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Mathematical Sciences in the FY 2008 Budget

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Highlights

x Federal support for the mathematical sciences is slated to grow from an estimated $415.84 million in FY 2007 to an estimated $454.17 million in FY 2008, an increase of 9.2 percent.

x The National Science Foundation's (NSF) Division of Mathematical Sciences (DMS) would increase by 8.6 percent to $223.47 million.

x 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 Research Project Agency (DARPA), National Security Agency (NSA), and Office of Naval Research (ONR)) would increase by 10.0 percent. The majority of this increase comes from DARPA (50.0 percent).

Introduction

Research in the mathematical sciences is funded primarily 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 2008 would come from the NSF, contributing approximately 49.2 percent of the federal total. The DOD accounts for around 20.7 percent of the total, with the NIH supplying 17.7 percent, and the DOE around 12.4 percent. The NSF currently accounts for almost 80.0 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. The DOD, DOE, and NIH support research in the mathematical sciences that contributes to the missions of these agencies.

The DOD supports mathematical sciences research and related activities in several programs: the Directorates of Mathematics, Information, and Life Sciences and Physics and Electronics, within the AFOSR; the Mathematical and Information Sciences Division within the ARO; the Mathematics, Computers, and Information Sciences Research 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 subprogram. 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).

Trends in Federal Support for the Mathematical Sciences

The FY 2008 estimated aggregate spending for mathematical sciences research and related activities would be $454.17 million, a potential increase of 9.2 percent over FY 2007 estimated

spending. The NSF Division of Mathematical Sciences budget would increase by 8.6 percent in FY 2008, while the DOD agencies would increase by 10.0 percent for FY 2008. DARPA increases its mathematical sciences spending by 50.0 percent while ARO mathematics budget decreases by 14.3 percent. The remaining DOD agencies would essentially have little or no growth in FY 2008. The DOE mathematical sciences budget increases by 15.9 percent while the NIH funding increases by 5.7 percent.

The mathematical sciences make major contributions to the country's intellectual capacity and the need for results from the mathematical sciences in scientific discovery and technological innovation is on an accelerating pace. Many disciplines depend on discoveries in the mathematical sciences to open up new frontiers. Even so, 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.

Insert Table 1. Here

National Science Foundation (NSF): The Division of Mathematical Sciences (DMS), http://www.nsf.gov/div/index.jsp?div=DMS, 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 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 mathematical sciences, as well as to promote interaction with other disciplines.

The DMS is slated to receive a budget of $223.47 million in FY 2008, an increase of $17.73 million or 8.6 percent over the FY 2007 budget. The $17.73 million is broken down as follows: $7.30 million for core programs; $5.20 million for Cyber-enabled Discovery and Innovation (CDI), and NSF-wide initiative; $1.50 million for Science Beyond Moore's Law, an MPS initiative; $1.0 million for discovery-based undergraduate experiences; and $2.73 million for mathematical sciences institutes and networks.

The mathematical sciences designation as an NSF priority area ended in the FY 2007 budget. The FY 2008 MPS budget reflects spending of $6.62 million for continuing priority area awards made in prior years. Other components of the priority area investment will return to core programs for continued support.

For FY 2008, the DMS has several priorities. Core support for the mathematical sciences includes individual investigator awards, support for graduate and postdoctoral students within individual awards, and investments in formal interdisciplinary partnerships. The objective of CDI is to

broaden the nation's capability for innovation through the development of a new generation of computationally based discovery concepts and tools that can deal with complex, data-rich systems. Areas of emphasis for the mathematical sciences include algorithm development and computational tools for large-scale problems of scientific importance, modeling of phenomena that occur over a large range of spatial and temporal scales, and finding patterns in the structure of large data sets. Going beyond Moore's law will require algorithms that increase the speed of basic computations exponentially in concert with hardware improvements. Emphasis will include algorithm design, analysis, and implementation; scalability in space and time; quantification of errors and uncertainty in visualization of large data sets. Broadening participation in the mathematical sciences will support interactions and research networks among a diverse population, including students and researchers at a wide array of institutions. Education and training activities include research experiences and mentoring activities aimed at increasing the number of U.S. students choosing careers in the mathematical sciences.

Air Force Office of Scientific Research (AFOSR): Funding for the mathematical sciences at AFOSR is found in the Directorates of Mathematics, Information, and Life Sciences and Physics and Electronics. 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; improved mathematical methods and algorithms that exploit advanced computational capabilities in support of Air Force computing interest; 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. See the website http://www.afosr.af.mil. The AFOSR FY 2008 budget for the mathematical sciences would increase 2.8 percent over FY 2007.

Army Research Office (ARO): The Mathematics Program, housed in the Mathematical and Information Sciences Division, http://www.arl.army.mil/main/main/default.cfm?Action=29&Page=194, manages the following programs: modeling of complex systems; computational 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, robotics, 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 2008 budget for the Mathematical Sciences Division is $12 Million. The ARO budget would decrease by 14.3 percent from FY 2007.

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, http://www.darpa.mil/dso/thrust/math/math.htm. 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, 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, Sensor Topology and Minimal Planning, 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, http://www.darpa.mil/MTO/personnel/healy_d.html. These include the following programs: Analog-to-Information, Cognitively Augmented Design for Quantum Technology, Multiple Optical Non-redundant Aperture Generalized Sensors, Non-Linear Mixed Signal Microsystems, and Space-Time Adaptive Processing. The DARPA mathematics budget would increase by 50.0 percent over FY 2007.

Department of Energy (DOE): Mathematics at DOE is funded through Advanced Scientific Computing Research Program (ASCR) under its sub-program, Mathematical, Information, and Computational Sciences Division (MICS), http://www.science.doe.gov/ascr/mics. Funding for the mathematical sciences is found in the Applied Mathematics activity, the Scientific Discovery through Advanced Computing (SciDAC) activity, the Scientific Applications Partnerships activity, and the Open Science Grid. The Applied Mathematics activity supports research 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. Applied Mathematics 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 2008 Applied Mathematics activity budget includes increased support for mathematical research issues relevant to petascale science (+ $2 million), research in optimization control and risk analysis in complex systems (+ $1.9 million), support for multiscale mathematics (+ $2.5 million), and funding for the Computational Science Graduate Fellowship Program (+ $1.0 million). Support for multiscale mathematics is $11 million in FY 2008. Around eight percent of ASCR's budget goes to university based research. The DOE FY 2008 budget for the mathematical sciences will increase by 15.9 percent over FY 2007.

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 at around $12 million year 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 5.7 percent in FY 2008.

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, 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. For more information, see the website http://www.nsa.gov/msp/index.cfm**.** The NSA mathematics budget would remain unchanged for FY 2008

Office of Naval Research (ONR): The ONR Mathematics, Computers, 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. For more information see the website, http://www.onr.navy.mil/sci_tech/31/311/default.asp. The Mathematical, Computer, and Information Sciences Division's budget would remain unchanged in FY 2008

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

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

	FY 06 Actual	FY 07 Estimate	FY 08 Request	Change 2007-08 Amount	Change 2007-08 Percent
National Science Foundation					
DMS	199.52	205.74	223.47	17.73	8.6 %
Department of Defense					
AFOSR	32.1	36.0	37.6	1.6	2.8
ARO	14.0	14.0	12.0	-2.0	- 14.3
DARPA	16.0	18.0	27.0	9.0	50.0
NSA*	4.0	4.0	4.0	0.0	0.0
ONR*	13.6	13.6	13.6	0.0	0.0
Total DOD	79.7	85.6	94.2	8.6	10.0
Department of Energy**					
Applied Mathematics	32.0	29.5	36.9	7.4	25.1
SciDAC	2.7	10.0	10.0	0.0	0.0
SAPs	1.0	7.6	7.9	0.3	3.9
OSG	.8	1.3	1.3	0.0	0.0
Total DOE	36.5	48.4	56.1	7.7	15.9
National Institutes of Health					
NIGMS	38.0	38.0	42.0	4.0	10.5
NIBIB	38.7	38.1	38.4	0.3	0.8
Total NIH	76.7	76.1	80.4	0.3	0.4
Total All Agencies	392.42	415.84	454.17	38.33	9.2

*Estimates based on previous budgets.
Budget information is derived from agency documents and conversations with agency program managers and representatives.
** Scientific Discovery through Advanced Computing (SciDAC); Scientific Applications Partnerships (SAPs); Open Science Grid (OSG)