Mathematical Sciences in the FY 2001 Budget

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Overview

Galileo's famous description of the universe states that, "This grand book is written in the language of mathematics." In more ways today than Galileo could possibly have imagined, the universe teaches us mathematics everywhere we look with a scientific eye. Mathematicians are dedicated to discerning, understanding, and articulating the most basic patterns of nature. The powerful arguments and techniques they develop are not only beautiful but also incredibly useful in many different and unanticipated contexts. The phrase "do the math" has come to mean "figure it out" in almost any situation.

The United States benefits greatly from its world leadership in mathematics. However, independent reports warn that support for mathematics in this country has not kept pace relative to other disciplines and relative to other countries. The absolute totals for grants in this field always tend to be smaller than in the laboratory sciences, of course. Statistics prompting concern relate instead to the percentages of faculty and graduate students with federal support, the percentages of their research and development (R&D) expenses covered, and the percentage of American citizens entering and remaining in the field. Strong support for science generally, as reflected in the President's budget request this year, is the best way to make sure that mathematics remains in balance among the portfolio elements necessary for continued progress and prosperity.

The federal government, like the economy as a whole, depends on mathematics and mathematicians to pursue many critical activities and priorities. Multidisciplinary initiatives especially rely on the work of mathematicians to provide new and existing language for the chapters of Galileo's book that scientists are filling in on topics such as information technology, nanotechnology, genomics, and biocomplexity. Along with participating in targeted work like this, the field of mathematics is one where curiosity-driven, investigator-initiated, and peer-reviewed funding mechanisms have proven particularly appropriate and successful. Providing this kind of support is a public sector responsibility. Indeed, most research on mathematics takes place at institutions of higher education and in government laboratories. Mathematicians also perform valuable functions throughout the economy, but few private firms can afford to invest much in research whose benefits, though great in total, may be distributed too widely in space and time to be adequately rewarded by market mechanisms.

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Responsibility for the majority of mathematical research funding in the United States therefore rests on three federal agencies: the National Science Foundation (NSF), the Department of Defense (DoD), and the Department of Energy (DoE). NSF provides more than half of all federal support for the mathematical sciences and can focus more on basic research than can other mission agencies. Programs located in the Army, Navy, Air Force, and Defense Advanced Research Projects Agency (DARPA) at DoD together account for about a third of federal support for the mathematical sciences. DoE's Mathematical, Information, and Computational Sciences program makes up most of the rest of the dedicated spending on mathematics.

Other federal agencies, such as the National Aeronautics and Space Administration (NASA), the National Institutes of Health (NIH), the National Institute for Standards and Technology (NIST), the Department of Transportation (DoT), and the Environmental Protection Agency (EPA), are also involved with mathematics in many ways. For example, mathematical research at NIST focuses on "analytical and computational methods for solving scientific problems of interest to American industry," and NIH has begun facilitating grants that include support for mathematicians and other fundamental researchers. Because spending related to mathematical research at these agencies is generally integrated into other categories of work rather than budgeted as dedicated programmatic funds for mathematics, the scale of their support is difficult to estimate in advance. This article therefore focuses on explicit expenditure plans at NSF, DoD, and DoE.

Highlights

- The Division of Mathematical Sciences at the NSF requests $130.31 million, an increase of $23.92 million (22.5%) over FY 2000.
- Basic research accounts at the DoD would grow to $1.217 billion, an increase of 4.9% above the FY 2000 level of $1.161 billion.
- The DoE's Mathematical, Information, and Computational Sciences (MICS) program would increase by $50.6 million (42.5%), for a total of $169.7 million. The MICS request includes $33.05 million for applied mathematics research, an increase of $9.7 million or 41.5% over FY 2000.

FY 2001 R&D Funding Requests, by Agency

The table at the end of this article shows the FY 2001 budget request for the mathematical sciences research at NSF and for R&D at the DoD and DoE. Below are brief descriptions of each and the funding levels requested by the President.

National Science Foundation

NSF's Division of Mathematical Sciences (DMS) supports a wide range of projects aimed at developing and exploring the properties and applications of mathematical structures. Research sponsored by DMS is conducted in areas including analysis, geometry, topology, foundations, algebra, number theory, applied mathematics, statistics, probability, biomathematics, and computational mathematics, as well as various multidisciplinary areas. The FY 2001 budget request for the DMS is $130.21 million, an increase of $23.92 million or 22.5% over FY 2000. In its budget materials NSF states that "in FY 2001, mathematics will receive high priority within the Mathematical and Physical Sciences directorate. The mathematical sciences continue to play essential roles in both independent discovery and in support of other fields of research; indeed, mathematics forms the foundation of both today's and tomorrow's science, engineering, computation, and technology. The mathematical sciences—linked with science and engineering—provide the computation, visualization, algorithms, models, and theoretical tools of discovery." Of the $23.92 million increase, $17 million would be allocated to research grant awards, and $6.92 million would be provided to enhance support both for the Vertical Integration of Research and Education in the Mathematical Sciences (VIGRE) program and for research institutes.

Department of Energy

The Mathematical, Information, and Computational Sciences (MICS) program investigates the mathematical underpinnings of challenges that range from supercomputing to the human genome project and from chemical structures to mechanical engineering. The Applied Mathematics Program, for example, funds research in the mathematics of physical systems, optimization and mathematical programming, dynamical systems theory and chaos, geometric and symbolic computation, as well as numerical analysis and scientific computation. In FY 2001 the MICS program would be provided $169.68 million, an increase of $50.61 million or 42.5%. Applied mathematics research within MICS would receive $33.05 million, an increase of $9.7 million or 41.5%. Increases would go to the Computational Sciences Graduate Fellowship program and for the competitive selection of two "enabling technology" centers focused on algorithms and mathematical libraries for critical DoE applications on terascale computers.

Department of Defense

Because of the size of the DoD budget (which alone is nearly the same size as the rest of the federal discretionary budget), it is very difficult to determine the exact funding levels from year to year for mathematics-related programs within the DoD services and agencies. It is possible, however, to determine the funding levels for basic and applied research within the Army, Navy, Air Force, and DARPA. It is within these accounts that the vast majority of mathematics-related DoD research is funded.

Below is a brief discussion of the DoD research and development budget request, followed by descriptions of the mathematics-related funding provided by the various services, including the National Security Agency.

The administration's FY 2001 budget request for the DoD Research, Development, Training and Evaluation account (all categories) would be $37.9 billion, a decrease of approximately $400 million from the FY 2000 funding level of $38.3 billion (−1%). The President's request emphasizes information technology R&D, the government-wide nanotechnology initiative, counterproliferation R&D, and "protecting against 21st century threats."

Most university-based research is funded through the department's "6.1" or basic research accounts. Agency-wide, these 6.1 accounts would receive $1,217.4 million, an increase of 4.9% over the FY 2000 level of $1,160.9 million. Among the services' basic research programs, the Army 6.1 account would receive $201.0 million, a decrease of $3.4 million (−1.7%) over FY 2000. The Navy, which sponsors the largest basic research program, would receive $397.5 million, an increase of $23.2 million (6.2%). The Air Force basic research program would be cut from $213.8 million in FY 2000 to $206.1 million in FY 2001, a decrease of 3.6%. The Defense-wide basic research program, which includes funds for DARPA, would be funded at $412.8 million, an increase of $44.4 million (12.1%) over the FY 2000 appropriations.

The federal government, like the economy as a whole, depends on mathematics and mathematicians to pursue many critical activities and priorities.

The much larger applied research accounts at DoD—the so-called "6.2" programs—would receive a 7.8% decrease in FY 2001, from $3.410 billion in FY 2000 to $3.144 billion in FY 2001. Within these funds, the Army applied research program would be cut dramatically, from $790.9 million to $602.5 million (−23.8%); Navy applied research programs would decrease from $622.4 million to $527.1 million (−15.3%); the Air Force applied programs would decrease from $596.8 million to $590.3 million (−1.1%); and Defense-wide applied research programs would increase slightly from $1.400 billion to $1.424 billion (1.7%).

Defense Advanced Research Projects Agency (DARPA): The Applied and Computational Mathematics Program seeks to combine new mathematical techniques with high-performance computing hardware technology "to revolutionize the DoD's modeling and simulation capability" to improve over "previous methods such as engineering trial and error." Supported research focuses on developing new mathematical algorithms, such as those based on wavelets and partial differential equation techniques for image processing and data compression, as well as on control strategies for advanced materials processing.

Air Force Office of Scientific Research (AFOSR): The Directorate of Mathematics and Space Sciences is responsible for basic research in mathematical, computer, and space sciences. Many critical research activities are multidisciplinary and involve support from the other scientific directorates within AFOSR. For example, the control theory and mathematical modeling research supported by this directorate complements many structural, fluid mechanics, and propulsion research programs run by the Directorate of Aerospace and Materials Sciences. Mathematical research supported by the Air Force spans a range of fields, including, for example: optimization and discrete mathematics, including linear and nonlinear programming and computational geometry; physical mathematics and applied analysis, including nonlinear optics, the mathematics of materials, inverse problems, and theoretical fluid dynamics; signal processing, probability, and statistics, drawing on wavelet methods and reliability analysis; and computational mathematics using novel parallel computing, reliable numerical methods, and spectral techniques.

Army Research Office (ARO): Mathematical sciences play a key role in the analysis and modeling issues that arise in military science, engineering, and operations. For example, ARO explains that some promising approaches to computer vision for automatic target recognition require research in a wide range of mathematical areas including constructive geometry, numerical methods for stochastic differential equations, Bayesian statistics, tree-structured methods in statistics, probabilistic algorithms, and distributed parallel computation. ARO's Mathematics and Computer Science Division therefore attempts systematically to advance fundamental knowledge that relates to the Army's needs, supporting extramural basic research in applied analysis and physical mathematics; computational mathematics; stochastic analysis, applied probability, and statistics; systems and control; software and knowledge-based systems; and discrete mathematics and computer science. In particular, ARO supports several centers and institutes that fall under the University Research Initiative.

Office of Naval Research (ONR): The Mathematical, Computer, and Information Sciences Division, part of the ONR's Information, Surveillance, and Electronics Department, supports "fundamental investigations into mathematical foundations for models, computability, and processes." This includes research in the mathematical areas of applied analysis, discrete mathematics, numerical analysis, operations research, visualization, and probability and statistics in support of the naval mission. Applications range from enhancing surveillance techniques to improving human-computer interaction.

National Security Agency (NSA): By its own account, NSA is one of the largest employers of mathematicians in the U.S. and perhaps the world. Since 1987 the NSA Mathematical Sciences Program has funded critical mathematical research in the areas of algebra, number theory, discrete mathematics, probability, statistics, and cryptology. Using these techniques, mathematicians at NSA contribute directly to the two missions of the agency: while some "help design cipher systems that will protect the integrity of U.S. information systems, others search for weaknesses in adversaries' codes." For security reasons the NSA does not disclose the exact amounts it will spend, but the agency does state that it will continue to "vigorously" support mathematics research proposals.

Federal Support for R&D (in millions of dollars)

Agency	FY 2000 Estimate	FY 2001 Request	FY 00–01 % Change
National Science Foundation			
DMS	$ 106.29	$ 130.21	22.5
Department of Defense			
AFOSR Basic	213.8	206.1	−3.6
AFOSR Applied	596.8	590.3	−1.1
ARO Basic	204.4	201.0	−1.7
ARO Applied	790.9	602.5	−23.8
ONR Basic	374.3	397.5	6.2
ONR Applied	622.4	527.1	−15.3
Defense-wide Basic	368.4	412.8	12.1
Defense-wide Applied	1,400.0	1,424.0	1.7
Department of Energy			
MICS	119.1	169.7	42.5

Note: Budget request amounts for DoD programs supporting mathematical sciences research were not available at press time. To show general trends in R&D funding, the requested amounts for DoD funding programs across all areas of science are presented here.