

Mathematical Sciences in the FY 2007 Budget

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HIGHLIGHTS

- Federal support for the mathematical sciences is slated to grow from an estimated \$384.00 million in FY 2006 to an estimated \$396.34 million in FY 2007, an increase of 3.2 percent.
- The National Science Foundation's (NSF) Division of Mathematical Sciences (DMS) would increase by 3.2 percent to \$205.74 million.
- The aggregate funding for the mathematical sciences in the Department of Defense (DOD) agencies (Air Force Office of Scientific Research (AFOSR), Army Research Office (ARO), Defense Advanced Project Agency (DARPA), National Security Agency (NSA), and Office of Naval Research (ONR)) would increase by 8.5 percent. The majority of this increase comes from two agencies, AFOSR (15.6 percent) and DARPA (9.1 percent).

INTRODUCTION

Research in the mathematical sciences is funded through the National Science Foundation, the Department of Defense (including the National Security Agency), the Department of Energy (DOE), and the National Institutes of Health (NIH). As in previous years, the majority of federal support for the mathematical sciences in FY 2007 would come from the NSF, contributing approximately 51.9 percent of the federal total. The DOD accounts for around 20.9 percent of the total, with the NIH supplying 19.8 percent, and the DOE around 7.4 percent. NSF currently accounts for almost 80 percent of the federal support for academic research in the mathematical sciences and is the only agency that supports mathematics research broadly across all fields. DOD, DOE, and

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NIH support research in the mathematical sciences that contributes to the missions of these agencies.

DOD supports mathematical sciences research and related activities in several programs: the Directorate of Mathematics and Information Sciences within the AFOSR; the Mathematical Sciences Division within the ARO; the Mathematical, Computer, and Information Sciences Division within the ONR; the Defense Sciences Program and the Microsystems Technology Office within DARPA; and the Mathematical Sciences Program within the NSA.

The DOE funds mathematics through its Applied Mathematics program within the DOE Mathematical, Information and Computational Sciences program. The National Institutes of Health funds mathematical sciences research primarily through the National Institute of General Medical Sciences (NIGMS) and through the National Institute of Biomedical Imaging and Bioengineering (NIBIB).

Several other agencies have small amounts of funding for mathematics research as it relates to agency missions. These agencies include the National Aeronautics and Space Administration (NASA), the Environmental Protection Agency (EPA), and the National Institute of Standards and Technology (NIST).

TRENDS IN FEDERAL SUPPORT FOR THE MATHEMATICAL SCIENCES

The FY 2007 estimated aggregate spending for mathematical sciences research and related activities would be \$396.34 million, a potential increase of 3.2 percent over FY 2006 estimated spending. The NSF Division of Mathematical Sciences budget would increase by 3.2 percent in FY 2007, while the DOD agencies would increase by 8.5 percent for FY 2007. AFOSR surprises with a 15.6 percent increase, while DARPA increases by 9.1 percent. The remaining DOD agencies would essentially have no growth in FY 2007. All other agencies would remain level or decrease slightly.

The mathematical sciences are making major contributions to the country's intellectual capacity and the need for results from the mathematical sciences in scientific discovery and technological innovation is accelerating. Many disciplines depend on discoveries in the mathematical sciences to open up new frontiers. Mathematical sciences

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research supports new results in the life and social sciences as well as more traditional fields, such as the physical sciences, computer science, geosciences, and engineering.

Yet, even with this increasing need for mathematics, many mathematical scientists who are performing excellent research and who submit grant proposals deemed of very high quality, are consistently either not funded or are under funded. According to the *Science and Engineering Indicators*, 2006 Edition, in FY 2003, only 31.0 percent of full-time mathematical sciences faculty, having doctoral degrees, received federal research support. This is much lower than most other fields of science.

Table 1: Federal Funding for the Mathematical Sciences (millions of dollars) #

	FY 05 Actual	FY 06 Estimate	FY 07 Request	Change 06-07 Amount	Change 06-07 Percent
National Science Foundation					
DMS	200.24	199.30	205.74	6.44	3.2%
Department of Defense					
AFOSR	30.3	32.1	37.1	5.0	15.6%
ARO	10.0	10.0	10.0	0.0	0.0%
DARPA	19.2	16.5	18.0	1.5	9.0%
NSA	3.5	4.0	4.0	0.0	0.0%
ONR	<u>13.6</u>	<u>13.6</u>	<u>13.6</u>	0.0	0.0%
Total DOD	<u>76.6</u>	<u>76.2</u>	<u>82.7</u>	6.5	8.5%
Department of Energy					
Applied Mathematics	29.6	29.4	29.5	0.1	0.3%
National Institutes of Health					
NIGMS	35.0	38.0*	38.0*	0.0	0.0%
NIBIB	<u>38.2</u>	<u>41.1</u>	<u>40.4</u>	-0.7	-1.7%
Total NIH	<u>73.2</u>	<u>79.1</u>	<u>78.4</u>	-0.7	-0.9%
Total All Agencies	<u>379.64</u>	<u>384.00</u>	<u>396.34</u>	12.34	3.2%

* Estimates based on conversation with program officer.

Budget information comes from agency documents and conversations with program managers and representatives.

National Science Foundation (NSF): The Division of Mathematical Sciences (DMS),¹ is housed in the NSF Directorate of the Mathematical and Physical Sciences (MPS). This directorate also contains the Divisions of Astronomical Sciences, Chemistry, Materials Research, Physics, and Multidisciplinary Activities. The DMS supports advances in the intellectual frontiers of the mathematical sciences, activities contributing to advancing knowledge in other scientific and engineering fields, and research that is critical to national competitiveness.

The mathematical sciences would continue to be an NSF-wide priority area in FY 2007, the last year of this five-year designation. The Foundation has budgeted \$78.45 million to carry out the priority area activities in FY 2007, with \$69.26 million of this amount coming from the DMS and the remaining \$9.19 million coming from throughout the Foundation. The NSF-wide allocation (\$9.19 million) depends on cooperative funding opportunities with other NSF directorates and requires matching funds from the DMS. The mathematical sciences were first designated an NSF priority area in FY 2003. In 2003, the Mathematical Sciences Priority Area was projected to receive \$109.50 in the FY 2007 budget. The current budget environment has severely curtailed this Priority Area.

The DMS is slated to receive a budget of \$205.74 million in FY 2007. This 3.2 percent increase is the first increase in the DMS budget since FY 2004. The DMS budget has increased \$26.95 million since FY 2003, the first year the mathematical sciences was designated a priority area, and when the DMS budget was \$178.79 million. The DMS budget increased \$21.56 million or 12.1 percent from FY 2003 to FY 2004 with the last increase of \$5.39 million to come in the FY 2007 budget. The FY 2007 MPS budget is slated for a 6.0 percent increase over FY 2006.

The DMS has essentially two modes of support: research and education grants, and institutes. Grants include individual-investigator awards, awards for multidisciplinary groups of researchers, and educational and training awards aimed at increasing the number of U.S. students choosing careers in the mathematical sciences. The DMS provides core support for five mathematical sciences research institutes as well as major support for three other institutes. These institutes, funded on a competitive basis, serve to develop new ideas and directions in the

¹ <http://www.nsf.gov/div/index.jsp?div=DMS>

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mathematical sciences, as well as to promote interaction with other disciplines.

For FY 2007, the DMS has the following priorities:

- Maintaining a strong program of research grants, both single investigator and small group research grants;
- Investing in algorithm development and computational tools for large-scale problems of scientific importance;
- Broadening participation in the mathematical sciences;
- Maintaining research training activities in the mathematical sciences;
- Continuing support for the Mathematical Sciences Priority Area, while initiating the mainstreaming of its activities in the DMS portfolio.

Air Force Office of Scientific Research (AFOSR):² The Directorate of Mathematics and Information Sciences provides funds for research in the mathematical sciences in support of the Air Force mission. The AFOSR mathematics program includes specific portfolios in dynamics and control, physical mathematics and applied analysis, computational mathematics, optimization and discrete mathematics, electromagnetics, and signals communication and surveillance. Current areas of interest include cooperative/collaborative control of a team of unmanned aerial vehicles conducting operations; innovative methods and algorithms that improve modeling and simulation capabilities that will enable understanding, prediction, and control of complex physical phenomena crucial to the Air Force; the development of accurate models of physical phenomena that enhance the fidelity of simulation; and the development of resilient algorithms for data representation in fewer bits, image reconstruction/enhancement, and spectral/frequency estimation in the presence of external corrupting factors. The AFOSR budget would increase 15.6 percent over FY 2006.

Army Research Office (ARO): The Mathematics Program,³ housed in the Mathematical Sciences and Information Sciences Division, manages the following programs: modeling of complex systems; computational

² See the AFOSR web site <http://www.afosr.af.mil>

³ <http://www.arl.army.mil/main/main/default.cfm?Action=29&Page=194>

mathematics; discrete mathematics and computer science; probability and statistics and stochastic analysis; and cooperative systems. The Mathematical Sciences Division plays an essential role in the modeling, analysis, and control of complex phenomena and large-scale systems which are of critical interest to the Army. The areas of application include wireless communication networks, image analysis, visualization and synthetic environments, pattern recognition, test and evaluation of new systems, sensor networks, network science, and autonomous systems. The division also works closely with the Computer and Information Sciences Division of ARO to develop mathematical theory for systems control, information processing, information assurance, and data fusion. The FY 2007 budget for the Mathematical Sciences Division remains at the FY 2006 level.

Defense Advanced Research Projects Agency (DARPA): The Defense Sciences Office (DSO) inside DARPA has a mathematics program encompassing both Applied and Computational Mathematics and Fundamental Mathematics.⁴ The thrusts of DSO's programs are structured around focused initiative areas in interdisciplinary and core mathematics. Current program areas include: Discovery and Exploitation of Structure in Algorithms, Femtosecond Adaptive Spectroscopy Techniques for Remote Agent Detection, Geospatial Representation and Analysis, Integrated Sensing and Processing, Mathematical Time Reversal, Predicting Real Optimized Materials, Protein Design Processes, Quantum Information Science and Technology, Robust Uncertainty Management, Stochastic and Perturbation Methods in PDE Systems, and Waveforms for Active Sensing as well as Focus Areas in Theoretical Mathematics, Fundamental Laws of Biology, and Topological Data Analysis. The Microsystems Technology Office has several programs where mathematical algorithms play a central role in the optimization, control, and exploitation of microelectronic and optical systems.⁵ These include the Analog-to-Information program, the Multiple Optical Non-redundant Aperture Generalized Sensors program and the Non-Linear Mixed Signal Microsystems program. The DARPA mathematics budget would increase by 9.1 percent over FY 2006.

Department of Energy (DOE): Mathematics is funded through the Applied Mathematics program of the Mathematical, Information, and

⁴ <http://www.darpa.mil/dso/thrust/math/math.htm>

⁵ <http://www.darpa.mil/mto/People/PMs/healy.html>

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Computational Sciences Division (MICS) of DOE.⁶ Research is conducted on the underlying mathematical understanding of physical, chemical, and biological systems and advanced numerical algorithms that enable effective description, modeling, and simulation of such systems on high-end computing systems. Research in applied mathematics supported by MICS underpins computational science throughout the DOE. The Applied Mathematics program supports work in a wide variety of areas of mathematics, including: ordinary and partial differential equations, numerical linear algebra, fluid dynamics, optimization, mathematical physics, control theory, accurate treatment of shock waves, mixed elliptic-hyperbolic systems, and dynamical systems.

The FY 2007 budget for the Applied Mathematics Program increases the Computational Sciences Fellowship program by \$ 500,000 to \$4 million. The FY 2007 budget also includes \$8.5 million, the same as for FY 2006, for the Atomic to Macroscopic Mathematics (AMM) effort which provides the research support in applied mathematics needed for understanding complex physical processes that occur on a wide range of interacting length- and time-scales. The AMM effort supports university researchers, partnerships between universities and national laboratories, and multidisciplinary research teams at national laboratories. The FY 2007 Applied Mathematics budget would increase by 0.3 percent over FY 2006.

National Institutes of Health (NIH): The NIH funds mathematical sciences research through the National Institute of General Medical Sciences (NIGMS) and the National Institute of Biomedical Imaging and Bioengineering (NIBIB). Mathematical sciences areas of interest are those that support the missions of NIGMS and NIBIB. Currently NIGMS is supporting a biomathematics initiative in cooperation with the National Science Foundation and NIBIB is participating in a joint initiative with the NSF and other NIH institutes, “Collaborative Research in Computational Neuroscience.” The aggregate budget for the mathematical sciences in NIBIB and NIGMS would decline by 0.9 percent, in FY 2007.

National Security Agency (NSA): The Mathematical Sciences Program of the NSA administers a Grants Program that supports fundamental research in the areas of algebra, number theory, discrete mathematics,

⁶ <http://www.science.doe.gov/ascr/mics>

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probability, and statistics. The Grants Program also accepts proposals for conferences and workshops in these research areas. In addition to grants, the Mathematical Sciences Program supports an in-house faculty Sabbatical Program. The program administrators are especially interested in funding initiatives that encourage the participation of underrepresented groups in mathematics (such as women, African-Americans, and other minorities). NSA is the largest employer of mathematicians in the United States. As such, it has a vested interest in maintaining a healthy academic mathematics community in the United States.⁷ The NSA mathematics budget would remain unchanged for FY 2007.

Office of Naval Research (ONR): The ONR Mathematical, Computer, and Information Research Division's scientific objective is to establish rigorous mathematical foundations and analytical and computational methods that enhance understanding of complex phenomena, and enable prediction and control for Naval applications in the future. Basic research in the mathematical sciences is focused on analysis and computation for multi-phase, multi-material, multi-physics problems; predictability of models for nonlinear dynamics; electromagnetic and acoustic wave propagation; signal and imaging processing; modeling pathological behaviors of large, dynamic complex networks and exploiting hybrid control to achieve reliability and security; optimization; and formal methods for verifiably correct software construction.⁸ The Mathematical, Computer, and Information Sciences Division's budget would remain unchanged in FY 2007.

Note: Information gathered from agency documents and from agency representatives.

⁷ For more information, see the website <http://www.nsa.gov/msp/index.cfm>

⁸ For more information see the website, http://www.onr.navy.mil/sci_tech/31/311/default.asp