MATHEMATICAL AND PHYSICAL SCIENCES

MATHEMATICAL AND PHYSICAL SCIENCES $1,061,270,000

The FY 2004 Request for the Mathematical and Physical Sciences Activity (MPS) is $1,061.27 million, an increase of $119.70 million, or 12.7 percent, over the FY 2003 Request of $941.57 million.

MPS Funding
(Dollars in Millions)

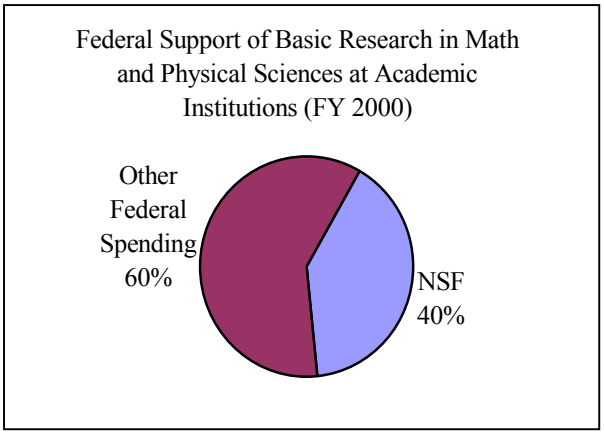
	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Astronomical Sciences	165.99	161.25	183.07	21.82	13.5%
Chemistry	162.82	160.80	181.71	20.91	13.0%
Materials Research	219.37	219.32	246.12	26.80	12.2%
Mathematical Sciences	151.53	181.87	201.87	20.00	11.0%
Physics	195.88	193.31	217.50	24.19	12.5%
Multidisciplinary Activities	24.83	25.02	31.00	5.98	23.9%
Total, MPS	$920.42	$941.57	$1,061.27	$119.70	12.7%

Totals may not add due to rounding.

The Mathematical and Physical Sciences Activity supports research, infrastructure, and education in the mathematical and physical sciences. The purpose of this work is threefold: to deepen our understanding of the physical universe; to use this understanding in service to society; and to prepare the next generation of scientists who are essential for continued progress.

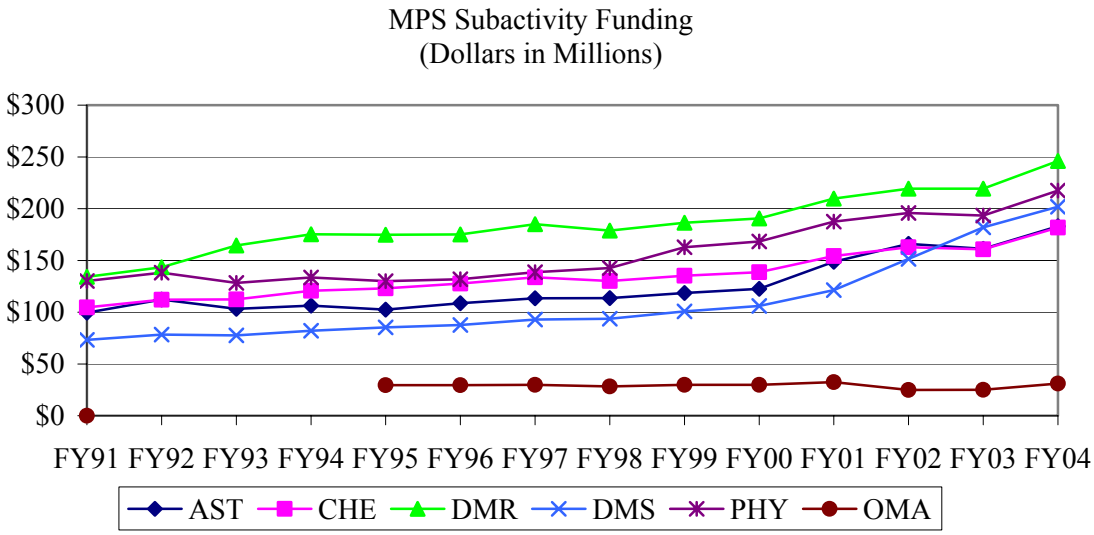
RELEVANCE

MPS provides about 40 percent of the federal funding for university-based basic research in the mathematical and physical sciences. Within the astronomical sciences, MPS provides about 33 percent of the federal support in this area; in chemistry, 31 percent; in physics, approximately 31 percent; in materials research approximately 50 percent; and in mathematics more than 58 percent.



MPS-supported research in the physical and mathematical sciences provides the backbone for advances in other technical, engineering, and health-related disciplines, and provides a broad basis for industrial and technological development. Knowledge of the fundamental processes of matter, of the structure and evolution of the universe, of the complex laws governing chemical interactions, of the behavior and control of molecules at the nanoscale, and of the mathematical tools needed to formulate and solve such problems has played a fundamental role in the technological leadership of the United States and in maintaining its health, economy, defense, and homeland security. Most of the research is of an exploratory nature and is long-term in duration and in impact. It is often difficult for industry to support such investigations. This research support provides training for the future U.S. science, engineering, and

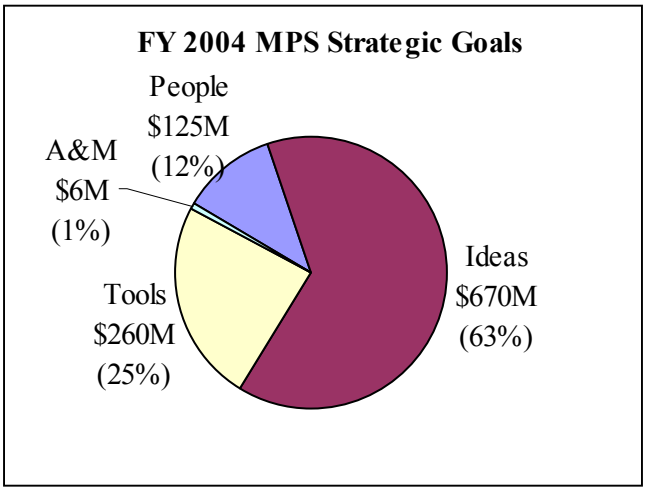
technology workforce. It is appropriate for NSF to be the lead agency in this area, as it is the only federal agency whose mission is to support basic research.



STRATEGIC GOALS

NSF's three strategic focus areas guide MPS activities:

- PEOPLE: Improvement in the quality of education, training and diversity in the fields of astronomy, chemistry, mathematics, materials research and physics. MPS advances education and training for current mathematical and physical scientists, increases the diversity of these communities, facilitates education of future generations of mathematical and physical scientists, and enhances the public's knowledge of astronomy, chemistry, mathematics, materials research and physics.



- IDEAS: Advancement of knowledge of the mathematical and physical sciences, including both maintaining base support across all the physical and mathematical science fields and identifying opportunities where more focused support can play a catalytic role in advancing scientific progress.

- TOOLS: Enhancement of the infrastructure for the conduct of research in the physical sciences. MPS will identify and make investments in instrumentation and facilities, including support and upgrade of existing state-of-the-art facilities needed to perform world-class research.

MPS's support for ongoing core and new activities contributes to NSF's efforts to achieve its strategic goals, and to the administration and management activities necessary to achieve these goals.

Summary of MPS Funding by Strategic Goal
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Estimate	FY 2004 Estimate	Change Amount	Change Percent
People	95.81	116.53	124.67	8.14	7.0%
Ideas	594.91	597.11	670.25	73.14	12.2%
Tools	223.41	222.49	260.36	37.87	17.0%
Administration & Management	6.29	5.44	5.99	0.55	10.1%
Total, MPS	$920.42	$941.57	$1,061.27	$119.70	12.7%

People (+$8.14 million, for a total of $124.67 million)

People represent NSF's most important investment in the mathematical and physical sciences. The strength of our technical and instructional workforce is dependent on an adequate supply of talented scientists and teachers. In FY 2002, MPS spent over $95 million on this strategic resource, which represents about one-third of the total MPS investment in researchers and students. To ensure a 'diverse, internationally-competitive and globally-engaged workforce of scientists, engineers and well-prepared citizens,' investments will be made in all phases of education. This includes K-12 through undergraduate, graduate, and continuing education, as well as outreach activities. Along this continuum, undergraduate education represents a "pressure point" in the system. Decisions to enter research and teaching involving mathematical and physical sciences are typically made during the undergraduate years. Undergraduates provide a considerably more diverse talent pool than is currently represented in the mathematical and physical sciences. Funding will support new programs and enhance existing ones at the undergraduate level that draw from this large, diverse group of students and provide more effective preparation for research and teaching. Partnerships will be supported that lead to enhanced teacher preparation, broadened graduate and postdoctoral opportunities, and more informed teaching and learning strategies. New instruments and approaches will be developed that increase access to mathematical and physical sciences for both specialist and non-technical audiences. MPS support for People totals $124.67 million in FY 2004, an increase of $8.14 million, or 7.0 percent, over the FY 2003 Request of $116.53 million.

MPS People Investments
(Dollars in Millions)

	FY 2003 Estimate	FY 2004 Estimate	Change Amount	Change Percent
K-12	5.23	6.13	0.90	17.2%
Undergraduate	23.46	25.21	1.75	7.5%
Graduate & Professional	85.34	90.33	4.99	5.8%
Other People Support	2.50	3.00	0.50	20.0%
Total, People	$116.53	$124.67	$8.14	7.0%

To enhance multidisciplinary education, teaching, and training activities MPS will:

- Increase support for the Research Experiences for Teachers (RET) program by $500,000 to a total of $3.0 million.

- Increase support for the NSF Graduate Teaching Fellows in K-12 Education (GK-12) program by $430,000 to $2.40 million.
- Increase support for stipends by $970,000, for a total of $8.03 million, in the Astronomy and Astrophysics Postdoctoral Fellowship program, Discovery Corps program and the MPS Distinguished International Postdoctoral Research Fellowship program. The Discovery Corps program will both enhance postdoctorals' research skills and contribute to the development of national research infrastructure.
- Increase support for Research Experiences for Undergraduates (REU) sites by $100,000 to $15.0 million.
- Initiate support for a new activity, Undergraduate Research Centers (URCs) in Chemistry that will markedly increase opportunities for undergraduate research. URCs will be supported initially by a combination of new funding and redirected funds for a total of $3.0 million.
- Increase support for CAREER program by $3.50 million to $40.0 million resulting in an increase of approximately 35 awards.
- Increase support for the Integrative Graduate Education and Research Traineeship (IGERT) program by $1.58 million to $8.76 million.
- Increase support for MPS programs in public science education by $500,000 to $2.80 million to support the MPS Internships in Public Science Education (IPSE) program and the educational outreach program for "Telescopes for Teaching."
- Initiate two new research activities through an investment of $300,000 – one aimed at understanding the barriers to women and minorities in the academic chemistry profession and the other at supporting research within academic chemistry departments into how students learn chemistry concepts.

Ideas (+$73.14 million, for a total of $670.25 million)

Research supported by the MPS Activity pushes the limits of our fundamental understanding of the universe in which we live. Discoveries and advances in the fundamental sciences of astronomy, chemistry, materials research, mathematical sciences and physics drive the productivity and growth of the economy. Innovations from the results of MPS-sponsored research have generated entirely new industries. In today's global economy, it is crucial that substantial investments are made in science and engineering if the United States is to maintain its competitive lead. MPS support for Ideas totals $670.25 million in FY 2004, an increase of $73.14 million, or 12.2 percent, over the FY 2003 Request of $597.11 million.

For the country to maintain a healthy economy, provide a better life for its citizens, and promote national security, it is important to maintain a balance across all disciplines of science and engineering. Advances in the medical sciences, from the discovery of techniques to synthesize new pharmaceuticals to the development of lasers for eye surgery, have relied heavily on the fundamental research of the past two decades, as has the phenomenal advances in computer hardware and information management and analysis. In addition, MPS supports research aimed at addressing some of the most fundamental questions that can be asked about the universe in which we live. MPS-supported scientists are investigating the origins of the universe and the solar system and developing theories of why matter exists.

The field of Quantum Science and Technology (QST) is emerging from discoveries at the interface between classical and quantum phenomena in physics, chemistry, materials research, engineering and computation. QST comprises the science and engineering underlying the creation and manipulation of material in quantum states. Such states have unique properties and the laws of quantum mechanics are needed to characterize their behavior. Quantum phenomena are at the heart of an understanding of the

origins of the universe, the nature of chemical bonding, the phenomena that occur in nanoscale materials, and the relationship between physical forces. QST has the potential for profound impact on all areas of science, on the convergence of information technology and nanoscale science and engineering, and on the future of computing and communications. The next five to ten years are likely to see the emergence of QST as a key to 21st Century technology.

To enhance the effectiveness of individual investigators, stimulate multidisciplinary research activities and interagency partnerships, and expand efforts in international activities, MPS will:

- Increase support for individual investigators and groups by $43.44 million to support the NSF goal of increasing the average research award size to $128,000 with a duration of 3 years.
- Increase support for MPS Centers by $28.10 million to $131.84 million.
- In addition to the International Materials Institutes discussed below, MPS will continue to develop research programs that contribute to the development of a globally aware and internationally engaged scientific workforce.
- Increase support for Research at Undergraduate Institutions by $1.60 million to $11.10 million.
- Develop programs, in collaboration with the intelligence community, to emphasize scientific research of particular relevance to national security needs.

MPS supports a variety of multidisciplinary research centers and groups through programs such as Mathematical Science Research Institutes, Collaborative Research in Chemistry, Materials Research Science and Engineering Centers, and Physics Frontiers Centers. MPS also plays a significant role in supporting Science and Technology Centers and Nanoscale Science and Engineering Centers. In addition, MPS promotes international research collaborations through activities such as the International Materials Institutes. In FY 2004, MPS will establish up to five new Partnerships for Research and Education in Materials (formerly Collaboratives for Materials Research and Education) at minority-serving institutions.

MPS Centers
(Dollars in Millions)

	FY 2003 Estimate	FY 2004 Estimate	Change Amount	Change Percent
Chemistry Centers	10.39	19.70	9.31	89.6%
Mathematical Science Research Inst.	14.00	15.00	1.00	7.1%
Materials Centers[1]	52.76	56.56	3.80	7.2%
Nano Centers	6.31	12.81	6.50	103.0%
Physics Frontier Centers	13.00	13.00	0.00	0.0%
STCs[2]	7.28	14.77	7.49	102.9%
Total, Centers Support	$103.74	$131.84	$28.10	27.1%

[1]Materials Centers includes support for MRSECs, International Materials Institutes and Partnerships for Research and Education in Materials.
[2]The increase for STC funding reflects new awards made in September 2002. These funds are shown in Integrative Activities in the FY 2003 Request, and are transferred to the appropriate managing R&RA Activity in the FY 2004 Request.

MPS support for centers in FY 2004 will include:

- Increase support for Chemistry Centers and Groups by $9.31 million to $19.70 million. This includes both Collaborative Research in Chemistry and Environmental Molecular Science Institutes (EMSI). New Chemical Bonding Centers will be established to explore fundamental aspects of chemical bonding, the bond that links atoms together into myriad forms of matter that define our existence. These centers will address grand challenges in the chemical sciences such as small molecule interactions, chiral chemistry, glycochemistry, protein folding, the molecular origins of life, and sensors. The EMSI program is a collaborative activity among MPS, the Directorate for Geosciences and the Department of Energy Office of Basic Energy Sciences.
- Enhance the Mathematical Sciences Research Institutes by $1.0 million, to a total of $15.0 million.
- Increase total funding for materials centers, collaborations and institutes by up to $3.80 million to a total of $56.56 million. This includes an increment of $1.80 million to establish two to three new International Materials Institutes (IMIs) at U.S. universities in partnership with NSF's Office of International Science and Engineering. IMIs foster enhanced international collaboration in materials research and education and serve as the initial U.S. nodes in developing a virtual Materials World Network. It also includes funds to establish four to five new Partnerships for Research and Education in Materials (PREMs -- formerly Collaboratives for Materials Research and Education in the FY 2003 Request). PREMs link materials research and education at minority-serving institutions with existing materials centers, facilities and focused research groups. The new PREMs will support research and training for up to 100 undergraduate and graduate students annually.
- Provide full or partial support for up to five additional Nanoscale Science and Engineering Centers, an increase of $6.50 million to a total of $12.81 million.
- Maintain the Physics Frontiers Centers (PFC) program at $13.0 million.
- STC support includes two additional centers from the FY 2002 competition transferred from the Office of Integrative Activities: University of Washington Center for Materials and Devices for Information Technology Research and University of California, Davis Center for Biophotonics Science and Technology. Total funding is $14.77 million for four centers.

Priority Areas

In FY 2004, MPS will support research and education efforts related to broad, Foundation-wide priority areas in Biocomplexity in the Environment, Information Technology Research, Nanoscale Science and Engineering, Mathematical Sciences, and Human and Social Dynamics.

MPS Investments in Priority Areas
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Biocomplexity in the Environment	4.95	4.70	4.70	0.00	0.0%
Information Technology Research	32.66	35.52	35.04	-0.48	-1.4%
Nanoscale Science and Engineering	98.68	103.92	110.42	6.50	6.3%
Mathematical Sciences	30.00	47.39	70.19	22.80	48.1%
Human and Social Dynamics	N/A	N/A	0.50	0.50	N/A

Biocomplexity in the Environment (BE): MPS will provide $2.35 million for the NSF-wide BE competition. In addition, another $2.35 million will be spent on research and education in BE-related areas. New Environmental Molecular Science Institutes will be supported with a particular emphasis on molecular level processes occurring in water and aqueous media. In addition MPS will support research in the modeling of environmental phenomena and the development of environmentally benign materials and chemical and materials processing methods.

Information Technology Research (ITR): MPS will provide $35.04 million for the ITR priority area that will focus on:

- Essential contributions to algorithm development, statistical analysis, optimization theory, network design, the physics of information, understanding the limits to computation, and the fundamentals of quantum, biological, molecular and optical computing.
- Remote access and control of experimental facilities such as accelerators (Large Hadron Collider) and telescopes.
- Advanced computational methods resulting, for example, in the design of more effective drugs and specialized materials, and better understanding of the formation of galaxies.
- Development of specialized Web-based tools and digital libraries for the physical sciences.
- Development of tools for the transparent manipulation and rapid dissemination of the information contained in huge databases, including, for example, efforts to unify astoronomical data (National Virtual Observatory).
- New support for interdisciplinary groups of physical scientists and pure and applied mathematicians focused on solving problems with significant time horizons, needing long-term investment in software development and infrastructure.

Nanoscale Science and Engineering (NSE): The early 21st Century may come to be seen as the start of the nanotechnology revolution. MPS is a primary player in the NSF nanoscale science and engineering priority area, and MPS grantees play a key role in developing the fundamental understanding that must undergird future technological applications of this exciting area of science and engineering. The intellectual challenges to be overcome are formidable. In FY 2004, MPS investment in the NSE priority area will increase by $6.50 million to $110.42 million, and will focus on the following:

- Support for the National Nanofabrication Infrastructure Network (formerly the NNUN).
- Full or partial support for five to six new Nanoscale Science and Engineering Centers (NSECs) addressing research and education at the interface between NSE and other priority areas.
- Fundamental research addressing such areas as nanoscale structures, novel phenomena and quantum control, nanoscale processes in the environment, multiscale modeling theory and simulation.
- Interdisciplinary teams pursuing major long-term objectives, including nanoscale materials 'by design', nanoscale electronics, photonics and magnetics.

Mathematical Sciences: In FY 2004, the MPS request includes $70.19 million, an increase of $22.80 million over the FY 2003 Request of $47.39 million, for the Mathematical Sciences priority area. MPS investments in this area will be through individual investigator grants, focused research groups, institutes, and partnerships, all within three categories: (1) fundamental mathematical and statistical sciences, (2) interdisciplinary research connecting the mathematical sciences with science and engineering, and (3) mathematical sciences education.

Education and training activities will support the advancement of mathematical skills and the mathematical sciences workforce, with support for undergraduate and graduate education and postdoctoral training coupled with curriculum reform.

Interdisciplinary emphases will include:

- The mathematical and statistical challenges posed by large data sets such as those generated by genomics research, satellite observation systems, seismic networks, global oceanic and atmospheric observation networks, automated physical science instruments, and modern engineering sensor and actuator systems.
- Managing and modeling uncertainty, where improved methods for assessing uncertainty will increase the utility of models across the sciences and engineering and result in better predictions of extreme or singular events, thus improving the safety and reliability in such systems as power grids, the Internet, and air traffic control.
- Modeling complex nonlinear systems where, across the sciences and engineering, there is a great need to analyze and predict emergent complex properties, from social behaviors to brain function, and from communications networks to multi-scale business information systems and complex engineering systems. For example, tremendous opportunities exist on the interface with the life sciences, where new mathematical models can significantly advance understanding of biological processes.

Human and Social Dynamics: In FY 2004 MPS requests $500,000 for the Human and Social Dynamics priority area. MPS activities in this area include: the development of statistical tools for decision making under uncertainty, modeling and analysis of cellular automata to understand how human and social dynamics between individuals translate into behavior of large groups and organizations, further development and application of spatial statistical methods as they apply to the social sciences, and development of computational tools for extracting information from large databases.

Tools (+$37.87 million, for a total of $260.36 million)

The pace and breadth of scientific discovery are growing at unprecedented rates, driven by revolutions in tools for science. The U.S. has a leadership role in this process. Today's scientific agenda involves phenomena at or beyond the limits of our measurement capabilities, requiring new generations of powerful, complex, costly tools. Investments in facilities and instrumentation will not only have great scientific payoffs but also will provide training for the next generation of researchers. MPS support for Tools totals $260.36 million in FY 2004, an increase of $37.87 million, or 17.0 percent, over the FY 2003 Request of $222.49 million.

State-of-the-art user facilities are essential to astronomy, physics, and many areas of materials research. Investment in facilities necessarily includes not only support for ongoing operations and maintenance, but also periodic upgrades to the core facility and to ancillary instrumentation. Further, R&D toward new capabilities to meet the needs of the MPS disciplines is essential to assure continued leadership.

MPS investments in tools was over $223 million in FY 2002, and the portfolio of world-class facilities that MPS maintains for the science and education communities represents a capital investment of well over $1 billion. The increase of annual support by $37.87 million is greatly leveraged in terms of enabling new science opportunities: providing for full operations of the Laser Interferometer Gravitational-Wave Observatory (LIGO) and for early operations of the Large Hadron Collider (LHC) ATLAS (A Toroidal Large Angle Spectrometer) and CMS (Compact Muon Solenoid) detectors, exploiting unique capabilities for particle physics at the Cornell Electron Storage Ring (CESR) and for radioactive ion beams at Michigan State University's National Superconducting Cyclotron Laboratory, and supporting operations of the National Astronomy Centers, the Gemini Observatories, and the National High Magnetic Field Laboratory (NHMFL). While increases for operations of some of the astronomy, physics, and materials research facilities are modest, the additional funds will enhance instrumentation development, facility operations reliability, and community access to these facilities.

Importantly, this increase will provide a start towards critical support for some mid-scale instrumentation needs – a scale between the Major Research Instrumentation and the Major Research Equipment and Facilities Construction funding – identified as a serious funding gap by the National Science Board Infrastructure Task Force. This level of opportunity has become important for researchers across MPS disciplines. There is an emerging need for leveraging science such as can be enabled by the development of instrumentation for neutron and light sources, high magnetic field laboratories, moderate-scale detector experiments, and astronomical observing facilities. In addition, support for upgrades such as new detectors or data collection techniques can dramatically improve the efficiency and sensitivity of existing instrumentation at much-reduced cost.

MPS Investments in Tools
(Dollars in Millions)

	FY 2003 Estimate	FY 2004 Estimate	Change Amount	Change Percent
Cornell Electron Storage Ring	19.49	21.00	1.51	7.7%
Gemini	12.60	14.20	1.60	12.7%
LHC ATLAS and CMS Detector Operations[1]	[5.00]	10.00	[5.00]	100.0%
LIGO	29.50	29.00	-0.50	-1.7%
MSU National Superconducting Cyclotron Lab	14.70	15.20	0.50	3.4%
National Astronomy Centers	84.33	91.63	7.30	8.7%
National High Magnetic Field Laboratory	24.00	24.50	0.50	2.1%
Other Facilities[2]	14.87	16.18	1.31	8.8%
Research Resources	23.00	38.65	15.65	68.0%
Total, Tools Support	$222.49	$260.36	$37.87	17.0%

[1] Funding for LHC operations in FY 2003 was in disciplinary research within Ideas.
[2] Includes the Wisconsin Synchrotron Radiation Center, Cornell High-Energy Synchrotron Source, National Nanofabrication Users Network, National Center for Atmospheric Research, and Digital Library.

In FY 2004, MPS support for Tools includes:

- An increase of $1.51 million, to a total of $21.0 million, for the Cornell Electron Storage Ring (CESR).
- An increase of $1.60 million for the Gemini Observatories, to a total of $14.20 million. Both the northern and southern Gemini telescopes are now in regular science operations. Included in this amount is $1.0 million for partial return of Chile's share of construction funding, with which the U.S. assumes a portion of the Chilean share of the Observatory, along with increased observing access for U.S. astronomers.
- An increase of $5.0 million for early operations of the U.S. groups participating in the ATLAS and CMS detectors at the Large Hadron Collider (LHC), including computing and software development. Funding of operations was requested through Ideas in FY 2003.
- A total of $29.0 million for full operations of the Laser Interferometer Gravitational-wave Observatory (LIGO) to run their interferometers at sites at Hanford, WA and Livingston, LA in coincidence with each other and with gravitational wave detectors abroad.
- An increase of $500,000 for Michigan State University's National Superconducting Cyclotron Laboratory (NSCL), to a total of $15.20 million, providing full operations and research at this unique radioactive ion beam facility.
- An increase of $7.30 million, to a total of $91.63 for support of the National Astronomy Centers:

  - NAIC will be supported at the level of $10.30 million, an increase of $1.30 million, to enable continued operation and maintenance of the renovated Arecibo telescope and the development of instrumentation to take advantage of its greater sensitivity. Additional support of $1.80 million is provided through the Geosciences Activity.
  - NOAO/NSO is planned at the level of $38.60 million, an increase of $2.90 million. NSO facilities provide solar telescopes for use by the U.S. astronomical community. Activities in FY 2004 include continued design and planning for the Advanced Technology Solar Telescope (ATST), an instrument that will use new techniques such as adaptive optics to provide a unique capability for investigating a wide range of important questions in solar physics. Within this amount, $4.0 million, unchanged from FY 2003, is included for the Telescope System Instrumentation Program (TSIP), which is administered for the community through NOAO.
  - NRAO is supported at the level of $42.73 million, an increase of $3.10 million. This level of support will provide for operations, maintenance, and instrumentation for the unique telescopes of NRAO, such as the Robert C. Byrd Green Bank Telescope, the Very Large Array (VLA), and the Very Long Baseline Array (VLBA). Activities in FY 2004 include making continued improvements and enhancements to the expanded VLA and optimization of science operations of the Byrd Telescope.
- Funding for the National High Magnetic Field Laboratory (NHMFL) increases by $500,000 in FY 2004 to a total of $24.50 million. The increase reflects the integrating of the National High Field Mass Spectrometry Facility, which was supported as a separate facility in FY 2003 by the Chemistry Subactivity, into the NHMFL.
- An increase of $15.65 million to a total of $38.65 million for Research Resources reflects a new emphasis on intermediate-scale instrumentation. Examples of such activities include new developments in adaptive optics hardware and techniques for current and future generations of optical and infrared telescopes, support for grid computing for information-intensive experiments in physics and astronomy, and instrumentation for NSF-supported users of beam lines at synchrotron and neutron facilities such as the DOE Spallation Neutron Source (SNS). The SNS will produce the most intense beam of neutrons in the world, and provide unprecedented performance for neutron scattering research. The Department of Energy and NSF will work in coordination to develop and support a world-class suite of instruments that makes optimal use of the SNS beams, and that will meet the needs of users across a broad range of disciplines including chemistry, physics, materials research, engineering, geology and biology. The instrumentation phase of this project is currently estimated to cost approximately $300 million over 10 years. To date, NSF has provided approximately $1.50 million for initial R&D. Up to $2.0 million in additional support for planning neutron scattering beam line instrumentation at the SNS will be provided in FY 2004.

Administration and Management

Administration and Management provides for administrative activities necessary to enable NSF to achieve its strategic goals. Requested funding for FY 2004 is $5.99 million, an increase of $550,000 over FY 2003. This includes the cost of Intergovernmental Personnel Act appointments and contractors performing administrative functions.

QUALITY

MPS maximizes the quality of the R&D it supports through the use of a competitive, merit-based review process. The percent of basic and applied research funds that were allocated to projects that undergo

merit review was 88 percent in FY 2002, the last year for which complete data exist. This percent excludes support for the National Radio Astronomy Observatory, the National Optical Astronomy Observatories, and the National Astronomy and Ionosphere Center, which, although regularly merit reviewed using NSF's peer review system, because of their designation as Federally Funded Research and Development Centers, are not included.

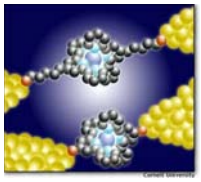
To ensure the highest quality in processing and recommending proposals for awards, MPS convenes Committees of Visitors, composed of qualified external evaluators, to review each program every three years. These experts assess the integrity and efficiency of the processes for proposal review and provide a retrospective assessment of the quality of results of NSF's investments.

The Directorate also receives advice from the Advisory Committee for Mathematical and Physical Sciences (MPSAC) on such issues as: the mission, programs, and goals that can best serve the scientific community, how MPS can promote quality graduate and undergraduate education in the mathematical and physical sciences, and priority investment areas in MPS-supported research. The MPSAC meets twice a year and members represent a cross section of the mathematical and physical sciences with representatives from many different sub-disciplines within the fields as well as a cross section of institutions including industry, broad geographic representation, and balanced representation of women and under-represented minorities.

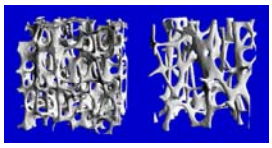
PERFORMANCE

Mathematical and Physical Sciences Research Highlights for FY 2002

Examples of significant discoveries or advances resulting from MPS-supported research include:



- An interdisciplinary team of physicists and chemists led by Paul McEuen, Dan Ralph and Hector Abruna at Cornell University has fashioned transistors from single molecules. When electronic devices are shrunk to the nanometer scale, they enter a physical regime different than larger devices. As part of their explorations of electron motion on the smallest possible length scales, the group has demonstrated a transistor device that reaches the ultimate limit in which an electron hops on and off a single atom between two contacts.

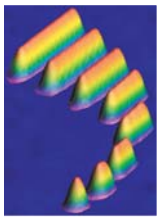


- Scientists at the University of Houston have developed computer-based models of the structure of porous bones, discovering a new relationship between the loss of bone strength and reductions of bone density. The findings may improve bone density tests as well as serving as a new diagnostic tool for estimating the strength of elastic networks.

- For the first time, scientists have detected the seeds of matter that led to the formation of clusters of galaxies. The techniques used by researchers at the California Institute of Technology to make this discovery will also provide more accurate measurements of the fundamental parameters that determine the structure and evolution of the universe.

- At Hampton University, the Center for the Study of the Origin and Structure of Matter will help develop detectors for the Large Hadron Collider at CERN, a facility that will examine the structure of matter. In addition to participating in the research, the Center will build and strengthen a collaborative network of researchers at Historically Black Colleges and Universities, and will encourage K-12 students to pursue careers in science.

- At the University of North Carolina, the Science and Technology Center for Environmentally Responsible Carbon Dioxide Processes is devising ways to replace aqueous and organic solvents in key manufacturing and service processes with liquid carbon dioxide. The Center is expected to have a significant impact in replacing solvents that can harm the environment, such as those used in textile dying, degreasing, and cleaning.



- Scientists at the University of California, Irvine have been able to construct gold wires a single atom in diameter. At left is a scanning tunneling microscope image of a series of gold chains, with the chain in the upper left being 20 atoms long. Although this technology is in its infancy, such wires might be used to connect molecules to form a molecular circuit, with the possibility of controlling and altering the behavior of the individual molecules in the circuit. In principle, it might be possible to construct a motor that could be controlled to carry out specific functions at the molecular level (Image courtesy of Wilson Ho, University of California, Irvine).

- **The 2002 Nobel Prize in Chemistry:** One of the recipients is John Fenn of Virginia Commonwealth University. Fenn developed techniques that allow large biologically important molecules such as proteins to be placed in a gaseous state, where their components can be analyzed and identified by the technique of mass spectroscopy. This ability to "make elephants fly," as Fenn describes it, is used to analyze the chemical composition of proteins rapidly and accurately. The technique has been critical to advances in the development of pharmaceuticals and to progress in the field of proteomics.

- **The 2002 Nobel Prize in Physics:** One of the recipients is Raymond Davis, Jr., of the University of Pennsylvania and the Brookhaven National Laboratory, who pioneered experiments in the 1960s to detect neutrinos from the Sun. His experiment detected significantly fewer neutrinos than predicted by models of the interior of the Sun, stimulating decades of theoretical and experimental work to resolve the discrepancy. This result played a major role in development of the theory that neutrinos change from one type to another and that at least one type actually does have mass.

- **The 2002 Fields Medal:** Vladimir Voevodsky, currently at the Institute for Advanced Study in Princeton, New Jersey, shared the 2002 Fields Medal with Laurent Lafforgue of the Institut des Hautes Études Scientifiques (IHÉS) in France. The Fields Medal is the world's highest honor for mathematical research. Voevodsky conducted his prize-winning research in algebraic geometry and number theory, developing novel ways to describe the geometric shapes of solutions to algebraic equations.

Other Performance Indicators

The tables below show the growth in the number of people benefiting from MPS's funding, and trends in growth of award size, duration and number.

Number of People Supported in MPS Activities

	FY 2002 Actual	FY 2003 Estimate	FY 2004 Estimate
Senior Researchers	5,769	6,400	6,000
Other Professionals	1,149	1,170	1,100
Postdoctorates	2,215	2,240	2,300
Graduate Students	7,002	6,400	7,000
Undergraduate Students	6,068	3,200	6,000
K-12 Students	225	285	390
K-12 Teachers	784	700	800
Total Number of People	23,212	20,395	23,590

MPS Funding Profile

	FY 2002 Actual	FY 2003 Estimate	FY 2004 Estimate
Number of Requests for Funding	8,835	8,500	9,000
Dollars Requested (in millions)	$6,739	$6,800	$6,900
Total Number of Awards	4,879	4,750	4,800
Statistics for Competitive Awards:			
Number	2,105	1,900	2,100
Funding Rate	35%	35%	35%
Statistics for Research Grants:			
Number of Research Grants	1,613	1,550	1,600
Median Annualized Award Size	$83,319	$88,000	$100,000
Average Annualized Award Size	$111,601	$124,000	$145,000
Average Award Duration, in years	3.1	3.0	3.2

ASTRONOMICAL SCIENCES $183,070,000

The FY 2004 Request for the Astronomical Sciences (AST) Subactivity is $183.07 million, an increase of $21.82 million, or 13.5 percent, over the FY 2003 Request of $161.25 million.

Astronomical Sciences Funding
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Astronomical Research	165.99	161.25	183.07	21.82	13.5%
Total, AST	$165.99	$161.25	$183.07	$21.82	13.5%

NSF is the lead federal agency for ground-based astronomy, providing about two-third of the federal support for this area of science, including almost all federal support for radio astronomy.

AST includes support for astronomical and astrophysical studies of the origins and characteristics of planets, the Sun, other stars, our galaxy, extragalactic objects such as clusters of galaxies and quasars, and the structure and origin of the Universe. The development of advanced technologies and instrumentation, and university radio observatories are also supported. Support includes funding for undergraduate and graduate students and postdoctoral fellows. Also supported within this area is NSF's Electromagnetic Spectrum Management (ESM) program, which participates with other federal agencies in coordinating the use of the electromagnetic spectrum for research and other activities.

The FY 2004 Request includes $77.24 million for research and instrumentation support in the Astronomical Sciences that will advance research in cosmology and the origin and evolution of the universe, the formation of stars and planets, and particle astrophysics. A number of these activities involve interagency partnerships. A new focus on providing support for mid-scale instrumentation needs will address community priorities such as the development of adaptive optics systems for telescopes and the availability of modern, instrumented small aperture telescopes for programs of student training, research, and educational/public outreach. Support will also be provided for research and development that may lead to highly recommended new facilities such as the Giant Segmented Mirror Telescope (GSMT) and Large-Aperture Synoptic Survey Telescope (LSST). Through the Information Technology Research priority area, support will be provided for research and applications in databases, data mining, and high-speed computation. The Science and Technology Center (STC) for Adaptive Optics will be funded within AST in FY 2004.

- Researchers supported by NSF in the Astronomical Sciences and the Office of Polar Programs extended their work to measure the very faint fluctuations in the microwave light emitted by the hot gas in the early universe, from a time before stars and galaxies formed. Pushing the limits of available technology, the Cosmic Background Imager (CBI) detected minute variations in the cosmic microwave background radiation that show, for the first time, the seeds of matter and energy that would later evolve into clusters of hundreds of galaxies. Their images are the sharpest and most sensitive yet made of the point at which photons were first emitted 14 billion years ago. As the universe expanded, the gravity of dark matter within the clumps made them collapse into clusters of galaxies. (http://www.astro.caltech.edu/~tjp/CBI/)

- A team of astronomers from the Sloan Digital Sky Survey (SDSS) collaboration has discovered a stream of stellar debris emanating from a star cluster that is being torn apart by the Milky Way. The

detection of this stream, the first of its kind, supports theorists' view that star clusters are destroyed by the tidal forces of the Milky Way. Such extended streams of tidal debris provide a new way to determine the mass distribution of the dark matter halo of our galaxy. (http://www.sdss.org/news/releases/20020603.pal5.html)

Astronomical Sciences includes support for four national facilities: the National Astronomy and Ionosphere Center (NAIC), the National Optical Astronomy Observatories (NOAO), the National Solar Observatory (NSO), and the National Radio Astronomy Observatory (NRAO). Also included is the U.S. share of operations for the International Gemini Observatory, twin 8-meter telescopes located in the northern and southern hemispheres. These facilities together provide world-class observing capabilities throughout the electromagnetic spectrum, from radio to infrared and optical regimes of the electromagnetic spectrum.

FY 2004 support for national facilities totals $105.83 million, an increase of $8.90 million, and includes:

- Support for Gemini Observatory at a level of $14.20 million, an increase of $1.60 million. Both the northern and southern Gemini telescopes are now in regular science operations. The Gemini Observatory, an international partnership with six other countries, and the premier optical/infrared facility available to the entire U.S. astronomical community, remains the highest priority among our optical and infrared facilities. Included in this amount is $1.0 million for partial return of the Chilean construction capital, with which the U.S. assumes a portion of the Chilean share of the Observatory, gaining increased observing access for U.S. astronomers.

- NAIC will be supported at the level of $10.30 million, an increase of $1.30 million. This level of support will enable continued operation and maintenance of the renovated Arecibo telescope and the development of instrumentation to take advantage of its greater sensitivity. Additional support of $1.80 million is provided through the Geosciences Activity.

- Support for NOAO/NSO at the level of $38.60 million, an increase of $2.90 million. NOAO provides optical/infrared observational facilities to the U.S. astronomical community in both the northern and southern hemispheres, and operates the U.S. Gemini Science Center, which provides support for U.S. astronomers to use the Gemini Observatory. NOAO is leading the community effort to establish a detailed scientific justification and conceptual design for the Giant Segmented Mirror Telescope (GSMT) and the Large-Aperture Synoptic Survey Telescope (LSST), both of which were highly recommended future facilities in recent community reports. NSO facilities provide solar telescopes for use by the U.S. astronomical community. Activities in FY 2004 include continued design and planning for the Advanced Technology Solar Telescope (ATST), an instrument that will use new techniques such as adaptive optics to provide a unique capability for investigating a wide range of important questions in solar physics. ATST will be of significant value to studies in atmospheric sciences and space weather in addition to astronomical research. Included also within this amount is $4.0 million for the Telescope System Instrumentation Program (TSIP), which is administered for the community through NOAO. TSIP, which began in FY 2002, is a program to unify the privately held and the national optical and IR observatory facilities through a program of support for instrument development and facility improvement in exchange for public access to private facilities.

- NRAO is supported at the level of $42.73 million, an increase of $3.10 million. This level of support will provide for operations, maintenance, and instrumentation for the unique telescopes of NRAO, such as the Robert C. Byrd Green Bank Telescope, the Very Large Array (VLA), and the Very Long Baseline Array. Activities in FY 2004 include making continued improvements and enhancements to the expanded VLA and optimization of science operations of the Byrd Telescope.

CHEMISTRY $181,710,000

The FY 2004 Request for the Chemistry (CHE) Subactivity is $181.71 million, an increase of $20.91 million, or 13.0 percent, over the FY 2003 Request of $160.80 million.

Chemistry Funding
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Chemistry Research	162.82	160.80	181.71	20.91	13.0%
Total, CHE	$162.82	$160.80	$181.71	$20.91	13.0%

The single unifying theme in chemistry is the chemical bond, the bond that links atoms together into myriad forms of matter that define our existence. CHE supports research that enables matter to be manipulated, measured, and modeled through management of chemical bonds. The level of sophistication with which this can now be done is illustrated by the ability to image and position individual atoms and molecules; to watch chemical bonds form and break on time scales as short as femtoseconds; to prepare and screen enormous libraries of chemical compounds for desired characteristics; and to calculate physical and chemical properties of matter with great accuracy. Chemical advances are leveraged by sharing them with researchers in other disciplines, including interdisciplinary fields like nanotechnology and biotechnology.

Chemistry directly impacts our daily lives through its contributions to production of food, shelter, clothing, energy, medicine, and countless products that enhance our quality of life. Basic research, education, and instrumentation supported by CHE contribute to environmental quality and to industrial strength through advancements in fundamental knowledge and the professional development of our technical workforce. Approximately three-fourths of the CHE investment is in individual investigators and collaborative research centers, with the balance in instrumentation and human resource development.

Noteworthy developments involving CHE-supported scientists this year included the following:

- One of the recipients of the 2002 Nobel Prize in Chemistry is John Fenn of Virginia Commonwealth University. Fenn developed techniques that allow large biologically important molecules such as proteins to be placed in a gaseous state, where their components can be analyzed and identified by the technique of mass spectroscopy. This ability to "make elephants fly," as Fenn describes it, is used to analyze the chemical composition of proteins rapidly and accurately. The technique has been critical to advances in the development of pharmaceuticals and to progress in the field of proteomics.

- Joseph DeSimone of the University of North Carolina-Chapel Hill and colleagues, in collaboration with DuPont, introduced a new technology for manufacturing Teflon® and related fluoropolymers based on environmentally benign supercritical carbon dioxide as a solvent. DuPont has built a $40 million pilot plan in North Carolina to exploit these scientific advances. This work also shows promise for use in industries ranging from dry cleaning to microelectronics.

- Bruce Lipshutz of the University of California at Santa Barbara and co-workers developed a method to synthesize Coenzyme Q10 in fewer steps and in higher yield than had previously been

accomplished. Q10 has been described as a "miracle nutrient" because of its potential to invigorate our cells, fight a variety of diseases, and perhaps even slow the aging process. Lipschutz's discovery promises to provide an inexpensive commercial synthesis to this important compound.

The FY 2004 Request of $181.71 million, an increase of $20.91 million, includes:

- Support for CHE core programs devoted to basic chemical research will grow by $5.85 million to $134.45 million in FY 2004. Additional funds will be used largely to increase average grant size and duration and to support new principal investigators.

- Support for chemistry centers will increase by $9.31 million to $19.70 million. In addition to the Environmental Molecular Science Institutes and Collaborative Research in Chemistry centers, Chemical Bonding Centers (CBCs), will be launched. The CBCs will allow large teams of researchers to attack grand challenges in chemical bonding, such as "How are bonds made and broken as reactants transform into products?" Quantum Science and Technology (QST) will receive enhanced emphasis, both in center and core individual investigator projects, reflecting the critical role that quantum mechanics plays in understanding and manipulating chemical bond formation.

- Support will be initiated for mid-scale instrumentation that exceeds what is available in cost and scope through the Chemistry Research Instrumentation and Facilities program and the NSF Major Research Instrumentation program. Pilot projects and workshops that identify appropriate investment strategies will be supported with an additional $1.21 million. Support for ruggedized, miniaturized, low-cost instrumentation that can make workhorse instruments like mass spectrometers and nuclear magnetic resonance spectrometers more accessible will be provided through existing programs.

- CHE will provide $2.10 million for new undergraduate and postdoctoral programs that draw on the nation's rich geographic, institutional, and demographic diversity. Undergraduate Research Centers will support faculty teams working with teams of first- and second-year college students to attract a larger and more diverse group of students to the technical workforce. Additional international Research Experience for Undergraduates sites will be supported. Discovery Corps, a postdoctoral program, will be piloted to enhance research skills and contribute to the development of national research infrastructure.

- CHE support for the NSF priority area in nanoscale science and engineering will increase by $910,000 and will include the Nanotechnology Undergraduate Education initiative, whose impact on technical workforce development and science literacy will be evaluated.

- CHE will increase funding for programs designed to increase the participation of underrepresented groups in chemistry research and the overall number of students going into chemistry by $1.53 million.

- Support for the National High Field Mass Spectrometry Facility is being integrated into the National High Magnetic Field Laboratory (NHMFL) and future funding will be provided through NHMFL. CHE will provide $500,000 in FY 2004 for the NHMFL to support this facility. Total funding for the NHMFL in FY 2004 is $24.50 million, with the remainder of funds coming from the Materials Research Subactivity.

MATERIALS RESEARCH $246,120,000

The FY 2004 Request for the Materials Research (DMR) Subactivity is $246.12 million, an increase of $26.80 million, or 12.2 percent, from the FY 2003 Request of $219.32 million.

Materials Research Funding
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Materials Research	219.37	219.32	246.12	26.80	12.2%
Total, DMR	$219.37	$219.32	$246.12	$26.80	12.2%

DMR supports research and education to advance the fundamental understanding of materials, to enable the development of materials with superior properties, and to enhance the understanding of the interconnections among synthesis, processing, composition, structure and properties of materials and how these factors affect their performance. Materials research integrates a wide range of activities spanning both science and engineering. It extends from investigations of fundamental phenomena in condensed matter physics and solid-state chemistry to research on functional materials including metals, ceramics, polymers, biomaterials, and electronic, photonic and magnetic materials. Its practitioners include physicists, chemists, materials scientists, and engineers, and, increasingly, it benefits from the participation of researchers from an even wider range of disciplines such as biochemistry, biology, earth sciences, mathematics, computer science, and medicine.

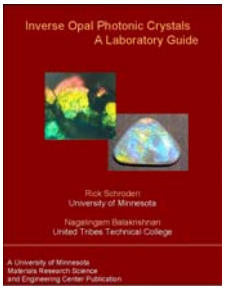
NSF provides about half the total federal support for university-based basic research in materials. The technological and societal significance of the field is far-reaching. DMR supports education, fundamental research and facilities that are critically important to the future advancement of industries and technologies ranging from electronics and communications to information technology, transportation and aerospace, energy, environmental protection, manufacturing, medicine and health care, packaging, and civil infrastructure. More than half of DMR's portfolio consists of support for individual investigators and focused research groups. The balance supports 29 Materials Research Science and Engineering Centers (MRSECs), and experimental facilities for shared use, including the National High Magnetic Field Laboratory (NHMFL), user facilities for x-ray synchrotron radiation and neutron scattering, and a new Science and Technology Center in materials and devices for information technology research.

Researchers and educators supported by DMR made exciting progress this year. For example:

- Max Lagally and colleagues at the University of Wisconsin have shown that nanoscale interfaces between two mismatched crystalline materials induce stresses that may have a surprisingly large effect on the fabrication and performance of ultra-small microelectronic devices.

- Strength and ductility are two important mechanical properties of any material system, but materials are rarely strong and ductile at the same time. En Ma and colleagues at the Johns Hopkins University have developed a new metal-processing technique that produces a strong, ductile material composed of a combination of micrometer- and nanometer-sized grains. This research may point the way to a new generation of super-strong high-ductility alloys.

- The Materials Research Science and Engineering Center at the University of Minnesota supports a comprehensive education program involving the Native American community through partnerships with Tribal Colleges in the upper Midwest. Recently, faculty and students from Tribal Colleges and the Center teamed up to develop a *Photonic Crystals Laboratory Guide* which includes step-by-step procedures for the synthesis of photonic crystals based on metal oxides. Instructors at Tribal Colleges, four-year colleges, and universities can download the guide from the Web at no charge.



The FY 2004 Request includes several enhancements and new activities:

- DMR will increase support for the NSF priority area in nanoscale science and engineering by $5.30 million to $76.23 million in FY 2004. The increment will include partial support for up to five new nanoscale science and engineering centers, support for new awards through core programs, and support for the National Nanotechnology Infrastructure Network (NNIN). Overall DMR support for other NSF priority areas (ITR, BE and Mathematics) will increase by $1.36 million to a total of $12.09 million.

- Support for research into the fundamental physics and chemistry of materials and investigation of materials phenomena in DMR core programs will be enhanced by up to $10.0 million, primarily through awards to individual investigators and focused research groups. This will include enhanced support for Quantum Science and Technology (QST), using the coherent control of quantum phenomena toward applications that may include quantum computing, mesoscopic physics, the manipulation of nuclear or electronic spin states, quantum electronics in nanoscale organic and inorganic materials, and the probing and manipulation of materials processes and properties.

- Up to $2.0 million will be provided to establish four to five additional Partnerships for Research and Education in Materials in FY 2004 (formerly Collaboratives for Materials Research and Education in the FY 2003 Request), enabling minority-serving institutions to strengthen their research and education activities in materials through links to existing materials groups, centers and facilities. Support for international collaboration in materials research and education through centers and disciplinary research programs will be enhanced by up to $3.0 million, and $1.80 million will be provided to establish two to three new International Materials Institutes through open competition.

- An additional $4.50 million will be provided in FY 2004 to enhance operations supporting fundamental research at DMR user facilities, and to plan the development of new mid-scale research resources, including synchrotron and neutron beam lines whose cost and scope is beyond that of the NSF Major Research Instrumentation (MRI) program. This amount includes up to $2.0 million to support initial planning for beam line instrumentation at the DOE Spallation Neutron Source (SNS).

- DMR support for the National High Magnetic Field Laboratory will be unchanged at $24.0 million in FY 2004, although an additional $500,000 will be provided to the NHMFL through the Chemistry Subactivity to support the integration of the National High Field Mass Spectrometry Facility into the NHMFL.

MATHEMATICAL SCIENCES $201,870,000

The FY 2004 Request for the Mathematical Sciences (DMS) Subactivity is $201.87 million, an increase of $20.0 million, or 11.0 percent, over the FY 2003 Request of $181.87 million.

Mathematical Sciences Funding
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Mathematical Sciences	151.53	181.87	201.87	20.00	11.0%
Total, DMS	$151.53	$181.87	$201.87	$20.00	11.0%

Advances in science and engineering, driven in part by increasingly sophisticated and readily available computing environments, have lifted the mathematical sciences to the forefront of science and engineering, reshaping modern discovery through quantitative predictions, instrumentation development, modeling, visualization, computational algorithms, and optimization methods. Science and engineering are becoming more mathematical and statistical, not only in the physical, engineering and informational sciences, but also the biological, geophysical, environmental, social, behavioral, and economic sciences.

NSF has a crucial role in the support of basic academic research in the mathematical sciences, providing more than 58 percent of all federal university-based support. NSF-supported research involves a broader range of infrastructure, fundamental research, and multidisciplinary research topics than that sponsored by other federal agencies that support academic mathematical sciences research. Especially important is the critical function of the mathematical sciences in the education and training of the nation's scientific and engineering workforce.

DMS includes areas such as analysis, geometry, topology, foundations, algebra, number theory, combinatorics, applied mathematics, statistics, probability, biomathematics, and computational mathematics. Awards in these areas support a variety of research projects, multidisciplinary projects, and Focused Research Groups, with some grants including funding for graduate and postdoctoral students as well as for workshops, computing equipment and other research and education needs. In addition, DMS supports infrastructure efforts across the mathematical sciences, including national research institutes, postdoctoral research fellowships, graduate education, broadened career experiences for researchers, increased participation in the nation's research personnel base, research conferences and workshops, shared scientific computing research equipment, and undergraduate investments such as Research Experiences for Undergraduates (sites and supplements).

The pervasive nature of the mathematical sciences in underpinning and enabling much of today's scientific, engineering, and commercial activities is illustrated by the following examples:

- Researchers in a Focused Research Group at Stanford University are developing topological methods in data analysis. This project brings sophisticated ideas from the mathematical sciences, including algebraic topology, probability, and statistics, together with techniques from computational mathematics and computer science, to develop new methods to analyze data that are difficult to investigate using classical linear methods. These new methods will be especially useful when the data is obtained by sampling with noise from highly curved or singular spaces in high-dimensional spaces.

- A researcher at Cornell University applying algebraic techniques to combinatorial problems that arise in discrete and convex geometry has made recent progress in enumerating the faces of complex polytopes by introducing techniques from algebraic geometry. The type of information sought has been of use in the design of geometric algorithms for problems in robotics and motion planning and, more recently, in the analysis of randomization schemes for the management of data.

- Researchers at the University of Minnesota and Cornell University have developed probabilistic models to understand the ability of competing species to co-exist. The model was developed to study the ability of different strains of the barley yellow dwarf virus to co-exist.

- A researcher and his colleagues at the Santa Fe Institute have used ideas from the economic theories of risk aversion to create a general model of yield-risk management that produces strategies to minimize the likelihood of total ruin. The design principle, called "constrained optimization with limited deviations" or COLD, allows the effective elimination of the likelihood of disasters if one accepts a very small loss in average system performance. This method was used to study a problem in which forest managers are faced with maximizing timber yields with acceptable levels of risk.

- The Institute for Pure and Applied Mathematics at UCLA conducted a program on "Large Scale Communication Networks" in March-June 2002 that included discussions of packet-switching protocols and their optimization. A revision of the Internet's basic transmission control protocol (TCP) developed in that research program was successfully implemented and tested in November 2002 by a Caltech/SLAC research team working on fast, large networks for supercomputing.

The FY 2004 Budget Request of $201.87 million will enhance interdisciplinary research groups and other collaborative mechanisms that integrate the mathematical sciences with chemistry, materials research, physics, astronomy and other sciences and engineering.

Of special importance in FY 2004 is the Mathematical Sciences priority area investment of $67.39 million, an increase of $20.0 million over the FY 2003 Request. This investment reflects the importance of mathematical and statistical sciences in the kinds of crosscutting science and engineering research areas described above.

The FY 2004 increase in DMS will support:

- Research in dynamical systems, structure and geometry of the physical world, and other mathematical and statistical fundamental research necessary to support advances in interdisciplinary fields.

- Focused mathematical sciences research teams, interdisciplinary training groups, and other collaborative mechanisms related to advancing science and engineering, including continuation of the GEO-Math partnership for collaborative research in the mathematical sciences and geosciences. The FY 2003 interagency partnerships with the Defense Advanced Research Projects Agency (DARPA) and the National Institutes of Health (NIH) will be continued and it is anticipated that additional new collaborations with engineering and the biological, physical and computer sciences will be initiated.

- Enhancement of the national institutes in the mathematical sciences that address the growing interface between the mathematical sciences and other disciplines and the mathematical and statistical problems whose solutions will contribute to both fundamental knowledge and national needs. In FY 2002, three new national institutes were established.

- Enhancement of research training activities in the mathematical sciences.

PHYSICS $217,500,000

The FY 2004 Request for the Physics Subactivity is $217.50 million, an increase of $24.19 million, or 12.5 percent, over the FY 2003 Request of $193.31 million.

Physics Funding
(Dollars in Millions)

	FY 2002 Actual	FY 2003 Request	FY 2004 Request	Change Amount	Change Percent
Physics Research	195.88	193.31	217.50	24.19	12.5%
Total, PHY	$195.88	$193.31	$217.50	$24.19	12.5%

The Physics Subactivity (PHY) supports fundamental research in a broad range of physical phenomena, including support in: atomic, molecular, optical, and plasma physics; elementary particle physics; gravitational physics; nuclear physics; particle and nuclear astrophysics; and theoretical physics. Physics also supports interdisciplinary research, including: biological physics, complex systems, turbulence, and other developing interface areas associated with the core disciplines, for example the interface with information technology. The impact of physics research extends far beyond physics as a result of the discovery of new phenomena and the development of new techniques and basic tools that advance other fields, e.g., laser technology, biomedical technology, information technology, nanotechnology, energy science, including nuclear science, and many other techniques used in high technology industries.

Typical awards include funding for faculty salary support, graduate students, post-doctoral associates, instrumentation development, and other research needs. PHY supports an increasingly vigorous effort in the integration of research and education, including support of the Research Experience for Undergraduates (REU) program, the Faculty Early Career Development Program (CAREER), and important and innovative new outreach efforts aimed at improving links to K-12 teachers and students. The REU program continues to be very successful at reaching underrepresented minorities and women.

PHY provides support for a large portion of university-based research in the physics sub-disciplines, ranging from nearly 100 percent for gravitational physics to 30-50 percent for the other physics programs. The scope of support ranges from individual-investigator awards for research based at the investigator's home institution, to awards to major user groups with principal responsibility for experiments at national or international user facilities. PHY also supports centers and institutes in many areas and national user facilities for certain subfields. The user facilities represent important elements of the national infrastructure: in elementary particle physics, the Cornell Electron Storage Ring (CESR); in nuclear physics, the Michigan State University National Superconducting Cyclotron Laboratory; and in gravitational physics, the Laser Interferometer Gravitational-Wave Observatory (LIGO). Center activities include: support for Physics Frontiers Centers, including centers in the areas of biological physics, cosmological physics, gravitational physics, coherent ultrafast optical science, and the structure and origin of matter, the latter at an HBCU (Historically Black College or University); and a new Science and Technology Center (STC) in biophotonics.

In a recent development at the Physics Frontiers Center 'Frontiers of Optical, Coherent and Ultrafast Science' (FOCUS) at the University of Michigan, investigators succeeded in laser-cooling, trapping, and imaging individual cadmium ions for use in quantum information experiments. This was the first demonstration of sympathetic cooling of a single atom that can be simultaneously optically addressed. This technique will be extremely important for the future use of a register of Cd^+ ions for quantum

computing, where sympathetic cooling would quench possible motional decoherence without destroying internal quantum coherence.

PHY oversees a construction project funded through the Major Research Equipment and Facilities Construction (MREFC) Account – the Large Hadron Collider (LHC) ATLAS and CMS detectors. Construction funding for the LHC detectors began in FY 1999 and concludes in FY 2003 (see the MREFC chapter for additional information). LIGO, which was also funded through the MREFC Account, is fully operational in FY 2004, with all interferometers operating in coincidence (the 2- and 4-km interferometers at Hanford and the 4-km interferometer at the Livingston site; see the Tools chapter for additional information).

Some recent trends and areas of future emphasis are particle and nuclear astrophysics, biological physics, computational and information-intensive physics, and underground science. New programs have been established to emphasize these topics. The particle and nuclear astrophysics program has been reinforced by the recent report "Connecting Quarks to the Cosmos: Eleven Science Questions for the New Century" (National Academies Press, 2002). The FY 2003 Request called for a major NSF-sponsored workshop on neutrino physics and underground science and a National Academy of Sciences assessment of the need for investment in this field. Both the workshop (Neutrino and Subterranean Science, 17-19 September, 2002) and the report ("Neutrinos and Beyond: New Windows on Nature" (National Academies Press, 2002)) have been completed; with an emphasis on research needs in underground science.

In concert with other MPS subactivities, PHY will increase its emphasis of support for mid-scale instrumentation such as, moderate-scale neutrino, cosmic ray and gamma ray detectors, and the development of resources such as grid computing which serve the data requirements of several information-intensive physics and astrophysics experiments. Another area of increased emphasis is Quantum Science and Technology (QST). In the area of QST, PHY will emphasize quantum information science with support of forefront research in the cooling, trapping, and manipulation of atoms using ultrafast and ultracold techniques.

The FY 2004 Request for PHY includes:

- An increase of $10.68 million in research projects to a total of $140.30 million. PHY will continue to support forefront areas of physics, with some emphasis on particle and nuclear astrophysics, computational and information-intensive physics, quantum information science, biological physics and on advanced R&D towards next generation particle accelerators and gravitational wave detectors. Education and outreach activities will receive continued emphasis: enhancing K-12 science teacher training, expanding diversity within the research community, integrating research and education, and broadening the role physics plays in new and emerging areas of research, including the training of young physicists. Part of this increase will provide support for the new STC in biophotonics ($3.96 million).

- An increase of $13.51 million for facilities and research resources to a total of $77.20 million includes: support for full operations of the Michigan State National Superconducting Cyclotron Laboratory's radioactive ion beam facility for a total of $15.20 million; support full operations of LIGO to a total of $29.0 million as the lab focuses on coincidence observations between the lab's two detector sites as well as with foreign gravitational wave detectors; and an increase of $1.51 million for CESR operations to a total of $21.0 million, to enable exploration of critical weak and strong elementary particle interaction phenomena and to sustain the important accelerator physics research activity at Cornell. Early operations of the LHC ATLAS and CMS detectors will be supported for a total of $10.0 million. Development of grid computing capabilities will continue at a total of $2.0 million.

MULTIDISCIPLINARY ACTIVITIES $31,000,000

The FY 2004 Request for the Multidisciplinary Activities Subactivity is $31.0 million, an increase of $5.98 million or 23.9 percent over the FY 2003 Request of $25.02 million.

Multidisciplinary Activities Funding
(Dollars in Millions)

	FY 2002 Actual	FY2003 Request	FY2004 Request	Change Amount	Change Percent
Research Project Support	24.83	25.02	31.00	5.98	23.9%
Total, OMA	$24.83	$25.02	$31.00	$5.98	23.9%

The Multidisciplinary Activities Subactivity (OMA) enables and facilitates MPS support of particularly novel, challenging, or complex projects of varying scale in both research and education that are not readily accommodated by traditional organizational structures and processes. This is done primarily in partnership with the five other MPS Subactivities to encourage multidisciplinary proposals from all segments of the MPS community and especially to encourage initiatives by multi-investigator, multidisciplinary teams pursuing problems on a scale that exceeds the capacity of individual investigators. Most often, these cooperative undertakings involve two or more partners – both from MPS and beyond – that join with OMA to push in new directions of scientific understanding and that broaden and enrich education and research training activities in the MPS disciplines. Examples of such multi-investigator, multidisciplinary and often multi-institutional projects facilitated by OMA include the initial awards in Collaboratives for Research in Chemistry, Environmental Molecular Science Institutes, and Physics Frontier Centers.

OMA facilitates partnerships between MPS and other NSF activities, other agencies, industry, national laboratories, state and local governments, and international organizations. Such partnerships are critically important to the pursuit of the strategic goals of the Foundation and of the MPS community and contribute significantly to the preparation of a diverse workforce that is broadly trained, flexible, and globally competitive. Facilitation by OMA of both disciplinary partnerships and organizational partnerships is vital to the accelerated discovery of new ideas, the development of new tools, and the broadened training necessary to enable the Nation's workforce to meet new and rapidly evolving demands. Examples of the importance of such partnerships are seen in the Grant Opportunities for Academic Liaison with Industry (GOALI) program, the NSF-European Commission cooperation in international research and research training, the MPS, ENG, SBE and DOE cooperative development and support of the Pan American Advanced Study Institutes program, and the NSF-EPA partnership in support of research in technology for a sustainable environment and in environmental statistics.

The Subactivity supports innovative experiments in physical science and mathematics education that could lead to new paradigms in disciplinary and multidisciplinary graduate and undergraduate education. It also is a focal point within MPS for activities to facilitate the development of a diverse and globally competitive workforce. The MPS research infrastructure serves as a resource to enhance the K-12 teaching cohort and broaden the discovery-based learning experiences of K-16 students, and to draw upon MPS-supported research as an effective platform for public science education. Examples of OMA investment in these educational arenas include Research Experiences for Teachers, which provides in-service and pre-service K-12 teachers with discovery-based learning experiences in the MPS disciplines; support, in partnership with the EHR/DUE Subactivity, of a new multi-institutional, multidisciplinary Center for the Integration of Research, Teaching, and Learning at the University of Wisconsin which, in

collaboration with Michigan State University and Pennsylvania State University, is creating an interdisciplinary program to prepare graduate students, postdoctoral researchers, and current faculty to meet the challenges of STEM higher education; and support for Internships in Public Science Education (IPSE), a program that brings recent science results from MPS-supported research to the public by promoting partnerships between the MPS research community and specialists in public science education.

In FY 2004, OMA will continue to work with other MPS Subactivities and programs across the Foundation with an emphasis on fundamental research in the area of Quantum Science and Technology (QST), research at the interface between MPS and the Biological Sciences Activity, and an MPS focus on mid-scale instrumentation.

The FY 2004 Request of $31.0 million, an increase of $5.98 million, includes:

- Support for the Research Experiences for Teachers program will be increased by $500,000 to provide enriching discovery-based learning experiences for in-service and pre-service K-12 teachers.

- Increase support for GK-12 program by $430,000 to $2.40 million.

- Support for research partnerships with the other MPS Subactivities, including Research Partnerships for Diversity, that attract and retain individuals from traditionally underrepresented groups into doctoral programs in the MPS disciplines will be increased by $1.50 million.

- An investment of $1.0 million will support a new partnership with the DOE Office of Science will enable undergraduate students and faculty from underserved undergraduate institutions to participate in research activities at infrastructure-rich National Laboratories.

- Support of cooperative international research and training activities will be increased by $500,000 to enhance the global competitiveness of U.S. scientists, engineers, and students. Activities such as the MPS Distinguished International Postdoctoral Research Fellowship program and other such programs enable graduate students, postdoctorals, and faculty in the MPS disciplines to carry out research at the world's leading facilities and laboratories to develop and to enrich essential international dimensions of their individual research and education programs.

- Investment in research by multidisciplinary groups of scientists, mathematicians, and engineers leading to the development of next-generation instrumentation, particularly mid-scale instrumentation, will be increased by $1.0 million. Such instrumentation integrates modeling, computation and measurement to enable fundamental advances and broad training across a wide spectrum of disciplines.

- The Grant Opportunities for Academic Liaison with Industry (GOALI) program, which affords a vital mechanism for broadening graduate and postdoctoral training, will be continued at a level of $3.0 million, unchanged from FY 2003.

- Support for activities that draw upon the extensive MPS research investment for public science education will be increased by $500,000. The MPS Internships in Public Science Education activity supports partnerships between MPS researchers and the public science education communities, with focused emphasis on MPS-supported research centers and facilities.

- Support at the level of $1.92 million will facilitate the launch of the innovative Chemistry Undergraduate Research Centers (URCs) program and the attendant Discovery Corps.