Mathematical Sciences in the FY 2010 Budget

Samuel M. Rankin III

Highlights

• Federal support for the mathematical sciences is slated to grow from an estimated US$509.73 million in FY 2009 to an estimated US$536.69 million in FY 2010, an increase of 5.3 percent.

• The National Science Foundation's (NSF) Division of Mathematical Sciences (DMS) would increase by 8.9 percent to US$246.41 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 Research Project Agency (DARPA), National Security Agency (NSA), and Office of Naval Research (ONR) would decrease by 0.1 percent from FY 2009.

• The aggregate funding for the mathematical sciences in the Department of Energy (DOE) would increase by approximately 6.4 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, and the National Institutes of Health (NIH). As in previous years, the majority of federal support for the mathematical sciences in FY 2010 would come from the NSF, contributing approximately 45.9 percent of the federal total. The DOD accounts for around 19.8 percent of the total and the DOE 18.3 percent, with NIH supplying around 16.0 percent. The NSF currently accounts for over 60 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.

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

DOE funds mathematics through its Applied Mathematics and Scientific Discovery through Advanced Computing (SciDAC) programs within the DOE Office of Advanced Scientific Computing Research. 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 2010 estimated aggregate spending for mathematical sciences research and related activities would be US$536.69 million, a potential increase of 5.3 percent over FY 2009 estimated spending. The NSF Division of Mathematical Sciences budget would increase by 8.9 percent in FY 2010, while the DOD agencies would decrease by 0.1 percent from FY 2009. ONR increases its spending for the mathematical sciences by 8.1 percent, while AFOSR increases its spending by 5.0 percent, and ARO's mathematics budget decreases by 6.4

Samuel M. Rankin III is director of the AMS Washington office. His email address is smr@ams.org.

This article is a slightly revised version of a chapter about federal funding in the mathematical sciences in AAAS Report XXXIII, Research & Development FY 2010, published by the American Association for the Advancement of Science. The report is available on the Web at http://www.aaas.org/spp/rd/.

percent. The mathematical sciences budget of DARPA decreases by 15.5 percent from FY 2009, and the NSA mathematics budget is flat. The DOE mathematical sciences budget increases by 6.4 percent, while NIH funding grows by 1.2 percent.

The mathematical sciences make major contributions to the country's intellectual capacity and provide the tools, insight, and capability needed for innovation and technological progress. Many disciplines depend on research in the mathematical sciences to open up new frontiers and advance discovery. Mathematical sciences research contributes to advances in areas such as medicine, cyber security, weather prediction, digital data compression and mining, aeronautics, and computing, to name a few. 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 underfunded. According to the Science and Engineering Indicators, 2008 Edition, in FY 2006, only 34.6 percent of full-time mathematics faculty having doctoral degrees received federal research support. This is much lower than most other scientific fields.

The American Recovery and Reinvestment Act of 2009 (ARRA) provided the NSF Division of Mathematical Sciences with an additional US$98.00 million over the FY 2009 appropriated amount. This enabled the division to provide support for deserving investigators who, because of lack of funds, were not supported in the past. Many of the researchers supported via Recovery funds are in the early stages of their careers. If the NSF budget, and consequently the DMS budget, fails to grow adequately in the future, the ability to support more high-quality mathematical researchers will severely diminish.

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 and enables the advance of knowledge in other scientific and engineering fields.

DMS has essentially two modes of support: (1) research and education grants, and (2) institutes. Grants include individual-investigator awards; awards for groups of researchers, including multidisciplinary; educational and training awards aimed at increasing the number of U.S. students choosing careers in the mathematical sciences. 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. Usually 53 percent of the DMS budget is available for new research grants and the remaining 47 percent is used primarily to fund continuing grants made in previous years.

DMS is slated to receive US$246.41 million in FY 2010, an increase of US$20.23 million or 8.9 percent over FY 2009 funding. During FY 2009, the current funding cycle for four of the mathematical sciences research institutes will end. These institutes can recompete as part of an Institute Solicitation that will be announced in FY 2010. The FY 2010 budget request can accommodate an increase in the number and size of institute awards. Four to six awards are expected as the DMS Institute budget climbs to US$26.00 million, an increase of US$6.0 million. Other programs slated to receive increases are Cyber-enabled Discovery and Innovation (CDI), +US$5.20 million to a total budget of US$10.40 million; Science and Engineering Beyond Moore's Law (SEBML), +US$2 million to US$2.75 million; Solar Energy Research (SOLAR), +US$1.70 million to US$2.40 million; and Climate Research (CR) will begin at US$1.85 million.

SEBML continues the algorithmic "Moore's Law", the exponential increase in speed of basic computations due to innovative new algorithms and new mathematical frameworks for computation. SOLAR will support multidisciplinary teams engaged in potentially transformative research on efficient harvesting, conversion, and storage of solar energy. CR will focus on development of mathematical methods and effective computational techniques needed for simulation and analysis of climate models.

Air Force Office of Scientific Research (AFOSR)

Funding for the mathematical sciences at AFOSR is found in the Directorate of Mathematics, Information, and Life Sciences and the Directorate of 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 sensing, surveillance, and navigation. For additional information on the focus areas within each of these portfolios, refer to the Broad Area Announcement 2009-1 which can be viewed on the AFOSR public website at http://www.afosr.af.mil. The AFOSR FY 2010 budget for the mathematical sciences would increase by 5.0 percent over FY 2009.

Army Research Office (ARO)

The Mathematics Program, housed in the 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 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 Computing Sciences Division and Network Science Division of ARO to develop mathematical theory for systems control, information processing, information assurance, network design, and data fusion. The Mathematics Program budget would decrease by 6.4 percent from FY 2009.

Defense Advanced Research Projects Agency (DARPA)

The Defense Sciences Office (DSO) and the Microsystems Technology Office (MTO) inside DARPA both have mathematics programs cutting across mathematics and its applications. Current program areas include twenty-three mathematical challenges, analog-to-information, cognitively augmented design for quantum technology, discovery and exploitation of structure in algorithms, focus areas in theoretical mathematics, fundamental laws of biology, multiple optical non-redundant aperture generalized sensors, nonlinear mathematics for mixed signal microsystems, sensor topology and minimal planning, space-time adaptive processing, and topological data analysis. Further details can be found at `http://www.darpa.mil/dso/personnel/mann.htm`; `http://www.darpa.mil/dso/personnel/singpurwalla.htm`; and `http://www.darpa.mil/MTO/personnel/healy_d.html`. The aggregate DARPA mathematics budget decreases by 15.5 percent from FY 2009.

Department of Energy (DOE)

Mathematics at DOE is funded through the Office of Advanced Scientific Computing Research (ASCR), `http://www.science.doe.gov/ascr/`, one of six interdisciplinary research offices within DOE's Office of Science. Research supported by ASCR

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

	FY 08 Actual	FY 09 Plan	FY 09 ARRA	FY 10 Request	Change 2009–10 Amount	Change 2009–10 Percent
National Science Foundation						
DMS	211.75	226.18	98.00	246.41	20.23	8.9%
Department of Defense*						
AFOSR	36.60	47.60	00.00	50.00	2.40	5.0
ARO	12.00	12.50	00.00	11.70	-0.80	-6.4
DARPA	18.60	21.78	00.00	18.40	-3.38	-15.5
NSA	4.00	4.00	00.00	4.00	0.0	0.0
ONR	13.60	20.35	00.00	22.00	1.65	8.1
Total DOD	84.80	106.23	00.00	106.10	-0.13	-0.1
Department of Energy						
Applied Mathematics	32.15	40.16	@	44.85	4.69	11.7
SciDAC**	54.05	52.06	@	53.24	1.18	2.3
Total DOE	86.20	92.22		98.09	5.87	6.4
National Institutes of Health						
NIGMS*	45.00	47.00	@	47.00	0.00	0.00
NIBIB*	38.10	38.10	@	39.09	0.99	2.6
Total NIH	83.10	85.10		86.09	0.99	1.2
Total All Agencies	465.85	509.73	98.00	536.69	26.96	5.3

#Budget information is derived from agency documents and conversations with agency program managers and representatives.

**Estimates.*

***Scientific Discovery through Advanced Computing (SciDAC).*

@Unavailable at time of writing.

underpins computational science throughout DOE. ASCR funding for the mathematical sciences is found primarily in the Applied Mathematics program and the Scientific Discovery through Advanced Computing (SciDAC) program. The Applied Mathematics activity supports the research, development, and application of applied mathematical models, methods and algorithms to understand complex physical, chemical, biological, and engineered systems related to the department's mission. For example, the topics of supported research efforts include (1) numerical methods for the solution of systems of partial differential equations, large-scale linear or nonlinear systems, or very large parameter-estimation problems; (2) analytical or numerical techniques for modeling complex physical, biological or engineered phenomena, such as fluid turbulence, microbial populations, or network systems; (3) analytical or numerical methods for bridging a broad range of temporal and spatial scales; (4) optimization, control, and risk analysis of complex systems, such as computer networks and electrical power grids; and (5) mathematical research issues related to analysis of petascale data. The FY 2010 Applied Mathematics program budget will support the long-term cybersecurity and complex network systems challenges of open science that was transferred from Next Generation Networking for Science initiated in FY 2009 and will also support a new fellowship program for graduate students and young investigators in applied mathematics and high-performance computer science. In FY 2010 the Computational Partnerships activity will support a small number of new interdisciplinary teams focused on transforming critical DOE applications for extreme scale computing. These competitively selected teams will evaluate the impact of directions in computer hardware on application capability. They will form a critical interface to existing SciDAC Centers and Institutes on the tool and library implications of these developments and develop the understanding needed to enable these applications to execute effectively on future computer architectures. Aggregate funding for the mathematical sciences would increase by 6.4 percent over FY 2009.

National Institutes of Health (NIH)

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. The NIGMS Center for Bioinformatics and Computational Biology supports research in areas that join biology with the computer sciences, engineering, mathematics, and physics. The Center manages programs in computational biology, such as the generation of mathematical models of biological networks, the development of modeling and simulation tools, the conduct of basic theoretical studies related to network organization and dynamic processes, and the development of methods for the analysis and dissemination of computational models. NIGMS is currently supporting a biomathematics initiative at around US$12 million per year in cooperation with the National Science Foundation. NIBIB supports the mathematical sciences through its Mathematical Modeling, Simulation and Analysis Program Area. The aggregate budget for the mathematical sciences in NIBIB and NIGMS would increase by 1.2 percent over FY 2009.

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). As the largest employer of mathematicians in the United States, NSA 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 from FY 2009.

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 multiphase, multimaterial, multiphysics problems; predictability of models for nonlinear dynamics; electromagnetic and acoustic wave propagation; signal and image analysis and understanding. Also of interest are modeling pathological behaviors of large, dynamic complex networks and exploiting hybrid control to achieve reliability and security; optimization; 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 increase by 8.1 percent over FY 2009.

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