MATHEMATICAL AND PHYSICAL SCIENCES

MATHEMATICAL AND PHYSICAL SCIENCES $1,115,500,000

The FY 2005 Budget Request for the Mathematical and Physical Sciences (MPS) Activity is $1.115 billion, an increase of $23.99 million, or 2.2 percent, over the FY 2004 Estimate of $1.092 billion.

Mathematical and Physical Sciences Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Percent
Astronomical Sciences	187.07	196.55	204.35	7.80	4.0%
Chemisty	181.61	185.22	188.91	3.69	2.0%
Materials Research	241.39	250.89	253.18	2.29	0.9%
Mathematical Sciences	178.79	200.41	202.25	1.84	0.9%
Physics	224.50	227.67	235.76	8.09	3.6%
Multidisciplinary Activities	27.34	30.77	31.05	0.28	0.9%
Total, MPS	$1,040.70	$1,091.51	$1,115.50	$23.99	2.2%

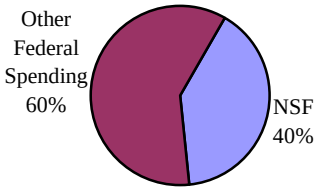
Totals may not add due to rounding.

The Mathematical and Physical Sciences Activity provides funds for research, supporting infrastructure, and development of human resources in the mathematical and physical sciences.

RELEVANCE

From the structure and evolution of the universe to the fundamental particles and processes of matter, from the behavior and control of molecules at the nanoscale to the complexity of their chemical interactions in materials and life processes, from developing new mathematical structures and theories to transforming them into models of natural systems that connect to computation, experimentation, and observation, the questions of MPS-supported research both stir the imagination and drive technological advances. Most of the research is of an exploratory nature. It requires sustained investment as well as access to the tools of advanced discovery. MPS-supported research provides the backbone for advances in other technical, engineering, and health-related disciplines, and provides a broad basis for industrial and technological development. It has played a fundamental role in the technological leadership of the United States and in maintaining its health, economy, defense, and homeland security. By linking research with education and training, MPS also promotes development of the future U.S. science, engineering, and technology workforce.

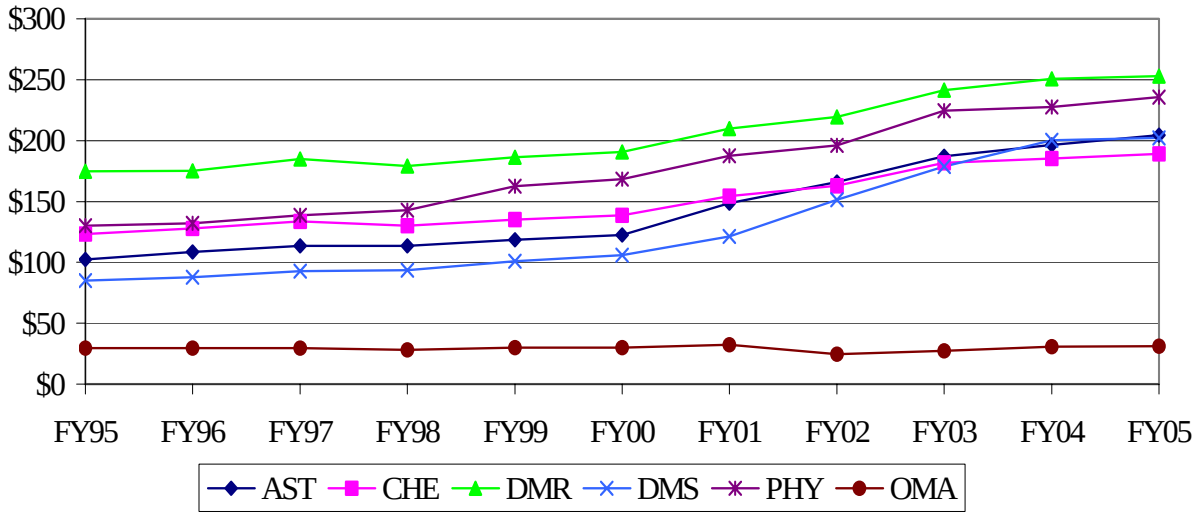
Federal Support of Basic Research in Math and Physical Sciences at Academic Institutions



NSF's role as lead agency in MPS research is appropriate, given its basic research mission. MPS provides about 40 percent of the federal funding for basic research at academic institutions in the mathematical and physical sciences. Within the astronomical sciences, MPS provides about 33 percent of the federal support in this area; in chemistry, about 31 percent; in physics, approximately 31 percent; in materials research approximately 50 percent; and in mathematics more than 58 percent. MPS collaborates with other disciplines within NSF

and partners with other agencies, the private sector, and other nations in exploring areas such as the physics of the universe, nanoscale science and engineering, molecular processes in the life and environmental sciences, mathematical modeling across scales of time and space, and the evolving scientific capabilities provided by emerging cyberinfrastructure. Such cooperation enhances the synergistic impact of MPS investments.

MPS Subactivity Funding
(Dollars in Millions)



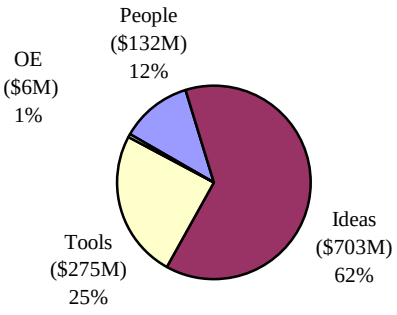
STRATEGIC GOALS

MPS contributes to achieving NSF's strategic goals through its investments in the people, ideas, and tools of mathematical and physical sciences and through its pursuit of organizational excellence.

- People: Investments aim to improve the quality and diversity of the U.S. science and engineering workforce and to enhance the public's knowledge of MPS fields by linking both formal and informal education and training programs to forefront research activities in the U.S. and other countries. This approach invigorates education through the excitement of discovery and contributes to an engagement in the global MPS enterprise.

- Ideas: Investments aim to enable strong, flexible disciplines that generate discoveries across the MPS frontiers, reach out to other disciplines on multidisciplinary frontiers, accept risky undertakings that promise significant advances on fundamental questions, and connect with learning, innovation and national interests. These investments include a mix of broad support across all MPS fields and catalytic support that promotes advances in identified areas of opportunity.

FY 2005 MPS Strategic Goals



- Tools: Investments aim to enhance the infrastructure supporting the conduct of research and education in MPS and related fields and enable broad access to it. The investments range from table-top instruments to international facilities with hundreds of users and include the development of new types of instrumentation. Remote access to facilities through increasingly sophisticated cyberinfrastructure complements on-site capabilities. MPS continually explores the needs and opportunities for investments in infrastructure, including both new capabilities and the operation and upgrade of existing state-of-the-art facilities needed to perform world-class research.

- Organizational Excellence (OE): MPS investments in Organizational Excellence provide for administrative activities necessary to enable NSF to achieve its mission and goals by enhancing the visibility and credibility of MPS programs in the scientific community and enabling state-of-the-art capabilities in award and oversight processes. These investments include support for Intergovernmental Personnel Act appointments and for contractors performing administrative functions.

Funding by Strategic Goal: Summary
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Percent
People	113.84	127.79	131.49	3.70	2.9%
Ideas	667.15	685.72	703.16	17.44	2.5%
Tools	253.57	271.86	274.71	2.85	1.0%
Organizational Excellence	6.14	6.14	6.14	0.00	0.0%
Total, MPS	$1,040.70	$1,091.51	$1,115.50	$23.99	2.2%

PEOPLE (+$3.70 million, for a total of $131.49 million)

MPS is committed to helping NSF ensure a diverse, competitive, and globally-engaged U.S. workforce of scientists, engineers, technologists and well-prepared citizens, the most important goal for ensuring the vitality of science and engineering in the future. All MPS investments focus on enabling people. When enabling people to carry out their ideas for discovery on the frontiers or to develop and use new tools for experimentation and observation, MPS also provides opportunities for learning through discovery. These less direct investments are critical for maintaining a broad focus in developing the next generation of scientists and engineers.

MPS complements this broad approach with targeted investments in people totaling $131.49 million in FY 2005, an increase of $3.70 million or 2.9 percent over FY 2004. This investment, representing a mix of MPS participation in NSF-wide programs, activities aimed at the particular interests of MPS fields, and experiments in collaboration with the Directorate for Education and Human Resources includes education activities at all levels, as well as public outreach and faculty development. Activities may target individuals, institutions, or collaborations depending on their objectives.

MPS regards undergraduate education as a "pressure point" in the system – where investments can influence decisions on future careers being made by a diverse talent pool. Connections to secondary students that draw them into science and engineering as well as to graduate programs that enable students to participate in advanced training complement undergraduate approaches. In all instances, MPS emphasizes the integration of research and education as a mechanism for enhancing undergraduate programs and increasing diversity.

MPS People Investments
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Individuals	80.74	92.16	95.85	3.69	4.0%
Institutions	7.24	5.44	5.77	0.33	6.1%
Collaborations	25.86	30.19	29.87	-0.32	-1.1%
Total, People	$113.84	$127.79	$131.49	$3.70	2.9%

Totals may not add due to rounding.

INDIVIDUALS

- Funding for Enhancing the Mathematical Sciences Workforce for the 21st Century increases by $2.0 million to $27.78 million through reorientation of $1.50 million from the CAREER program and $500,000 from postdoctoral fellowship activities. This program builds on the Vertical Integration of Research and Education in the Mathematical Sciences (VIGRE) program and includes a component for Research Training Groups in the Mathematical Sciences and a component for Mentoring through Critical Transition Points in the Mathematical Sciences;
- Across MPS, funding for the CAREER program decreases by $500,000 to a total of $40.30 million.
- Support for IGERT will increase by $1.24 million to $10.0 million to support about 25 additional students.
- Support for the post-doctoral and senior fellowship program, Discovery Corps, piloted in FY 2004, will be increased $500,000 to a total of $1.50 million and the MPS Distinguished International Postdoctoral Research Fellowship (MPS-DRF) will increase $250,000 to a total of $2.50 million to support about 10 additional fellows.
- Support for Research Experiences for Teachers (RET) will increase $500,000 to total $4.50 million and the NSF Director's Award for Distinguished Teaching Scholars (DTS) will increase $200,000 for a total of $500,000 to support about 50 additional K-12 teachers and discipline researchers/educators.
- Support for supplemental undergraduate student research experiences will remain constant at $4.42 million.

INSTITUTIONS

- Support for ADVANCE will increase $230,000 to $5.0 million.

COLLABORATIONS

- Support for Graduate Teaching Fellows in K-12 Education will increase by $100,000 to a total of $2.50 million.
- Support for MPS Internships in Public Science Education (IPSE) program will increase $500,000 to total $3.0 million.
- Investment in research and training activities at the scientifically rich interface between the MPS disciplines and the biological sciences will be increased by $400,000 to total $1.0 million.
- Support for the pilot program proposed to begin in FY 2004 for Undergraduate Research Centers will continue at a level of $3.0 million.

IDEAS (+$17.44 million, for a total of $703.16 million)

Discoveries in the fundamental sciences of astronomy, chemistry, materials research, mathematical sciences, and physics address some of the most fundamental questions about the universe and at the same time provide the basis for technologies that generate new industries. Their potential impact on the future economic health of the nation is profound.

The recent National Research Council report "Connecting Quarks with the Cosmos," frames an emerging research priority at the interface of physics and astronomy growing out of results that have radically altered our ideas about both the behavior and substance of the universe. The results make a strong case for the existence of new fundamental particles (dark matter) and a new, pervasive brand of energy (dark energy). Compelling questions awaiting answers include: What is the dark matter that dominates the matter content of the universe, and how is it related to as yet undiscovered fundamental particles? What is the dark energy that dominates the entire energy-matter content of the universe, and how does it relate to as yet undiscovered fundamental forces and fields? Can we detect gravitational radiation and use it to explore the most exotic bodies and processes in the universe as well as the relationship of general relativity and quantum mechanics? Working in cooperation with counterparts at NASA and the Department of Energy, MPS will embark on a coherent effort to understand this newly emerging area of the physics of the universe at the very smallest and very largest of spatial scales.

New advances in quantum and nanoscale phenomena will enable MPS researchers to move aggressively toward a more complete molecular-level understanding of life processes by addressing a basic research frontier in molecular science and technology: weak, non-covalent bonding interactions. Individually, each of these bonding interactions is quite weak, but collectively there is cooperative "strength in numbers" that causes proteins to fold, membranes to self-assemble, and enzymes to catalyze remarkable molecular transformations. Key questions involve the ability of collections of weak, non-covalent bonds to produce molecular complexity and emergent behavior. How can a disordered mixture of chemicals spontaneously transform to an organized, self-replicating molecular system? How are molecular reactions coupled to produce periodic behavior like circadian rhythms and heartbeats? MPS aims to produce a far more holistic picture of the chemical bonds that underpin molecular science and technology while yielding new technological opportunities in fields ranging from pharmaceuticals to biomaterials to agrochemicals.

MPS-supported scientists are now exploring physical systems over the entire spectrum of length and time scales. A realistic description of the physical laws governing such systems demands the full integration of theory with experiment and observation. It also requires the generation of sophisticated and mathematically precise models, the development of application-specific software to implement the models computationally, and the ability to manipulate and extract information from large, complex data sets. MPS scientists, along with computer scientists, have developed algorithms and application software to address these problems, creating new approaches in all disciplines (cyberscience) that leverage MPS's past investments in computational astronomy, chemistry, materials research, mathematics, physics, and statistics to support the development of new algorithms that enable the exploration of previously inaccessible areas of science through computation and simulation.

Research in the MPS disciplines is becoming increasingly multidisciplinary, as the examples above indicate. To facilitate interdisciplinary research MPS supports a variety of research centers and groups. These activities complement the support for individual investigators and small groups. Active participation in research and education activities in undergraduate institutions, as well as connections to Foundation-wide programs such as EPSCoR, CREST, SBIR, and STTR help expand capability in science and engineering. Through their support of students and postdoctoral researchers, MPS investments in

Ideas enhance capability by improving the quality of education and diversity of participation for the next generation of scientists and engineers.

MPS Ideas Investments
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Fundamental Science and Engineering	535.09	542.07	553.35	11.28	2.1%
Centers Programs	116.28	130.29	136.45	6.16	4.7%
Capability Enhancement	15.78	13.36	13.36	0.00	0.0%
Total, Ideas	$667.15	$685.72	$703.16	$17.44	2.5%

Totals may not add due to rounding.

FUNDAMENTAL SCIENCE AND ENGINEERING

- Support for disciplinary research will increase $11.28 million to total $551.71 million, increasing average annualized award size by $5,000 to $140,000.
- Initiate focus on the emerging areas of Physics of the Universe with an increase of $9.0 million to support observational and theoretical efforts to understand the nature of dark energy and dark matter; expand support of numerical relativity and theoretical cosmology, neutrino physics, and cosmic microwave background radiation; and support research and development of the Atacama Cosmology Telescope.
- Provide $1.50 million to enhance the understanding of the physical and chemical bases of life processes, with emphasis on the molecular level.
- Support for the NSF priority area in Nanoscale Science and Engineering will increase by $20.66 million through a redirection from other activities of $18.32 million and $2.34 million included within the Centers Program for an investment total of $132.14 million. MPS will place emphasis on structures, phenomena, and quantum control at the nanoscale.
- Increased support of $7.06 million for cyberinfrastructure to a total of $31.99 million. This funding supports the development of new algorithms that enable the exploration of previously inaccessible areas of science through computation and simulation; promotes the development of new methods for extracting information from ever larger and increasingly complex data sets; unifies seemingly disparate practices in scientific computing and data analysis and lays the foundation for the development and application of new concepts and tools that take advantage of the growing computational infrastructure.

CENTERS PROGRAMS

MPS Centers
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Chemistry Centers	13.39	16.85	18.90	2.05	12.2%
Materials Centers[1]	54.65	56.56	58.90	2.34	4.1%
Information Technology Centers	0.30	0.00	0.00	0.00	0.0%
Mathematical Sciences Research Institutes	14.77	15.10	16.60	1.50	9.9%
Nanoscale Science and Engineering Centers	5.98	11.78	11.78	0.00	0.0%
Physics Frontier Centers	12.25	15.20	15.40	0.20	1.3%
Science and Technology Centers	14.94	14.80	14.87	0.07	0.5%
Total, MPS Centers Programs	$116.28	$130.29	$136.45	$6.16	4.7%

Totals may not add due to rounding.

[1]Materials Centers includes support for Materials Research Science and Engineering Centers (MRSECs), International Materials Institutes and Partnerships for Research and Education in Materials.

- Support for Chemistry Centers will increase by $2.05 million to total $18.90 million, increasing the expected number of Chemical Bonding Centers focusing on research related to the MPS emphasis area of the molecular basis of life processes.
- Support for the Materials Centers increases by $2.34 million to $58.90 million to enable establishment of up to three new MRSECs. This increase will support the NSF nanoscale science and engineering priority area. Additional funds may be redirected as needed from existing MRSECs through recompetition.
- Increased support for the Mathematical Sciences Research Institutes of $1.50 million to total $16.60 million to address the growing interface with other disciplines.

CAPABILITY ENHANCEMENT

- MPS investments in Research in Undergraduate Institutions and Research Opportunity Awards remain constant at $13.36 million.

TOOLS (+$2.85 million, for a total of $274.71 million)

The MPS investment in Tools maintains a portfolio of world-class facilities for the science and education communities with a capital investment of well over $1.0 billion, develops instrumentation for cutting-edge research, and provides access to needed research resources. Increased annual support of $2.85 million over the FY 2004 Estimate to a total of $274.71 million significantly enables new science opportunities: allowing for appropriate levels of operations and maintenance at MPS FFRDCs and facilities, support for needed disciplinary instrumentation programs, and, importantly, an expansion of mid-scale instrumentation activities.

Continuing advances in communication, computation, sensing and data technologies are changing the way MPS scientists and engineers perform their work. MPS has been at the forefront in using high-end computing capabilities, linking data with computing through emerging grid technologies, developing embedded sensors that transmit data to researchers, and expanding the capacity for remote observing. MPS will continue to expand its development of cyberinfrastructure, linking these activities with existing, developing, and planned facilities and instrumentation.

The National Science Board Report *Science and Engineering Infrastructure for the 21st Century: The Role of the National Science Foundation* identified significant challenges in obtaining research instrumentation above the size of that provided through regular awards or instrumentation programs (generally below $2.0 million) but below the size of projects eligible for NSF's Major Research Equipment and Facilities Construction (MREFC) Account. MPS is moving to address these challenges, which include, for example, development of adaptive optics systems for telescopes; research and development for new large-scale instruments; and enhanced user support and instrumentation for neutron scattering experiments at the Department of Energy's Spallation Neutron Source (SNS).

MPS Investments in Tools
(Dollars in Millions)

Facilities	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Cornell Electron Storage Ring (CESR)	19.49	18.00	19.70	1.70	9.4%
GEMINI	13.48	14.12	14.93	0.81	5.7%
Large Hadron Collider	5.00	7.00	9.00	2.00	28.6%
Laser Interferometer Gravitational Wave Observatory (LIGO)	33.00	33.00	33.00	0.00	0.0%
MSU Cyclotron	15.65	15.65	16.65	1.00	6.4%
Nanofabrication (NNUN/NNIN)	1.75	2.65	2.65	0.00	0.0%
National High Field Mass Spectrometry Center	0.99	0.00	0.00	0.00	N/A
National High Magnetic Field Laboratory (NHMFL)	24.11	24.61	25.61	1.00	4.1%
RSVP		6.00	0.00	-6.00	-100.0%
Other MPS Facilities	12.90	11.41	11.41	0.00	0.0%
Facilities, Subtotal	**126.37**	**132.44**	**132.95**	**0.51**	**0.4%**
Digital Library	1.00	1.00	1.00	0.00	0.0%
Research Resources	26.05	30.28	42.48	12.20	40.3%
Infrastructure and Instrumentation, Subtotal	**27.05**	**31.28**	**43.48**	**12.20**	**39.0%**
NAIC	10.93	10.54	10.60	0.06	0.6%
NCAR	1.27	1.27	1.27	0.00	0.0%
NOAO	42.62	41.35	39.00	-2.35	-5.7%
NRAO	45.33	54.98	47.41	-7.57	-13.8%
FFRDCs, Subtotal	**100.15**	**108.14**	**98.28**	**-9.86**	**-9.1%**
Tools, Total	**$253.57**	**$271.86**	**$274.71**	**$2.85**	**1.0%**

FACILITIES

- An increase of $1.70 million to a total of $19.70 million for the Cornell Electron Storage Ring (CESR) to enable exploration of critical weak and strong elementary particle interaction phenomena and to sustain important accelerator physics research.
- An increase of $810,000 to $14.93 million for the Gemini Observatory will be sufficient to cover the U.S. share of operating costs, and a contribution of $1.0 million for the purchase of the Chilean share of the partnership.
- An increase of $2.0 million for operation of the ATLAS and CMS detectors for the Large Hadron Collider, including computing and software development, to a total of $9.0 million, continuing the ramp-up begun in FY 2003.
- Continued full operation and advanced detector research and development for the Laser Interferometer Gravitational-wave Observatory (LIGO) to run their interferometers at sites in Hanford, WA and Livingston, LA for a total of $33.0 million.

- An increase of $1.0 million, to a total of $16.65 million, for Michigan State University's National Superconducting Cyclotron Laboratory, a unique radioactive ion beam facility for nuclear physics, including nuclear astrophysics and nucleosynthesis. The increase is needed to enhance operations of this recently upgraded facility.
- A decrease of $6.0 million in planning activities for the Rare Symmetry Violating Processes (RSVP) project that was provided at the FY 2004 Estimate. RSVP consists of a pair of elementary particle physics experiments to probe very rare events giving clues to physics beyond the Standard Model. Funding for RSVP is requested through the MREFC Account in FY 2005.
- An increase of $1.0 million to $25.61 million for the National High Magnetic Field Laboratory in order to complete the integration of the Ion Cyclotron Resonance Facility at Florida State University into the NHMFL.

INFRASTRUCTURE AND INSTRUMENTATION

Support for Research Resources will increase by $12.20 million to $42.48 million. These funds will expand support for mid-scale instrumentation. Highlights include:

- Initiate $3.70 million to support the goals of the Physics of the Universe activity through technology development for the Large Synoptic Survey Telescope (LSST).
- Increase of $3.0 million to a total of $13.15 million will support research resources including the synchrotron and neutron beam lines, for example, whose cost and scope exceeds the Major Research Instrumentation program.
- Research and development in adaptive optics amounting to $3.0 million will move from NOAO administration to the instrumentation grants program in FY 2005. An additional $2.50 million will support design studies and technology development for the Giant Segmented Mirror Telescope (GSMT).

FEDERALLY-FUNDED RESEARCH AND DEVELOPMENT CENTERS

- Support for NRAO decreases by $7.57 million to $47.41 million following several one-time funding increments in FY 2004. First funds for early operations of ALMA, estimated at $1.0 million, will be part of NRAO operating expenditures in FY 2005.
- Support for NOAO decreases $2.35 million to $39.0 million. In FY 2003 and FY 2004, NOAO administered a $3.0 million program to support community research in adaptive optics as part of Giant Segmented Mirror Telescope (GSMT) technology development; in FY 2005 this activity is continued but under the mid-scale instrumentation activity mentioned above. A total of $4.0 million will support the Telescope Systems Instrumentation Program (TSIP), which is administered by NOAO on behalf of the community.
- Support for NAIC will increase by $60,000 to $10.60 million.

ORGANIZATIONAL EXCELLENCE ($6.14 million, unchanged from the FY 2004 Estimate)

MPS investments in Organizational Excellence provide funding for Intergovernmental Personnel Act (IPA) appointments, IPA travel and the administrative contracts necessary to conduct the level of program activity. These investments complement the work of the MPS staff, bringing new ideas to the table and enabling a closer connection with the MPS scientific community and a broader range of outreach and oversight activities.

PRIORITY AREAS

In FY 2005, MPS will support research and education efforts related to broad, Foundation-wide priority areas in Biocomplexity in the Environment, Nanoscale Science and Engineering, Mathematical Sciences, Human and Social Dynamics, and Workforce for the 21st Century.

MPS Investments in Priority Areas
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Biocomplexity in the Environment	5.21	4.70	4.70	0.00	0.0%
Nanoscale Science and Engineering	103.92	111.48	132.14	20.66	18.5%
Mathematical Sciences	47.39	70.19	70.19	0.00	0.0%
Human and Social Dynamics	N/A	0.50	0.50	0.00	N/A
Workforce for the 21st Century	N/A	0.00	1.03	1.03	N/A

- Biocomplexity in the Environment support will total $4.70 million. Environmental Molecular Science Institutes will be supported with a particular emphasis on developing a molecular level understanding of processes occurring in aqueous media. In addition, MPS will support research in the modeling of complex environmental phenomena and the development of environmentally benign materials and chemical and materials processing methods.

- Nanoscale Science and Engineering funding increases by $20.66 million to a total of $132.14 million. The increased funding will be used for partial support for up to three new MRSECs and support for individual investigators and interdisciplinary groups with an emphasis on structures, phenomena, and quantum control.

- Mathematical Sciences priority area support totals $70.19 million, unchanged from the FY 2004 Estimate. MPS investments will fall within three categories: (1) fundamental mathematical and statistical sciences, (2) interdisciplinary research connecting the mathematical sciences with science and engineering, and (3) targeted investments in mathematical sciences training activities. Special emphasis will be placed on mentoring advanced high school students through recent doctoral recipients at critical stages of their development in order to encourage them to enter and remain in mathematically related careers.

- MPS plans $1.03 million for the Workforce for the 21st Century priority area, largely through investments in Integrative Institutional Collaborations. The broad thrust of MPS investments in integrating research and education will provide a solid base for connecting the MPS scientific community with the priority area.

- Participation in HSD will be at $500,000, equal to the FY 2004 investment. It will include support for areas such as interdisciplinary research modeling the development and evolution of social and organizational behavior in complex systems.

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 87 percent in FY 2003, the last year for which complete data exist.

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.

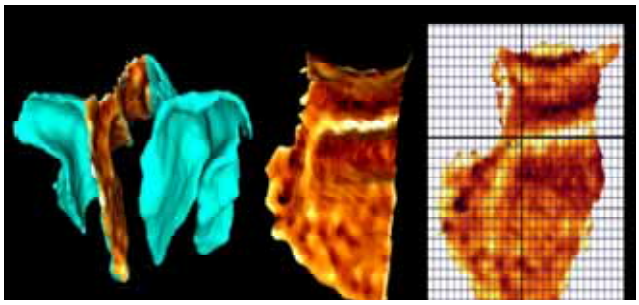
The Directorate also receives advice from the Advisory Committee for Mathematical and Physical Sciences (MPSAC) on such issues as: the mission, programs, and goals that can best serve the scientific community, how MPS can promote quality graduate and undergraduate education in the mathematical and physical 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 underrepresented minorities.

PERFORMANCE

2003 "Breakthrough of the Year."
Researchers supported by MPS were key participants in the work that was named Science Magazine's "Breakthrough of the Year" for 2003. The analysis of the distribution of the first quarter million galaxies mapped by Sloan Digital Sky Survey (SDSS) clearly showed that the galaxies are being affected by the repulsive effect of dark energy. The gravitational clustering patterns in the SDSS map reveal the makeup of the Universe from its gravitational effects and, by combining their measurements with that from NASA's WMAP, the SDSS team measured the cosmic matter to consist of 70 percent dark energy, 25 percent dark matter and five percent ordinary matter.

Understanding Nature's Super Glues.
Dr. Jonathan Wilker and colleagues at Purdue University are studying the adhesives used by marine organisms for sticking to surfaces. This work has shown that mussels concentrate iron from seawater and then use this metal to cure their glue. Efforts are underway to understand the bonding of many biological materials found in the oceans, such as barnacle cements, kelp adhesives, and coral reef structures. These biomaterials are providing inspiration for the development of applications such as new surgical glues to replace stitches and antifouling coatings to keep barnacles off ships. The figure shows a mussel adhering to a Teflon® sheet.

Computational Conformal Mapping and Scientific Visualization.
Computational and mathematical tools are needed to analyze data from human brain scans. A focused research group in the mathematical sciences led by Florida State University is applying tools developed through their award to a region of the brain (the medial prefrontal cortex), which has been implicated in depression and bipolar disease. This highly folded region is ideal for being analyzed with quasi-conformal "flat" maps in order to gain a better understanding of this region of the brain. By examining the folding patterns, curvature and shape of the flat maps of different subjects, diseased and non-diseased regions can be compared and measurements can be developed to quantify the similarities and differences between various regions.

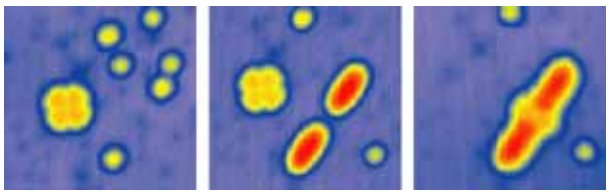


This highly folded medial prefrontal cortex region of the brain (left and center) is well-suited for analysis with quasi-conformal "flat" maps (right).

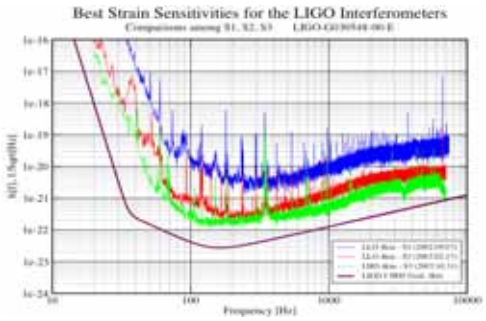
The group's work is leading to improved mathematical techniques for biomedical applications, while providing timely interdisciplinary training in mathematical biology for students and postdoctoral researchers.

Increasing the Participation of Underrepresented Groups in the Mathematical Sciences. The University of Maryland at College Park is working with Morehouse College, Bowie State University, Florida A&M University, North Carolina A&T, Spelman College, Trinity College of DC, and Xavier University to create a well-supported pathway to bring students from underrepresented groups to careers in the mathematical sciences. An annual Affiliates Workshop strengthens ties among these institutions. Sophomores and juniors participate in a Summer Institute that provides both academic classes and research experiences to reinforce the students' training and readiness for graduate study. Graduate fellowships and teaching assistantships enable students to continue to graduate work.

Materials at the Spatial Limit. Wilson Ho's research group at University of California-Irvine has constructed tiny chains consisting of 1 to 20 atoms of gold, silver or manganese. The synthesis of structures atom-by-atom using the scanning tunneling microscope is introducing novel ways to develop and study new materials and nanostructures. These results employ a new experimental approach to shed light on basic problems in molecular electronics, and to obtain new insight into the mechanisms of electrical conductivity through molecules. The image at right is not a simulation – it follows the chemical assembly of an entirely new molecule that Ho and his students synthesized by moving a copper-containing molecule into the gap between two gold atom chains.

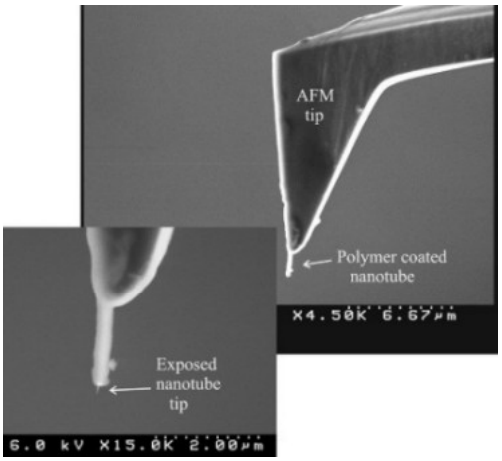


LIGO Completes Third Science Run at Near Design Sensitivity. The Laser Interferometer Gravitational-wave Observatory (LIGO) is an NSF-supported facility consisting of three laser interferometers designed to observe and study the gravitational waves predicted by Einstein's General Theory of Relativity. The goal in the present award, which extends from FY 2002 to 2006, is to accumulate one year's worth of observations at the design sensitivity, an unprecedented capability that would allow sensing the change caused by a gravitational wave in apparent distance between the interferometer mirrors of 4×10^{-18} m or one-thousandth of a proton diameter. In August 2002 LIGO began a series of observations with the first science run or "S-1 run" which lasted two weeks at a sensitivity approximately 100 times from the LIGO design goal. S-2, the second in the series, extended



from February 14, 2003 to April 14, 2003 and achieved sensitivities approximately 10 times from the design goal. The third run, S-3, extended from October 31, 2003 to January 8, 2004 and achieved sensitivities only about 3.5 times away from the goal. LIGO is now by far the most sensitive interferometer ever built and the solid progress in the past year and a half gives confidence that the design goals will be reached soon.

A New Probe for Understanding Cell Behavior. A group of researchers from the University of Florida has developed a new way to study cells at the nanoscale. They coat the tiny nanotube probe of an atomic-force microscope with a uniform layer of polymer and then remove the polymer from just the end of the nanotube. This coating dramatically stiffens the nanotube against buckling and makes the attachment of the nanotube to the probe tip extraordinarily robust. This new technique will provide unprecedented electrochemical and structural information about the electro- and neurophysiology of cells. The knowledge gained could impact our understanding in areas ranging from heart arrhythmias to the release of neurotransmitters, with implications for the treatment of nervous system disorders.



Other Performance Indicators

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

Number of People Involved in MPS Activities

	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate
Senior Researchers	6,063	6,000	5,900
Other Professionals	2,403	2,300	2,350
Postdoctorates	2,406	2,440	2,450
Graduate Students	7,124	7,200	7,100
Undergraduate Students	5,614	6,000	5,800
K-12 Students	310	320	320
K-12 Teachers	449	600	650
Total Number of People	24,369	24,860	24,570

MPS Funding Profile

	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate
Statistics for Competitive Awards:			
Number	2,268	2,120	2,110
Funding Rate	34%	34%	32%
Statistics for Research Grants:			
Number of Research Grants	1,710	1,650	1,610
Funding Rate	31.0%	32.0%	30.0%
Median Annualized Award Size	$100,000	$103,000	$105,000
Average Annualized Award Size	$128,590	$135,000	$140,000
Average Award Duration, in years	3.1	3.1	3.1

ASTRONOMICAL SCIENCES $204,350,000

The FY 2005 Budget Request for the Astronomical Sciences (AST) Subactivity is $204.35 million, an increase of $7.80 million, or 4.0 percent, over the FY 2004 Estimate of $196.55 million.

Astronomical Sciences Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Astronomical Sciences	187.07	196.55	204.35	7.80	4.0%
Total, AST	$187.07	$196.55	$204.35	$7.80	4.0%

NSF is the lead federal agency for ground-based astronomy, providing about two-thirds of the federal support for this area of science, including almost all federal support for radio astronomy. NSF works closely with NASA to coordinate ground-based astronomy activities. Astronomy Research and Instrumentation 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, at both public and private observatories, 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.

The FY 2005 Budget Request includes $92.41 million for research and instrumentation support in the Astronomical Sciences that will advance the scientific priorities of studies in cosmology and the origin and evolution of the universe and the formation of stars and planets. The request will support the initiation of several key areas of research and development identified by the Interagency Working Group on Physics of the Universe (POU) as well as continuation of efforts begun in FY 2004 and before. One new area will be the science program definition and technology development leading towards a Large Synoptic Survey Telescope (LSST), an instrument concept aimed at the determination of the nature of dark energy and the distribution of dark matter, two central challenges of the Physics of the Universe program. Construction of the Atacama Cosmology Telescope (ACT), supported jointly by the Divisions of Astronomical Sciences and Physics, and designed to map the cosmic microwave background temperature with resolution and sky coverage complementary to satellite experiments, will continue. Construction of VERITAS, a four element gamma-ray telescope and the operation of CDMS II, an underground experiment to search for dark matter particles, will continue jointly with the Division of Physics and the Department of Energy. A focus on providing support for mid-scale instrumentation needs begun in FY 2004 will continue to 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 the highly recommended Giant Segmented Mirror Telescope (GSMT). The Science and Technology Center (STC) for Adaptive Optics will be funded within AST in FY 2005.

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 2005 support for national facilities totals $111.94 million, and includes:

- Support for Gemini Observatory at a level of $14.93 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 the Chilean construction capital, with which the U.S. assumes a portion of the Chilean share of the Observatory, along with increased observing access for U.S. astronomers.

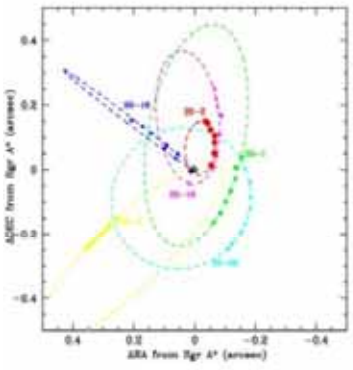
- NAIC will be supported at the level of $10.60 million. This level of support will enable continued operation and maintenance of the Arecibo telescope and the development of instrumentation to take advantage of its greater sensitivity.

- Support for NOAO/NSO at the level of $35.0 million, a decrease of $2.35 million from FY 2004. NOAO is involved in design and technology development for the GSMT and LSST. Levels of support for these activities within the NOAO base operating budget are expected to be approximately $1.20 million for LSST and $1.50 million for GSMT. Additional support for community-based R&D on adaptive optics totaling $3.0 million was managed by NOAO in FY 2004; those funds are being moved to the instrumentation grants program in FY 2005. NSO facilities provide solar telescopes for use by the U.S. astronomical community. Activities in FY 2005 include the final year of design and planning for the Advanced Technology Solar Telescope (ATST) ($2.0 million), an instrument that will use new techniques such as adaptive optics to provide a unique capability for investigating a wide range of questions in solar physics. ATST will be of significant value to studies in atmospheric sciences and space weather in addition to astronomical research.

  Included 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 of support for instrument development and facility improvement in exchange for public access to private facilities.

- NRAO is supported at the level of $47.41 million, a reduction from the FY 2004 Estimate of $7.57 million, the amount of a one-time funding increment in FY 2004 that enabled repairs to the Robert C. Byrd Green Bank Telescope and accelerated work on the Expanded Very Large Array (EVLA). This level of support will provide for operations, maintenance, and instrumentation for the Byrd Telescope, the Very Large Array, and the Very Long Baseline Array, for continued improvements and enhancements to the EVLA, and for early operations for ALMA.

Black Hole at the Galactic Center.
Recent work by Dr. Andrea Ghez has solidified the case for a massive black hole at the center of our Galaxy. With NSF support, she has used the orbits of stars near the center of the galaxy to infer the density of the dark mass at the Galactic core. Recently, using adaptive optics, and with a 7 year baseline, she has been able to follow the detailed orbits of a larger sample of fainter stars. One of these stars passes a mere 60 astronomical units from the central dark mass. The orbit of this star increases the constraints on the density of the dark mass by four orders of magnitude over her previous estimates, and eliminates several remaining alternatives to a supermassive black hole. Our own galaxy has now become the strongest case for a normal galaxy containing a supermassive black hole.



Orbit analysis for multiple stars orbiting the Galactic Center increases the implied dark mass density by four orders of magnitude over previous estimates.

CHEMISTRY $188,910,000

The FY 2005 Budget Request for the Chemistry (CHE) Subactivity is $188.91 million, an increase of $3.69 million, or 2.0 percent, over the FY 2004 Estimate of $185.22 million.

Chemistry Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Chemistry	181.61	185.22	188.91	3.69	2.0%
Total, CHE	$181.61	$185.22	$188.91	$3.69	2.0%

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 value of investments in molecular science and technology is evident in 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. An important basic research frontier is the development of an understanding of weak, non-covalent interactions and their cooperativity. These weak bonds are responsible for the structure of proteins, and they control the assembly of nanostructures. Investments in understanding the structure and reactivity of these complex systems will provide the basis for a detailed understanding of the molecular basis of life processes.

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 supports 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 National Medal of Science is John Brauman of Stanford University. By comparing molecular reactivity in the absence and presence of solvents, Brauman showed how solvents can dramatically influence the course of chemical reactions, particularly those involving ions. His work has provided a basic framework for understanding and controlling the impact of solvents on chemical reactivity.

- Alan Marshall of Florida State University and the National High Magnetic Field Laboratory has pioneered the use of ultra-high resolution Fourier transform ion cyclotron resonance mass spectrometry for characterizing the tens of thousands of chemical constituents of petroleum. He and his coworkers have coined the term “petroleomics” to describe this remarkable analytical tool that permits characterization of petroleum crude oil and its distillates based on their geochemical origin and method of processing.

- Jay Switzer of the University of Missouri at Rolla and co-workers have created a new process that produces so-called chiral films that are related as left- and right-hand mirror images. Such films can selectively bind the left- or right-handed form of chiral molecules. The researchers grew chiral copper oxide films by electrochemical methods on a gold substrate to demonstrate these effects. Roughly one-third of all pharmaceuticals are chiral, and this new process provides a means of synthesizing and separating pharmaceutical molecules of the correct handedness.

The FY 2005 Request of $188.91 million, an increase of $3.69 million, includes:

- Support for CHE core programs devoted to basic chemical research will grow by $380,000 to $141.45 million in FY 2005. Additional funds will be used largely to increase average grant size and to support principal investigators early in their research careers.

- Support for centers will increase by $2.05 million to $18.90 million. Chemical Bonding Centers (CBCs) will complement smaller, focused Environmental Molecular Science Institutes and Collaborative Research in Chemistry centers by providing support for long-term multi-disciplinary, multi-investigator projects that address grand challenges in the chemical sciences, such as the molecular origins of life processes. Approximately ten CBCs will be supported in an initial phase in FY 2005. These centers will collectively contribute to a more holistic understanding of chemical bonding, while providing insight into molecular processes spanning such interdisciplinary fields as the life sciences, environmental sciences, and nanotechnology.

- New support will be provided for cyberinfrastructure and for mid-scale instrumentation that exceeds what is available in cost and scope through the Chemistry Research Instrumentation and Facilities (CRIF) program and the NSF Major Research Instrumentation program. Pilot projects and workshops that identify appropriate investment strategies will be supported. Support for ruggedized, miniaturized instrumentation that can make workhorse instruments like mass spectrometers and nuclear magnetic resonance spectrometers more accessible will be provided through the CRIF program.

- CHE will support at the level of $2.10 million undergraduate, postdoctoral, and senior scientist programs that draw on the nation's rich geographic, institutional, and demographic diversity. Undergraduate Research Centers (URCs) 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 Experiences for Undergraduates (REU) sites will be supported. Discovery Corps Postdoctoral and Senior Fellowships will enable chemical scientists to combine their research expertise with professional service to address national needs, such as developing the workforce, creating jobs, and building research capacity. These activities will be supported by phasing out existing programs such as Research Sites for Educators in Chemistry.

- The Chemistry Subactivity will continue to support new demonstration projects of special interest to the field of chemistry, especially with respect to better preparing graduate students for competition in the diverse, global workforce. Of particular emphasis will be support of innovative programs that have the potential to increase the participation of underrepresented groups in the chemistry profession. The Subactivity will continue its efforts to develop programs to increase the scope of international collaborations in chemistry research.

MATERIALS RESEARCH $253,180,000

The FY 2005 Request for the Materials Research (DMR) Subactivity is $253.18 million, an increase of $2.29 million, or 0.9 percent, from the FY 2004 Estimate of $250.89 million.

Materials Research Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Materials Research	241.39	250.89	253.18	2.29	0.9%
Total, DMR	$241.39	$250.89	$253.18	$2.29	0.9%

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 28 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 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:


WOMEN IN CHEMISTRY

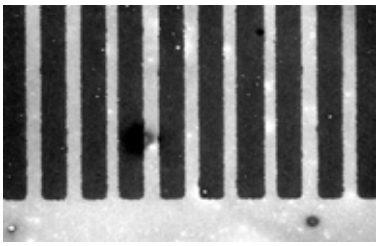
CHEMIST, TEACHER, SCHOLAR, MENTOR

- **Coherent Spin Organization in Nanostructures.** David Awschalom (University of California – Santa Barbara) and Nitin Samarth (Penn State University) have designed new artificial nanostructures that allow electronic spins to be controlled using electric and magnetic fields. The resulting 'electron spin gate' is a major step forward towards future 'spintronic' devices that may supersede today's electronic components in computers and communications.

- **Top recognitions to African-American Researchers.** DMR has placed special emphasis on attracting a broad diversity of scientists and educators and helping them develop their scientific careers. This year

three African-American grantees are receiving top international recognitions in their fields. Larry Dalton (U. Washington and USC) received the Materials Chemistry Award from the American Chemical Society, the world's largest scientific organization. This is the major research prize in the materials chemistry field worldwide. Joshua Otaigbe (U. Southern Mississippi) has received a major foreign honor, election as a Fellow of the United Kingdom Institute of Materials for contributions of international significance to polymer science and engineering. And Valerie Sheares Ashby, a CAREER grantee at Iowa State University, was featured in the ACS *Chemical & Engineering News* for her superb teaching, mentoring, and scholarly accomplishments.

- **Protein Photoresists.** Although nature provides remarkable examples of the materials properties of proteins (e.g., the strength and elasticity of spider silk), the technological development of protein-based materials has been frustrated by the difficulty of processing proteins and protein-like macromolecules into useful fibers, films and surface coatings. Researchers in the Center for the Science and Engineering of Materials at the California Institute of Technology have recently taken an important step toward solving this problem, by preparing proteins that can be processed by optical lithography techniques. They used amino acids that are sensitive to light to link together individual protein molecules into tough networks that resist dissolution in common solvents.



The FY 2005 Request includes several changes and enhancements:

- DMR will increase support for the NSF Nanoscale Science and Engineering priority area by $14.26 million to $90.95 million in FY 2005. The increment will include support for new individual investigator awards and focused research groups, and for up to three new materials research science and engineering centers (MRSECs).
- DMR support for the Mathematical Sciences priority area and for Biocomplexity in the Environment is unchanged at $1.08 million and $1.0 million, respectively.
- DMR support for cyberinfrastructure will be increased by $600,000 to $7.80 million, enhancing support for computationally-intensive research and education in materials.
- Support for research and education at the interface between materials, the biosciences and bioengineering will be increased by up to $1.0 million.
- Support for the IGERT program will be increased by $300,000 to $2.39 million, and support for the ADVANCE program will be increased by $60,000 to $1.24 million.
- Up to $3.0 million in additional funds will be provided in FY 2005 to support new mid-scale research resources, including synchrotron and neutron beam lines whose cost and scope is beyond that of the NSF Major Research Instrumentation program. This amount includes up to $2.50 million to support beam line instrumentation at the DOE Spallation Neutron Source (SNS).

Funds required for the new and enhanced activities described above total $19.22 million. An increase of $2.29 million is requested for DMR in FY 2005. The additional funds required will be generated by reducing support for Information Technology Research by $4.77 million to $5.23 million in FY 2005, and by reducing support for lower-priority research in individual investigator programs, groups and Centers by up to $12.16 million, equivalent to about 60 fewer awards in these areas. Award size and duration will be maintained at current levels.

MATHEMATICAL SCIENCES $202,250,000

The FY 2005 Request for the Mathematical Sciences (DMS) Subactivity is $202.25 million, an increase of $1.84 million, or 0.9 percent, over the FY 2004 Estimate of $200.41 million.

Mathematical Sciences Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Mathematical Sciences	$178.79	$200.41	$202.25	$1.84	0.9%
Total, DMS	$178.79	$200.41	$202.25	$1.84	0.9%

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 support involves a broader range of infrastructure and fundamental 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 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, Focused Research Groups, and Research Training 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, graduate, and undergraduate training opportunities, broadened career experiences for researchers, increased participation in the nation's research personnel base, research conferences and workshops, and scientific computing research equipment.

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:

- Computational and mathematical tools are needed to analyze data from human brain scans. A group involving researchers from Florida State University, the University of Tennessee, and the University of Minnesota is studying a region of the brain that has been implicated in depression and bipolar disease. The group's work is leading to improved mathematical techniques for biomedical applications, while providing timely interdisciplinary training.

- A group based at Duke University and North Carolina State University is studying fundamental problems in the dynamics of thin liquid films and fluid interfaces. These arise in problems ranging from industrial design of paints and microchip fabrication to medical applications including contact

lenses and the lining of the lung. Their work has produced and inspired more than sixty papers in connection with the project. The group's work is leading to improved mathematical and computational techniques for many industrial problems, while providing interdisciplinary training experiences for students and postdoctoral researchers.

- Zeta or L-functions are counting devices for the study of the distribution of prime numbers and related issues, and the first and most important example is the subject of the famous Riemann Hypothesis in number theory. An L-function has properties that yield valuable information even though values and roots of the function itself can be difficult to compute. Recent work has exposed ties between prime numbers and some very different objects: (a) statistics of zeros of L-functions seem to agree with statistics of very different objects computed in the physicists' random matrix theory, and (b) recent developments in geometry have established some of the links conjectured thirty years ago between number theoretic L-functions and linear representations of groups.

- Submicron-sized magnetic elements have found a wide range of applications, particularly as information storage, and are being explored as alternative random access memory devices. As the elements get smaller, the effect of thermal noise becomes more significant and the data retention time an increasing concern. It is expected that the limit below which thermal effects simply prevent data retention will affect the magnetic recording industry in the next five to ten years. Researchers from New York University and Princeton University have developed a technique for certain systems with computational advantages in terms of efficiency and flexibility.

- A researcher at the University of California has led a project to accurately predict wildfire hazard, to assess the uncertainty in these estimates and to determine how various meteorological and environmental variables are related. This has resulted in better ways of combining Burning Index (BI) records from different weather stations to obtain more accurate estimates of wildfire risk. Since the BI is used as a predictor, optimally using this information is critical.

The FY 2005 Budget Request of $202.25 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 is the Mathematical Sciences priority area investment of $67.39 million, which is maintained at the FY 2004 Estimate. The Mathematical Sciences priority area reflects the importance of the mathematical and statistical sciences in the kinds of crosscutting science and engineering research areas described above.

The FY 2005 increase in DMS will support:

- Maintaining the investment in focused mathematical sciences research teams, interdisciplinary training groups, and other collaborative mechanisms related to advancing science and engineering.

- Enhancement of the national institutes in the mathematical sciences that address the growing interface with other disciplines and the mathematical and statistical problems whose solutions will contribute to both fundamental knowledge and national needs.

- Enhancement of research training activities in the mathematical sciences and mentoring activities aimed at increasing the number of U.S. students choosing careers in the mathematical sciences. This will be achieved by redistributing funding of other targeted investments in people.

PHYSICS $235,760,000

The FY 2005 Request for the Physics Subactivity is $235.76 million, an increase of $8.09 million, or 3.6 percent, over the FY 2004 Estimate of $227.67 million.

Physics Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Physics	$224.50	227.67	235.76	$8.09	3.6%
Total, PHY	$224.50	$227.67	$235.76	$8.09	3.6%

The Physics Subactivity (PHY) supports fundamental research in a broad range of physical phenomena, including: 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, postdoctoral 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 Experiences 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 responsibility for experiments at national or international user facilities, such as the Large Hadron Collider (LHC) at CERN. 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, plasma physics, nucleosynthesis, and the structure and origin of matter, the latter at an HBCU (Historically Black College or University); and a Science and Technology Center (STC) in biophotonics.

A newly discovered double neutron star system has boosted predictions of rates for gravitational wave events for possible detection by LIGO. The first-known binary neutron star system, PSR 1913+16, yielded the first indirect detection of gravitational waves. To compensate for gravitational wave energy loss, the two neutron stars fall together and orbit faster. This system is thus a precursor of the coalescing

neutron star binaries that form a primary target for LIGO. The estimates of rates of such events within LIGO's range extrapolate from the number of precursors known in our own galaxy to the likelihood of more advanced systems in the galaxies accessible to LIGO. Recently, an international team of radio astronomers has discovered a new, closer, binary neutron star system, PSR J0737-3039, with even stronger gravitational effects. Vicky Kalogera, at Northwestern University, and her collaborators, calculated the implications of the new system for LIGO raising the predicted rates by a factor of 6 to 7 for the most optimistic estimates of events within LIGO's reach.

PHY oversees three major projects whose construction was or is expected to be funded through the Major Research Equipment and Facilities Construction (MREFC) Account. The ATLAS and CMS detectors for the LHC received construction funding from FY 1999 through FY 2003 (see the MREFC chapter for additional information). Partial operation of these LHC detectors is supported through the PHY Subactivity. LIGO, whose construction 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). Planning activities for the Rare Symmetry Violating Processes (RSVP) project will be undertaken in the PHY Subactivity in FY 2004 at the Likely Enacted level and this project is proposed in the MREFC Account in FY 2005 (see MREFC chapter for more information).

The recent National Research Council (NRC) report "Connecting Quarks with the Cosmos" provided major impetus to expand support of research on Physics of the Universe at the interface between physics and astronomy. Examples of areas to be emphasized in FY 2005 include: numerical relativity and theoretical cosmology, new activities to investigate dark energy, dark matter, neutrino physics, and cosmic microwave background radiation, and awards for additional new projects at the interface of physics and astronomy. Other subfields intended for emphasis include biological physics, computational physics, and nanoscale science. In concert with other MPS Subactivities, especially AST, PHY will continue its emphasis on 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.

The FY 2005 Request for PHY includes:

- An increase of $8.24 million in research projects and centers to a total of $142.38 million. PHY will continue to support forefront areas of physics, with expanded emphasis on projects at the interface between physics and astronomy as recommended in the NRC report "Connecting Quarks with the Cosmos." Additional areas slated for increases include biological physics, computational physics, and fundamental nanoscale studies. 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.

- A decrease of $1.30 million for facilities to a total of $78.35 million includes: an increase of $1.70 million for CESR operations to a total of $19.70 million, to enable exploration of critical weak and strong elementary particle interaction phenomena and to sustain important accelerator physics research activity at Cornell; an increase of $2.0 million for early operations of the LHC ATLAS and CMS detectors for a total of $9.0 million; continued support for full operations of LIGO and for advanced detector R&D at a total of $33.0 million; an increase of $1.0 million for operations of Michigan State University's National Superconducting Cyclotron Laboratory radioactive ion beam facility for a total of $16.65 million; and, a decrease of $6.0 million for planning activities for RSVP as funding for this construction project is requested through the MREFC Account in FY 2005.

MULTIDISCIPLINARY ACTIVITIES $31,050,000

The FY 2005 Budget Request for the Multidisciplinary Activities Subactivity is $31.05 million, an increase of $280,000, or 0.9 percent, over the FY 2004 Estimate of $30.77 million.

Multidisciplinary Activities
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Multidisciplinary Activities	27.34	30.77	31.05	0.28	0.9%
Total, OMA	$27.34	$30.77	$31.05	$0.28	0.9%

The Multidisciplinary Activities Subactivity (OMA) enables MPS support of novel, challenging, or complex projects of varying scale in both research and education that are not readily accommodated by traditional organizational structures and procedural 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 Very Energetic Radiation Imaging Telescope Array System (VERITAS), a multidisciplinary, ten-institution, two international-partner cooperative undertaking to develop an array of four twelve-meter aperture telescopes for the study of high energy gamma rays; the Atacama Cosmology Telescope (ACT), a multidisciplinary five-institution, multi-agency, international partnership to develop the capability to probe more deeply fundamental physics through observations of cosmic structure; and initial awards for the establishment of Physics Frontier Centers and for Undergraduate Research Centers in Chemistry.

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 for the new century 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 CHEPRO, the Inter-Regional Grid-Enabled Center for High Energy Physics Research and Educational Outreach at Florida International University, a multidisciplinary, multi-directorate cooperative activity that encompasses an integrated program of high energy physics research, network infrastructure development, and education and outreach at one of the largest minority-serving institutions in the U.S.; in the Grant Opportunities for Academic Liaison with Industry (GOALI) program; and in the U.S.-Europe and U.S.-Americas cooperative international research and research training activities in materials research.

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 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 support for Research Experiences for Teachers (RET), which provides in-service and pre-service K-12 teachers with discovery-based learning experiences in the MPS disciplines and which has benefited more than one thousand K-12 teachers since its inception in FY 1999; support, in partnership with the Education and Human Resources Activity (EHR), of the 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 preparing graduate students, postdoctoral researchers, and current faculty to meet the challenges of STEM higher education; support, in partnership with both the Biological Sciences and the EHR Activities, of multidisciplinary activities to enrich the mathematical sciences content of the undergraduate curriculum in the biological sciences as well as the biological sciences content of the undergraduate curriculum in the mathematical sciences; 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 2005, OMA will continue to work with other MPS Subactivities and programs across the Foundation with an emphasis on fundamental research on physics of the universe and on fundamental research on the molecular basis of life processes.

The FY 2005 Budget Request includes:

- Support for the Research Experiences for Teachers (RET) program that will be increased by $500,000 to $2.50 million. In partnership with the EHR Activity, an assessment of the impact of this program will be carried out.

- Increased support for the GK-12 program in the amount of $100,000 to a total of $2.50 million.

- Support for research partnerships with the other MPS Subactivities that attract and retain individuals from traditionally underrepresented groups into doctoral programs in the MPS disciplines will be increased by $250,000 to a total of $1.25 million.

- Support of cooperative international research and training activities will be increased by $350,000 to enhance the global competitiveness of U.S. scientists, engineers, and students. Activities such as the MPS Distinguished International Postdoctoral Research Fellowship program 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.

- Support for activities that draw upon the extensive MPS research investment for public science education will be increased by $600,000 to a total of $3.30 million. 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.

- 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 made at the level of $1.0 million. Such instrumentation integrates modeling, computation and measurement to enable fundamental advances and broad training across a wide spectrum of disciplines.