often within a single project. Millions of children and adults have engaged in independent and informal learning via these projects, and assessments repeatedly indicate that learners achieve intended cognitive and affect goals.

The workhorse of informal science education for a mass audience is film, and "Forces of Nature" (0205992) is an award-winning 40-minute giant-screen film that exemplifies the genre. Produced by National Geographic and so far viewed by well over 4 million people, this is a classic Division of Elementary, Secondary, and Informal Science Education (ESI) project that demonstrates the first-rate nature of the enterprise as carried out by professional informal science educators and media producers. A well-designed companion website at http://www.nationalgeographic.com/forcesofnature/ has received more than 7 million page views. Among the pages on this site are interactive "laboratories" in which, for example, users may design a volcano by choosing the amount of dissolved gas and the silica content (high or low) in a given magma chamber to produce shield, composite, or cinder cones, all with very different properties, behaviors, and impacts on human communities. Extensive ancillary materials on the website help teachers incorporate the film and/or its content into their classrooms through a variety of well-designed lesson plans, of which over 30,000 have so far been downloaded or distributed.

Other ESI-supported projects engage families, school children, and/or their teachers in group learning activities with a strong participatory and/or hands-on component. The Playful Invention and Exploration (PIE) Network has reached more than 100,000 young children and their families at museums around the country. This program "promoting science inquiry and engineering through playful invention and exploration with new digital technologies" (0087813) rests upon the Cricket technology developed by the MIT Media Lab. Children invent structures into which they incorporate tiny, programmable Crickets that control motors, lights, and sounds in response to various types of sensory input. The interactive inventions that result teach children important principles of science and engineering through hands-on practice. The children even learn basic programming methods by using a simple graphical programming language to make the Crickets operate the way they want it to in their invention. In a different strategy, Community Science Workshops (CSW) 0400403, 9552572, 9358519) take hands-on science activities *to* communities, where they have so far serviced more than 50,000 African-American, Hispanic, and Native American K-8 youth a year in just their after-school programs. If all CSW programs are included, more than 100,000 youth participated in CSW activities by the end of the first year alone. CSW's California-based ScienceMobile was even put in service to take hands-on science learning to Louisiana school districts where students and teachers had suffered from Hurricanes Katrina and Rita. Among the most important elements of this successful project are its emphases on establishing CSW sites in local partnerships with museums, science centers, and community organizations; developing self-sustainable financial support systems for each neighborhood center; and including entire communities (parents and teachers as well as students) in CSW activities.

A different arm of the Directorate for Education and Human Resources, DUE (Division of Undergraduate Education), also produced projects with significant positive impact on the Foundation's ability to promote public understanding and appreciation of science and mathematics. The Fun Works is a website developed as part of the "CaREN: Career Resources Education Network for STEM" project (0333426) in close association with the National STEM Science Digital Library (NSDL, a project also supported by Human Resources Division budget lines). The Fun Works site (http://www.thefunworks.org) presents middle-school students with youth-oriented information on careers in science and mathematics, with a focus on "careers you never knew existed" and how they relate to popular interests such as music and art, the adventurous call of exploration, and more widely-known careers in medicine or law. Site design is based on research into the ways middle-school students approach career development and preparation, with particular focus on the needs of females, students of color, and youth with disabilities. Current research on ways of effectively accessing and using digital resources, much of it in conjunction with the NSDL, was also used in designing the site. The result is an engaging resource that introduces students to the range and variety of career possibilities open to them, and that provides critical and practical information about how to prepare for the future as well as how to get involved in related activities right away. Lesson plans, activity ideas, and community-building opportunities help teachers incorporate the information into their classrooms.

The budget for the Division of Elementary, Secondary, and Informal Science Education program, which supports the three projects just described, is slated to hold fairly steady (in absolute dollars), but other relevant budget lines in the EHR Directorate are being cut by about 30%. The start and end dates for The Fun Works project are September 1, 2003 to August 31 of this year (2006), and DUE is one of the divisions being adversely affected. This project thus may represent one of the last of its kind, in combining cutting-edge research on education via digital libraries with research on learning in female, minority, and disabled students to pioneer new, effective methods of reaching such students regardless of their physical locations.

It has been postulated (even hoped) that the loss of funds for projects such as The Fun Works will be balanced by production of high-quality informal science education materials by scientists heretofore considered primarily research-based. The extremely innovative "sLowlife: A Traveling Exhibit of Plant Science and Art" (0531641) was supported by the generally research-oriented Biological Sciences Directorate's Molecular and Cellular Biosciences Division, and is highly noteworthy as a result. Through time-lapse photography and slow-motion film (in short video clips), art, and minimal text, this exhibit increases public awareness of the nature of plants as living organisms by clearly depicting the many types of motion in which they engage. It uses fascinating images and haunting sounds (original music created at the originating institution) to engage the viewer's sense of wonder and awe, and his or her appreciation of nature and of the science that reveals it. In the process, essential information is presented about scientific methodologies, the nature and complexity of cellular-level processes, physiological processes such as photosynthesis, how science and plants themselves relate to humans, and how American science-and-culture relationships have changed over the past few decades. A companion website at http://plantsinmotion.bio.indiana.edu/usbg facilitates community access to the exhibit and makes it accessible to people in areas where the exhibit will not appear. Embedded links in the web exhibit take users to active research laboratories and other sites that support and facilitate additional, independent exploration and learning. This project is a superlative example of the benefits that accrue from integration of research and education.

Whether other PIs will be able to similarly use multi-disciplinary collaborations of scientists, educators, and technicians to create outstanding public education materials; whether those efforts will be able to serve specific demographic groups in meaningful ways; and whether they will attract the nation's youth into science, engineering, or mathematics careers remains to be seen. Certainly the sLowlife project is an impressive demonstration of the potential.

## D. ORGANIZATIONAL EXCELLENCE OUTCOME GOAL

The ORGANIZATIONAL EXCELLENCE (OE) strategic outcome goal is, “an agile, innovative organization that fulfills its mission through leadership in state-of-the-art business practices.” NSF is successful when significant achievement is demonstrated for the following performance indicators:

- Human Capital Management: develop a diverse, capable, motivated staff that operates with efficiency and integrity.
- Technology-enabled Business Processes: utilize and sustain broad access to new and emerging technologies for business application.
- Performance Assessment: develop and use performance assessment tools and measures to provide an environment of continuous improvement in NSF’s intellectual investments as well as its management effectiveness.
- Merit Review: operate a credible, efficient merit review system.

The OE strategic outcome goal was added to the NSF Strategic Plan for FY 2003-2008 and helped to recognize the linkages between excellence in advancing science and excellence in organizational development. NSF’s merit review process is the keystone for award selection, through which NSF achieves its goals. All proposals for research and education projects are evaluated using two criteria: the intellectual merit of the proposed activity and its broader impacts. Specifically addressed in these criteria are the creativity and originality of the idea, the development of human resources, and the potential impact on the research and education infrastructure. Ensuring a credible, efficient system requires constant attention and openness to change.

The Advisory Committee for Business and Operations (AC/B&O) provides an assessment of the first three OE indicators (Human Capital, Technology-enabled Business Processes, and Performance Assessment), and the AC/GPA conducts an assessment of the Merit Review indicator. To perform this latter assessment, the 2006 AC/GPA used data and information from the:

2005 Committee of Visitors reports addressing Merit Review and Organizational Excellence
2005 Report to the National Science Board on the National Science Foundation’s Merit Review Process (NSB-06-21)
2005 Report of the National Science Board on the National Science Foundation’s Merit Review System (NSB-05-119)
2006 AC/B&O Assessment

Overall Findings: In conjunction with the findings of the AC/B&O and our own review of the Merit Review indicator, the OE subgroup concludes that the NSF has demonstrated <u>significant achievement and quality in all four indicators</u> of Organizational Excellence.

Overview (including highlights taken from the Report to the NSB on the NSF Merit Review Process): The merit review system is highly effective, trusted, and respected by participants within the science community. The process is thorough and has well-designed contingencies for handling non-procedural issues and allows for continuous improvement. This is indeed an impressive accomplishment given the heterogeneity of the NSF portfolio (single investigator grants, center grants, facilities/research infrastructure grants) and the diversity of peer review mechanisms (mail review only, panel review only, combination of mail and panel review, combination of mail and site visit review, inter-division and directorate review, etc.). It is even more impressive given that proposal pressure has increased by 38% from 2001 to 2004 (in 2005 a slight decrease in proposal number occurred) leading to a declining success rate (33% in 2000 to 23% in 2005). Despite severe budget constraints over the past five years, NSF has maintained an excellent and diverse program balance including single investigator grants, multi-investigator grants, center grants, and facilities grants and grants that promote high risk/high payoff “potentially transformative” grants. This success of this last category reflects the high quality of scientific knowledge and judgment of program managers and the Directorate/Division leaders. Statistically, there is no evidence of demographic bias in the award of grants during the period 2000-2005, which is an important result. The falling success rate is of concern, although the rate of decline is less for new awards (8%) than for those who have had prior awards (12%). Another important point is the percentages of standard grants and center/facilities/other grants have not changed significantly (2%) over the past 5 years. It is difficult to measure efficiency given that expected outcomes are generalized in solicitations, reports, and strategic goals.

Many COVs reported issues with the Broader Impact criterion and felt that NSF should do more to help reviewers and principal investigators, understand, and reflect their understanding in their written reviews and proposals, respectively. Requests for more guidance from NSF with respect to interpretation of the definition of “broader impacts” were common as were requests for specific examples of activities that would fit this criterion. In addition, some programs requested that more emphasis be placed on “societal impact” and broader participation of underrepresented groups when interpreting the Broader Impact Criterion. Several COVs commented that it was unclear how the two criteria should be weighted during proposal review, with most acknowledging that there should be discretion to adjust relative weighting among different types of programs and projects.

There is some concern that statistics are not available to document the diversity of the reviewer pool. Several recommendations have been made to address the apparent lack of reviewers from underrepresented groups.

Another concern is the potential problems of over-interpretation of statistics and data mining that can lead to erroneous conclusions. An example is a potential misinterpretation of declination statistics among different programs that may in fact reflect the comparison of different funding modalities or an event such as a special solicitation. It would be a tragedy if the excellent job of maintaining a fair and balanced portfolio that has been achieved thus far by NSF would be impacted by data mining that was not conducted by the most validated statistical approaches. Care should be exercised in the use of statistics to make critical decisions unless there are better data mining controls.

The highlight of efforts to utilize and sustain broad access to new technologies for business application has been the continuous improvement of FastLane. Utilization is now 100 percent. However, NSF adaptation to new technologies overall continues to be slow and the continued use of paper jackets in COV reviews is out-dated and impedes the efficiency of the process.

There is general praise for a diverse, capable, motivated NSF staff that operates with efficiency and integrity, particularly at a time of evolution of job responsibilities at NSF. The diversity of NSF programs and management formats together with the time investment require additional demands on NSF staff that are not always appreciated. In most cases, it seems that the faculty/program officer rotation process works well. Rotators are an important component of program management; however, programs also require highly experienced program managers with a broader understanding of the operation of the Foundation and the evolution that it is undergoing. If NSF seeks to undertake activities such as identifying a portfolio of "transformative" research, the expertise of experienced program managers will play a critical role. The identification of "program nuggets" is also probably critically dependent on the exceptional judgment of program managers.

NSF has many ongoing internal initiatives to use performance assessment tools and measures for continuous improvement in NSF's intellectual investments as well as its management effectiveness. However, none seem to be highly effective or well accepted as useful tools. NSF needs to tread carefully here; assessment tools that lead to the wrong conclusions could be disastrous.

Minutes and Observations from the AC/B&O (May 18-19, 2006): Independently, the AC/B&O reviewed the three indicators of the OE goal; Human Capital Management, Technology-enabled Business Process, and Performance Assessment. Based on their discussion, members of this committee responded to the question, "Does the evidence presented support NSF's determination that it has (or has not) "demonstrated significant achievement" for the indicator?" The Committee concluded, with reservations, that NSF's determination of demonstrating significant achievement for the three areas of OE is appropriate and supported by the evidence. For a complete review of these minutes, please see: (http://www.nsf.gov/oirm/bocomm/meetings/may_2006/documents/FacilSubcomFinalReportTKirk06-10-06.pdf

**Committee of Visitors' Comments on Merit Review**

This following section analyzes the responses made by the COVs and other advisory committees in relation to:

- quality and effectiveness of the program's review procedures,
- implementation of the NSF Merit Review Criteria by reviewers and program officers,
- selection of reviewers; and
- resulting portfolio awards under review.

*Reports on Merit Review:* COV Reports on the quality and effectiveness of the use of merit review procedures: After reviewing all the 2005 COV reports across all directorates, nearly half of the COV panels answered yes to the merit review process being appropriate, but they had issues with the process or recommendation to improve it. It appears that the COV template questions are not allowing the COV members to pinpoint their issues with the process consistently. Most were trying not to say "no" outright, but instead said "yes…but." This suggests the questions which the COVs respond to need to be further delineated to address specific sub-processes.

Two thirds of the 2005 COVs felt the process was both effective and efficient, while 1/3 of the COVs cited issues with efficiency due to paper-laden practices like jackets as well as other stated concerns. Nearly all praised the NSF staff for handling such large workloads within a short amount of time. Two-thirds of 2005 COVs felt reviews were consistent with stated priorities. One-third had issues with Broader Impact Criterion and felt NSF should do more to help reviewers understand and reflect their understanding in their written reviews. This continues to be a challenge for NSF.

Even though the 2005 COV reports answered "yes" to the question about individual reviewers providing sufficient information to PIs, about half of the COVs had issues with lack of details, non-expertise commentary and broader impact. This area seems to need further attention.

Most COVs found the panel summaries to provide adequate information to the PI and recognized a need for continuous improvement. The ITEST COV did not appear to answer question 5 in its report. The 2005 COV reported mixed responses to whether NSF program officers provided good rationale and supporting documentation for recommendations. More than 1/3 of COVs cited cases where they thought the NSF program officer documented actions but the reasons for awards or declination could have been more transparent. The 2005 COVs found that NSF handled nearly all proposals within 6 months for a compliance rate of about 85% overall.

*Implementation of the NSF Merit Review Criteria by reviewers and program officers:*
Overall, most Divisions reported that both review criteria (intellectual merit and broader impacts) were considered by reviewers, panels and program officers when making proposal funding decisions. In fact, many Divisions reported a chronological improvement in addressing both review criteria. However, many COVs reported persistent problems with application of Broader Impact Criterion in proposal preparation and review. Specifically, there were a number of comments on problems and inconsistencies with the definition and weighting of the broader impact criterion. Requests for more guidance from NSF with respect to interpretation of the definition of "broader impacts" were common as were requests for specific examples of activities that would fit this criterion. In addition, some programs requested that more emphasis be placed on "societal impact" and broader participation of underrepresented groups when interpreting the Broader Impacts Criterion. Several COVs commented that it was unclear how the two criteria should be weighted during proposal review with most acknowledging that there should be discretion to adjust relative weighting among different types of programs and projects (e.g. Ph.D. institutions versus non-Ph.D. institutions, education and outreach projects versus research projects, etc.).

The problem with interpretation of the broader impact criterion has been recognized for a number of years. The 2004 AC/GPA report noted that both the proposal descriptions and the review summaries of the Broader Impact Criterion were frequently cursory and lacked substance and that there was a large degree of inconsistency with respect to its treatment in reviews. The 2005 AC/GPA report noted that despite improvements in the numbers of proposals and reviewers that address the criterion (>90%), it needed better definition and more balance in its use in proposal review. The report went on to recommend that NSF address this issue by conducting workshops at national meetings to train and certify reviewers.

*Selection of reviewers:* Overall, COVs were highly satisfied with the performance of POs in dealing with a large number of proposals in an efficient manner and in developing panels comprising a diversity of experts who contribute to a highly credible merit review system.

In almost all cases, the COVs reported that a sufficient number of reviewers had been obtained for all proposals. In a notable exception to this, the MRI program COV reported that a "number" of proposals were reviewed only by two reviewers, which is insufficient, and that this problem was related to identifying and recruiting sufficient technical expertise for reviewing certain kinds of instrumentation proposals.

Uniformly, COVs praised the Program Officers of different programs for creating panels comprised of reviewers with appropriate expertise and qualifications. In addition, several COVs noted a good distribution of expertise on review panels, although calls for more reviewers from the social sciences, from industry, and from different educational institutions were made, especially for large, interdisciplinary proposals.

By far, the question that elicited the most concern from the vast majority of COVs was about the balance of reviewers from underrepresented groups. While the geographic balance appeared to be adequate in most cases, problems were frequently noted about the types of institutions and the number of reviewers from underrepresented groups. Three concerns were repeatedly expressed: 1) that there were insufficient data on either/or the types of institutions from which reviewers came or the racial and ethnic backgrounds of the reviewers; 2) that a large proportion of reviews did not self-identify by race or gender; and 3) the number of female reviewers or reviewers from underrepresented groups was in line with the distributions within the discipline. Some COVs were satisfied with the makeup of the panels if the panels reflected the diversity present within the discipline. This does not seem to address the spirit of the question as related to underrepresented groups.

*Resulting portfolio of awards under review:* The extreme heterogeneity of programs under review makes comment on the appropriateness of the portfolio difficult. The comments of the various individual COVs vary widely ranging from expressing concern about maintaining the appropriate distribution among single investigator and center awards to expressing concern regarding choice of focus of specific educational efforts. The only overarching comment appears that the balance of the portfolio appears, in general, to be appropriate.

It is not likely that answers to questions regarding the portfolio can be made more quantitative; given the necessary heterogeneity of the NSF investment business models for portfolio assessment will not apply.

Perhaps the only level where the question of portfolio can be answered in a meaningful way relates to maintaining an appropriate distribution of resources among ideas, tools, and people. That allocation appears appropriate based on COV reports, NSB reports, and reports to the NSB.

**Committee of Visitors Comments on Outcome Goal for Organizational Excellence**

The Outcome Goal for Organizational Excellence is to “provide an agile, innovative organization that fulfills its mission through leadership in state-of-the-art business practices.”

Various COVs noted NSF’s monumental responsibility for stewardship of the national scientific enterprise and the natural tension between stability vs. agility, and reliability vs. innovation. Another COV stated that an agile business is one that responds quickly to new opportunities, realities, and recommendations from customers, experts, and peers. While most of the COVs did not respond directly to each of the four critical management objectives (merit review, technology, staff, and assessment), there were several common remarks made for many programs.

First, COVs provided many examples of how individual programs, and their responsible POs, were achieving the goal of organizational excellence. In addition, the NSF staff, principally program officers, were often praised for their dedication to their work, and their efficiency, insight, and ability to overcome challenges. Several COVs mentioned the small size of the NSF staff having to deal with an increasing number of proposals, which challenges the ability of the POs to maintain and efficiently organize and run programs. One COV noted that a single PO was managing two separate programs. One division (GEO/ATM) was able to hire an interdisciplinary science assistant to support all of its programs, which led to a more efficient process because that person helped coordinate proposal data and results between programs.

Related to the number of proposals shepherded through a program was the proposal pressure versus the funding levels for each program. As is universally recognized, too often many highly rated proposals go unfunded. The NSF was urged to experiment with ways to encourage innovative, high quality proposals while also preventing the excess of wasted time and effort throughout the scientific community in nonproductive proposal preparation that results when success rates are very low. While the overall assessment was that the merit review system is highly credible, from the point-of-view of applicants whose proposals are rated "excellent/outstanding," but not funded, the process may be perceived as inadequate. Because so many proposals must be declined, the resubmission rate is often higher for subsequent panels, which makes it increasingly difficult to discriminate among applications in the top tier.

Another question was related to the information COVs and POs were using to assess a program---what performance assessment tools and measures were being used to provide an environment of continuous improvement in NSF's intellectual investments as well as its management effectiveness? COVs also mentioned that they did not have comprehensive knowledge of all of the tools that NSF uses to conduct performance assessment, which made it difficult for them to comment on this important process.

While cross-directorate collaboration was lauded in the pre-award phase of the GK-12 program, the COV recommended developing mechanisms for similar post-award collaboration and synthesis (for example in reading and responding to annual, final, and evaluation reports), which might further promote exchange between divisions and POs. COVs recognized the challenges of cross-directorate financial management, which may require a more flexible funding mechanism to insure that innovative interdisciplinary and high-priority programs are addressed in a timely manner.

The administration of programs has been greatly enhanced and streamlined by the use of FastLane, which has increased the efficiency and effectiveness to manage and track vast numbers of proposals and to help ensure that the review and reward process is fair and well-documented. While the use of e-jackets has the same promise of efficiency and effectiveness, several concerns were expressed about their use. It was also mentioned that several problems identified with the e-jacket system had not yet been addressed despite staff criticism.

NSF has long used rotators as a means to inject new ideas and to stimulate innovation within programs, however, COVs identified other ways that this might be done, including the use of regular internal meetings and retreats for continuous upgrading of strategy and identification of emerging areas for future investments. While the concept of rotators was uniformly praised, one COV suggested that permanent Division Directors be hired to promote sustained management and leadership within programs; this practice, however, is not followed throughout the NSF.

COVs noted that many PIs and panels did not adequately address the Broader Impacts Criterion in proposals and their review.  For instance, in BES, POs commented on broader impacts in their review analyses in only 52 of 100 files while commenting on intellectual merit in 73 of the 100 files.  COVs for both BES and HRD recommend that intellectual merit and broader impact criteria can and must go hand-in-hand within proposals and recommended that the two criteria be given equal importance.

**Comments on the Report of the National Science Board on the NSF's Merit Review System**

The NSF merit review system remains an international gold standard for review of science, engineering, and STEM education proposals, maintaining high standards of excellence and accountability.  NSF has a partnership with the extramural science community in which Federal financial support for this work flows through a core system of merit-based peer review administered by NSF staff with expertise in scientific disciplines.  The NSB fully supports the current NSF system of merit review, which uses the peer review process as the principle driver in funding decisions, and finds it to be a fair and effective way to review the more than 40,000 proposals the Foundation receives each year in a wide variety of subject areas.  The NSB also endorses the role of NSF's program officers' professional judgment, in concurrence with division directors, for addressing both Merit Review Criteria and for achieving a balanced portfolio of research and education awards.

The NSB has made several recommendations to improve the transparency and effectiveness of the review process.  The NSB notes that billions of dollars worth of declined proposals receive a high average rating through the NSF merit review system and yet are not funded.  Program officers use the results of peer review and their own expert judgment to create a well-balanced research and education portfolio, which may include consideration of geographic distribution as well as gender, ethnicity, and institutional diversity.  The merit review process also gives program officers flexibility in funding exceptionally high-risk, multidisciplinary, and innovative projects.  While the practice of funding high-risk projects has been investigated (see Assessment of Transformative/Bold/Innovative-High Risk Research and Education proposals from the 2005 ACGPRA Performance Assessment report), it is unclear whether the use of geographic, gender, ethnicity, or diversity criteria to make awards has also been studied.  It would be interesting to determine to what extent such practice actually occurs throughout the NSF.  Also, if the merit review process is designed to foster research in the larger science community that is consistent with the national goals of the Foundation and is to be carried out in a fair and unbiased fashion, would use of such criteria draw criticism from the community?

The NSB notes that these program officers are the heart of the merit review process, which depends on the experience and integrity of the POs.  The report states that the NSF budget has doubled in the past decade, resulting in a 50% increase in proposals and more than a doubling of proposals rated "excellent," however, NSF staff has increased less than 5% during the same time.  Thus, POs' workload has greatly increased.

In terms of the scientific, geographic, and institutional composition of review panels, reviewers in 2004 came from all 50 states, however, data on traditionally underrepresented groups serving as reviewers are incomplete.  This corroborates the findings of the COVs.  One problem is that only about 17% of reviewers (in 2004) provided information on gender and race/ethnicity.  While the 2004 AC/GPA voiced concern about the lack of data on the demographics of reviewers, this still remains a concern, based on other information provided to this year's AC/GPA.

The NSB document states that the two merit review criteria need not be weighted equally. The 2001 NAPA report stated that the Broader Impacts criterion was problematic because reviewers had difficulty interpreting what NSF meant by broader range of projects. In some cases, broader was associated with methods used in research rather than scientific content and in other cases broader was discussed in terms of novelty or uniqueness of research. In 2004, the ACGPA found that discussions of this criterion in proposals frequently lacked substance and appeared to be cursory at best, even though NSF now required a one-page discussion of both criteria in the project summary of the proposal. Broader impacts still remains a challenge for most reviewers, and PIs. One recommended solution to this problem was for NSF to conduct workshops at national meetings to train and certify reviewers - however, what about PIs?

The proportion of women and minorities to apply for and receive NSF grants has remained unchanged over the past eight years despite significant increases in the number of applications and overall number of awards, although direct funding to minority-serving institutions increased 176 percent over a 10-year period. It is unclear, however, how these numbers would be affected if grants from EHR were eliminated from this calculation.

The document states that POs can exercise significant discretion in determining whether completed reviews are usable. This seems surprising, unless in the context of COIs, especially since NSF staff generally indicated that assessing the potential value of the proposal requires a very thorough analysis of the strengths and weaknesses of the proposal across ALL reviewers. No data were included, however, to determine how significant this discretionary use of reviews is throughout the NSF.

It is also unclear to what extent the recommendations made in this report from the NSB have been addressed by the NSF, programs, or POs.

**ORGANIZATIONAL EXCELLENCE GOAL Recommendations**

1. Improve/revise Reviewer Management System (database of reviewers) to link or develop databases of reviewers or to seek different ways of finding reviewers. The diversity within the reviewer pool is a very complicated issue, and use of mechanisms other than self-declaration and voluntary compliance should be considered. The logical answer will likely be better education of the reviewer community on the importance of self-reporting of ethnicity/gender data. Reviewer training (including some component of sensitivity training) could improve an already highly effective process. Several recommendations were made to help rectify the perceived lack of underrepresented reviewers. A call for better record keeping was made by several COVs---perhaps the POs in charge of panels could record the gender and, to the extent possible, the racial and ethnic backgrounds of reviewers. These data are necessary to determine to what extent deficiencies in panel makeup actually exist. In addition, it was recommended that programs with a high diversity in the reviewer pool, such as those programs in HRD, were recommended to share their pool of reviewers with other NSF programs. A focus on broadening the stable of reviewers to include those from different academic institutions, such as community colleges, could also help broaden the diversity of reviewers. All programs were urged to continue the practice of inviting new reviewers to serve on panels with experienced reviewers. This practice was seen as positively affecting both the number and diversity of reviewers, but also the potential number of PIs from underrepresented groups. Finally, the Surface Earth Processes COV suggested that POs should seek reviewers from related sub-disciplines in science where minority participation is relatively higher to increase diversity in those programs typically homogeneous in nature.

2. We recommend that Intellectual Merit and Broader Impact criteria can and must go hand-in-hand within proposals and both must be considered by reviewers. NSF should modify the wording of the two Merit Review Criteria to insure that both are clearly articulated and both insure and support high standards of performance. We recommend that NSF establish supplemental guidelines and factors to consider in evaluating broader impact criterion that are readily available to PIs. In addition, we propose the following: First, that the guidelines and factors used to evaluate broader impacts criterion are made as transparent as possible and are communicated specifically to reviewers as well as PIs. Secondly, the guidelines should include specific instructions about the weighting of broader impacts criterion in proposal review with provisions, perhaps, to give discretion to divisions to apply differential weighting for specific programs as appropriate.

3. In order to reduce staff workload, we recommend that NSF consider ways to reduce repeated review of projects and programs, for example, extending the COV cycle, eliminating annual COV responses by the program officers. We also recommend the elimination of paper jackets.

4. Formalize the new Program Officer Development process for all divisions of NSF. Require all new POs to attend the PMS (boot camp) and provide required updates for permanent POs.

## *III. COMMITTEE RECOMMENDATIONS*

The Committee was asked to provide recommendations in two different areas:

1. How the Committee would operate under the proposed 2006-2011 Strategic Plan, specifically:
    a. what information will be needed to evaluate the "two crosscutting objectives;" and
    b. how the committee process might change given the new strategic plan.

2. General recommendations on how this year's information and process could be improved.

There appeared to be enough overlap between the two sets of recommendations that the Committee created the following single list of recommendations. Based on the overall review, the Committee generated twelve recommendations in three areas as shown below: (1) how to improve the performance assessment effort (e.g., data collection, analysis, guidance, etc), (2) some recommendations on how to improve the AC/GPA process, and (3) general recommendations on NSF priorities.

2006 RECOMMENDATIONS (listed in order of priority)

1. **New Strategic Plan Objectives.** There was considerable discussion about exactly what significant achievement toward the two new Strategic Plan objectives would mean. The definitions under each of the new objectives are basically further definitions of the new four goal areas and includes 14 sub-objectives. It was not clear how these objectives will be used in the evaluation process. NSF is encouraged to give more thought to how best use the new objectives as evaluation tools.

2. **Nuggets.** Nuggets should include more than, for example, just the number of or fact that minority students were included, but also, the specific activities and outcomes that

are desired. The selection process should allow the designation of "primary nuggets" to cross goal areas (e.g., People and Ideas). When available, nuggets should include measures of effectiveness and data on who has been affected and how. Program Officers (POs) should be encouraged to write nuggets as they evaluate annual reports (versus once-a-year for the AC/GPA process).

3. **Baselines.** NSF should develop analysis on research and education trends with baselines indicating how NSF efforts are contributing to change. Currently, it is not clear what research and education baselines we are using to assess performance and how NSF's role relates to the broader federal research and education efforts.

4. **Stimulate Education Research.** NSF is encouraged to do more to stimulate new and more in depth research in teaching and learning, particularly in engineering education, implementing and disseminating potential best practices as they are identified.

5. **Reports.** The Committee will continue to need relevant Advisory Committee, technical, and site visit reports, but the reports will need to reflect the new strategic plan goals, objectives, and priorities. NSF should continue to improve the quantitative measures in COV reports so that they can be compared across programs.

6. **Broadening Participation.** The Committee would like to see data on all aspects of "broadening participation." Specifically:
    a. More conclusive evidence is needed on whether NSF has indeed increased opportunities for underrepresented individuals and institutions.
    b. NSF should explore creative mechanisms to bring industry and academia together to achieve this goal.
    c. NSF should increase the number of non-EHR programs in the Committee information that have indicators showing diversity and inclusive workforces.

7. **Merit Review.** NSF should establish supplemental guidelines and factors to consider in evaluating the Broader Impacts Criterion. These should be made readily available to PIs to ensure that both criteria are clearly understood. The Reviewer Management System (database of reviewers) needs to be improved to enhance the diversity and overall quality of the review pool.

8. **Alignment of Goals, Outcomes, and Budgets**. The Committee would like to see information that links goals, objectives and priorities to budgets and outcomes across the NSF. This should also include aligning the research and educational initiatives within NSF with the priorities indicated in the National Academies report "Rising Above the Gathering Storm," particularly where the priorities outlined in the report and those of NSF overlap.

9. **Innovation.** NSF should provide a report on the most important innovations across the NSF directorates and embrace innovation as a fundamental element of its mission. The Committee would like to see how the NSF balances its risk portfolio to include: (1) high risk, transformative research, (2) important, lower-risk research, and (3) innovative research that may enhance near-term national competitiveness. The first two are converting dollars into knowledge and the third converting knowledge into dollars

10. **Facilities.** NSF needs to improve the management of large projects and consider the maintenance and sustainability of these for the long-term.

11. **Workload/Workforce.** NSF should examine ways to reduce workload (e.g., reduce inspections of inspections, increase intervals between COVs, etc). The Committee continues to be concerned about the workload that program officers continue to face. One thing to consider would be to discontinue the use of paper jackets that summarize the award decisions and make this process more electronic and transparent. The Committee also recommends that all new POs attend the Program Manager Seminar ("boot camp") and NSF should provide periodic updates for permanent POs. From previous Committee reports and given rising stress in the reviewer pool, the NSF needs to include the "reviewers" in its agency workforce analysis (i.e., how to increase the numbers and diversity in the pool).

12. **Process.** The Committee recommends the following related to the AC/GPA process:
    a. Committee members should have three-year terms that are staggered, with one-third rotating off each year. The terms of the Chair and Vice-Chair might be extended 1-2 years so they can both serve on the Committee and be in a position to become an informed and effective Committee leader.
    b. This year's orientation and pre-meeting materials and work enhanced the quality of the on-site discussion and should be continued.
    c. The Committee needs to provide each subgroup a reporting template so that the subgroup reports are uniform. That would substantial reduce the editing needed in the final production of this report.
    d. A decadal assessment to explore performance trends across the years at the Foundation level should be considered.

The Committee recommends that this list be discussed with NSF to ensure that it is not overly burdensome to NSF and yet provides the Committee with data needed to effectively complete its work.

## *IV. FUTURE CONSIDERATIONS FOR THE COMMITTEE*

In addition to the recommendations presented, there were two issues identified by the Committee that should be areas for future discussion during the 2007 AC/GPA process. First, each of the subgroups had questions concerning how the nugget selection could be more representative of directorate activities. Because these issues were raised at the end of the first day of deliberations, there was not time to fully explore with NSF staff how the nugget selection process could be improved to address the Committee's concern. However, it is recommended that this issue be addressed in the introductory remarks by NSF staff next year to provide the Committee with an understanding of the history of the nugget selection process and the work effort that is involved in making the nuggets available for review.

Secondly, some Committee members discussed the need for better guidance needed on how NSF expects to evaluate performance against the objectives in the new Strategic Plan. NSF needs to define what "significant achievement in leadership" of fundamental research and education is and how this relates to the new goals, objectives, and priorities. As the NSF staff considers the evaluation processes under the proposed strategic plan they are encouraged to consider this approach as one possibility. The Committee looks forward to discussing this possibility during their deliberations in 2007.

As part of the charge, the Committee was asked to examine how it would operate under the new NSF strategic plan. Specifically, the Committee was asked to identify: (1) what information will be needed to evaluate the “two crosscutting objectives”, and (2) how the committee process might change given the new strategic plan (e.g., how often to meet, committee membership, use of nuggets, what should be the threshold for success, etc). To accomplish this task, the Committee divided into subgroups representing the new strategic plan goal areas (discovery, learning, research infrastructure, and stewardship). Each subgroup reported its results to the Committee of the whole for general discussion. A table that includes all of the information needs identified by goal subgroups is included in Appendix B.

Given the new strategic plan objectives, the Committee will be asked if NSF made “significant achievement” toward the two new objectives (“To Inspire and Transform” and “To Grow and Develop”) in the four goal areas. Prior to the small group work, there was a general discussion of exactly what significant achievement toward these new objectives would mean. NSF is trying to reduce the number of objectives from the prior strategic plan (~16) to these two objectives. However, the definitions under each of the new objectives are basically further definitions of the new four goal areas and 14 sub-objectives. The Committee was unsure about how these objectives will be used in the evaluation process. Many of the investment priorities appear to be better metrics for monitoring progress toward the four goals. The committee members believe that NSF needs to give more thought to how best use these objectives as evaluation tools. That aside, the Committee outlined the information they believe would be needed for AC/GPA work next year and some suggestions about the overall AC/GPA process.

## APPENDIX A

**NSF Strategic Plan, FY 2003 – 2008**
**Strategic Outcome Goals and Indicators**

**IDEAS GOAL**: discovery across the frontier of science and engineering, connected to learning, innovation, and service to society.

Ideas Goal Indicators:

I1: (Contributions) Enable people who work at the forefront of discovery to make important and significant contributions to science and engineering knowledge.
I2**:** (Collaborations) Encourage collaborative research and education efforts across organizations, disciplines, sectors and international boundaries.
I3: (Connections) Foster connections between discoveries and their use in the service of society
I4**:** (Underrepresented individuals and institutions) Increase opportunities for underrepresented individuals and institutions to conduct high quality, competitive research and education activities.
I5**:** (Identifying new opportunities) Provide leadership in identifying and developing new research and education opportunities within and across S&E fields.
I6: (Cross-disciplinary) Accelerate progress in selected S&E areas of high priority by creating new integrative and cross-disciplinary knowledge and tools, and by providing people with new skills and perspectives
I7: (Identifying new opportunities) Support innovative research on learning and teaching that provides a scientific basis for improving science, technology, engineering and mathematics education at all levels.

**TOOLS GOAL**: broadly accessible, state-of-the-art science and engineering facilities, tools and other infrastructure that enable discovery, learning and innovation

Tools Goal Indicators:

T1: (Expand access) Expand opportunities for U.S. researchers, educators, and students at all levels to access state-of the-art S&E facilities, tools, databases, and other infrastructure.
T2: (Next generation facilities and platforms) Provide leadership in the development, construction, and operation of major, next-generation facilities and other large research and education platforms.
T3: (Cyberinfrastructure) Develop and deploy an advanced cyberinfrastructure to enable all fields of science and engineering to fully utilize state-of-the-art computation.
T4: (Data collection/analysis) Provide for the collection and analysis of the scientific and technical resources of the U.S. and other nations to inform policy formulation and resource allocation
T5: (Instrument technology) Support research that advances instrument technology and leads to the development of next-generation research and education tools.

**PEOPLE GOAL**: a diverse, competitive, and globally-engaged U.S. workforce of scientists, engineers, technologists and well-prepared citizens.

<u>People Goal Indicators:</u>

P1: (Greater diversity) Promote greater diversity in the science and engineering workforce through increased participation of underrepresented groups and institutions in all NSF programs and activities.

P2: (Global S&E workforce) Support programs that attract and prepare U.S. students to be highly qualified members of the global S&E workforce, including providing opportunities for international study, collaborations and partnerships.

P3: (Continuous learning) Develop the Nation's capability to provide K-12 and higher education faculty with opportunities for continuous learning and career development in science, technology, engineering, and mathematics.

P4: (Public understanding of science) Promote public understanding and appreciation of science, technology, engineering, and mathematics, and build bridges between formal and informal science education.

**ORGANIZATIONAL EXCELLENCE**: an agile, innovative organization that fulfills its mission through leadership in state-of-the-art business practices.

Organizational Excellence <u>Goal Indicators</u>:

OE1: Human Capital Management--develop a diverse, capable, motivated staff that operates with efficiency and integrity.

OE2: Technology-enabled Business Process--utilize and sustain broad access to new and emerging technologies for business application.

OE3: Performance Assessment--develop and use performance assessment tools and measures to provide an environment of continuous improvement in NSF's intellectual investments as well as its management effectiveness.

OE4: Merit Review--operate a credible, efficient merit review system.

**APPENDIX B.**

| AC/GPA Information Needs for the 2006-2011 NSF Strategic Plan | | | |
|---|---|---|---|
| **Discovery** | **Learning** | **Research Infrastructure** | **Stewardship** |
| 1. Nuggets, if: they are relevant to the new goals and objectives, they are more representative, and cross-directorate nuggets are allowed.<br>2. Committee of Visitor reports that reflect the new goal areas.<br>3. Broader quantitative data (e.g., SRS data).<br>4. Project report summaries. Site visit and workshop reports.<br>5. Advisory Committee or Directorate reports that track directorate-wide innovations (e.g., 10 most important projects). Evidence of world-class leadership.<br>6. Program budget information that ties to the goals, objectives, and priorities.<br>7. Baseline or trend data that shows number of proposals received, funded, number of first time PIs, number of new initiatives, number of participants from underrepresented groups, reviewers, etc. | 1. Define terms in NSF goals and objectives and how success will be measured on learning projects.<br>2. Trend data on learning. Need baselines to judge the impact of NSF programs over time (results from national or NSF studies of S&E and public literacy). How much did NSF contribute to a change relative to some acceptable baseline (e.g., NSF's contribution to S&E workforce)? What are other agencies and countries doing?<br>3. Relevant NSF and national reports. How much does cyberinfrastructure help in learning, what are the best practices for K-16 efforts to keep people in S&E, how do students choose to go or not go into S&E careers, quantitative and longitudinal data on student career paths, etc.<br>4. Award data by demographics, institutions, and award type (i.e., the diversity of participants, are HBCU, TCU, etc advancing into the top 100 institutions, are | 1. Nuggets that reflect significant discoveries that depended on research infrastructure. Nuggets that specifically address the new goals, objectives and priorities and are relevant.<br>2. COV, Advisory Committee, Technical, and relevant workshop reports. COV reports need to address the new goals, objectives, and priorities.<br>3. Information that shows the broadening participation of PIs, reviewers, etc.<br>4. Data on research infrastructure relevant to budgets, types of infrastructures, types of involved institutions and participants (demographics), utilization statistics and sustainability information, and SBIR information (development of new instrumentation) | 1. Nuggets and COV reports.<br>2. Site visit reports by NSF Program Officers.<br>3. Annual PI survey effectiveness of merit review criterion.<br>4. More NSF staff input on how things are working. Baseline and longitudinal data on participation (proposals, PIs, reviewers, etc). Surveys of NSF staff on how the performance evaluation process is working. Lessons learned on what did and didn't work (high risk versus failure, etc)<br>5. Minutes of interagency discussions on cross government research and education issues.<br>6. Summary of staff training relevant to merit review and performance evaluation.<br>7. Summary of strategic balance of NSF portfolio relative to the new goals, objectives, and priorities.<br>8. Baseline data on participation (PIs, institutions, reviewers, etc). |

| AC/GPA Information Needs for the 2006-2011 NSF Strategic Plan | | | |
|---|---|---|---|
| **Discovery** | **Learning** | **Research Infrastructure** | **Stewardship** |
| | EPSCOR and REU helping to broaden participation, etc).<br>5. Information that links priorities to budgets and outcomes (e.g., how much of the budget is focused on learning, how is that distributed across the NSF Directorates, number of people impacted by learning activities, etc).<br>6. COV reports and nuggets. Nuggets that look at particular learning issues (e.g., cyberinfrastructure that promotes learning and teacher training). | | |

The Electronic Tax Administration Advisory Committee (ETAAC) is pleased to deliver its 2019 Annual Report to Congress. Since the expansion of its Charter in 2016, ETAACâ€™s primary focus continues to be on protecting taxpayers and enhancing their experience.Â 5. The commitment and professionalism of the IRS leadership and staff during the government shutdown was exemplary. Notwithstanding the disruption, the IRS prepared and executed contingency plans that minimized the impact of the shutdown on its operations including its efforts to stop IDTTRF. Our report is organized to provide the reader with the opportunity to review key insights at a glance or to go deeper into the supporting details. Advisory Committee for GPRA Performance Assessment (13853); Agency Information Collection Description: In the event an employee Notice of Meeting Activities: Proposed Collection; is injured while operating a mechanical Comment Request power press, 29 CFR 1910.217(g) In accordance with the Federal requires an employer to provide AGENCY: U.S. Nuclear Regulatory Advisory Committee Act (Pub.Â  Does the The Committee reconvenes as a Committee scheduled for Thursday, May 25, 2006 of the Whole to hear progress reports from information have practical utility? at 11:15 a.m. The meeting will now be the strategic goalsâ€™ subgroups, discuss 2. Is the burden estimate accurate? held at 10 a.m. findings, recommendations, and the 3. Is there a way to enhance. Other reference documents: Government Performance and Results Act of 1993 (GPRA). Government Performance and Results Modernization Act of 2010. OMB Testimony on GPRA Modernization Act (7 pages, 125 kb). Memorandum: Delivering on the Accountable Government Initiative and Implementing the GPRA Modernization Act of 2010 (04/14/2011) (4 pages, 835 kb). Senate Committee on Governmental Affairs GPRA Report.