Mathematical Sciences in the FY 2011 Budget

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Highlights

• Federal support for the mathematical sciences is slated to grow from an estimated US$537.36 million in FY 2010 to an estimated US$558.34 million in FY 2011, an increase of 3.9 percent.

• The National Science Foundation's (NSF) Division of Mathematical Sciences (DMS) would increase by 5.0 percent to US$253.46 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 increase by 4.9 percent from FY 2010.

• The aggregate funding for the mathematical sciences in the Department of Energy (DOE) would increase by approximately 0.7 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 2011 would come from the NSF, contributing approximately 45.4 percent of the federal total. The DOD accounts for around 20.4 percent of the total, the DOE 17.7 percent, and NIH supplies around 16.5 percent. The NSF currently accounts for over 65 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 2011 estimated aggregate spending for mathematical sciences research and related activities would be US$558.34 million, a potential increase of 3.9 percent over FY 2010 estimated spending. The NSF Division of Mathematical Sciences budget would increase by 5.0 percent in FY 2011, while the DOD agencies would increase by 4.9 percent over FY 2010. AFOSR increases its spending by 14.1 percent, while ONR and ARO increase spending for the mathematical sciences by 4.5 and 4.2 percent, respectively. DARPA decreases by 21.2 percent, and NSA is flat. The DOE

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mathematical sciences budget increases by 0.7 percent, while NIH funding grows by 3.3 percent.

The American Recovery and Reinvestment Act of 2009 (ARRA) provided the NSF Division of Mathematical Sciences with an additional US$97.34 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 continue to support more high-quality mathematical researchers will severely diminish.

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 many areas, such as: medicine, cyber security, weather prediction, digital data compression and mining, aeronautics, and computing.

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. 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; and educational and training awards aimed at increasing the number of U.S. students choosing careers in the mathematical sciences. Each year, typically 60.0 percent of the DMS budget is available for new research grants, and the remaining 40.0 percent is used primarily to fund continuing grants made in previous years.

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

	FY 09	FY 10	FY 11 Request	Change 2010–11 Amount	Change 2010–11 Percent
National Science Foundation					
DMS*	322.18	241.38	253.46	12.08	5.0
Department of Defense*					
AFOSR	44.50	53.30	60.80	7.50	14.1
ARO	12.50	12.00	12.50	0.50	4.2
DARPA	20.78	17.52	13.80	-3.71	-21.2
NSA	4.00	4.00	4.00	0.00	0.0
ONR	22.60	22.00	23.00	1.00	4.5
Total DOD	104.38	108.81	114.10	5.29	4.9
Department of Energy					
Applied Mathematics	45.16	44.79	45.45	0.66	1.5
SciDAC**	59.70	53.29	53.30	0.01	0.0
Total DOE	104.86	98.08	98.75	0.67	0.7
National Institutes of Health					
NIGMS*	47.00	50.00	52.00	2.00	4.0
NIBIB*	38.10	39.09	40.03	0.94	2.4
Total NIH	85.10	89.09	92.03	2.94	3.3
Total All Agencies	616.52	537.36	558.34	20.98	3.9

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

**FY 2009 NSF-DMS budget includes US$97.34 million from American Reinvestment and Recovery Act.*

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

DMS is slated to receive US$253.46 million in FY 2011, an increase of US$12.08 million, or 5.0 percent over FY 2010 funding. Funding for core research will increase by US$13.55 million to a total of US$219.74 million. Other programs receiving increases are Climate and Energy Research (+ US$2.50 million to a total of US$9.50 million); Science and Engineering Beyond Moore's Law (SEBML) (+ US$1.20 million, total of US$3.95 million); MPS-Life Science Interface (+ US$2.39 million, total of US$2.39 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. As part of the Science, Engineering, and Education for Sustainability (SEES) portfolio, DMS will support development of potentially transformative mathematical, statistical, and computational methods needed for analysis and simulation of climate models and will increase its investment in the Solar Energy Initiative (SOLAR), a program supporting multidisciplinary teams engaged in research on the efficient harvesting, conversion, and storage of solar energy. MPS–Life Sciences supports potentially transformative research in mathematical and computational biology.

DMS will terminate these programs: Vertical Integration Research and Education (VIGRE); Proactive Recruitment in Introductory Science and Mathematics (PRISM); Scientific Computing Research Environments in the Mathematical Sciences (SCREMS); Interdisciplinary Grants in the Mathematical Sciences (IGMS); University-Industry Cooperative Research Programs in the Mathematical Sciences; and Computational Science Training for Undergraduates in the Mathematical Sciences (CSUMS). Savings from these programs will be reinvested in higher priority workforce and infrastructure programs.

Air Force Office of Scientific Research (AFOSR)

Portfolios for the mathematical sciences at AFOSR are 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, multiscale modeling, 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 Agency Announcement 2010–1 which can be viewed on the AFOSR public website at http://www.afosr.af.mil. The AFOSR FY 2011 budget estimate for mathematical sciences reflects an increase of 14.1 percent over FY 2010.

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, numerical analysis, probability and statistics, and biomathematics. 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, pattern recognition, test and evaluation of new systems, sensor networks, network science, autonomous systems, mathematics of biological 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 FY 2011 budget would increase by 4.2 percent over FY 2010.

Defense Advanced Research Projects Agency (DARPA)

The Defense Sciences Office, http://www.darpa.mil/dso/index.htm (DSO), and the Microsystems Technology Office (MTO), http://www.darpa.mil/mto/index.html, inside DARPA both have mathematics programs cutting across mathematics and its applications. Current programs include Focus Areas in Theoretical Mathematics; Mathematics of the Brain; Foundational Computer Science; Mathematical Challenges; and Nanostructure in Biology. The aggregate DARPA mathematics budget would decrease by 21.2 percent from 2010.

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 the interdisciplinary research offices within DOE's Office of Science. Research supported by ASCR 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, topics of supported research efforts include: (1) numerical methods research for equations related to problems such as wave propagation, electrodynamics, fluid flow, elasticity, and other natural or physical processes; (2) advanced linear algebra research for fast and efficient numerical solutions of linear algebraic equations that often arise when simulating physical processes; (3) computational meshing research for developing ways in which space can be broken up into regions, often geometrically complex, for

the purposes of simulation; (4) optimization research for mathematical methods for minimizing energy or cost, finding the most efficient solutions to engineering problems, or discovering physical properties and biological configurations; (5) mathematics for the analysis of extremely large datasets for identifying key features, determining relationships between these key features, and extracting scientific insights; and (6) mathematics of cyber security from a basic research perspective for addressing the understanding and discovery of anomalies in existing network data, modeling of large-scale networks, and understanding dynamics and emergent behavior on networks. SciDAC supports nine multi-institutional Centers for Enabling Technologies that are a focal point for bringing together a critical mass of leading experts from multiple disciplines to focus on key problems in a particular area such as performance, data management, optimization, or visualization. SciDAC also supports four multi-institutional institutes that are university-led centers of excellence which complement the efforts of the SciDAC Centers but with a role in the education and training of the next generation of computational scientists. Aggregate funding for the mathematical sciences would increase by 0.7 percent over FY 2010.

National Institutes of Health (NIH)

NIH funds mathematical sciences research through the National Institute of General Medical Sciences (NIGMS), http://www.nigms.nih.gov/About/Overview/cbcb.htm and the National Institute of Biomedical Imaging and Bioengineering (NIBIB), http://www.nibib.nih.gov/Research/ProgramAreas/MathModeling. 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 3.3 percent over FY 2010.

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/research/math_research/index.shtml. The NSA mathematics budget would remain unchanged from FY 2010.

Office of Naval Research (ONR)

The ONR Mathematics, Computers, and Information Sciences 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; and computational foundations for machine reasoning and intelligence to support integrated sensing, computing, communication/networking, and control of cyber-physical systems. For more information see the website, http://www.onr.navy.mil/sci_tech/31/311/default/asp. The Mathematics, Computers, and Information Sciences Research Division's budget would increase by 4.5 percent over FY 2010.

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