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Mathematical Sciences in the FY 2001 Budget

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OVERVIEW

Mathematical research studies the logical structures and processes that all scientists rely on to make sense of the world, from chaos to cryptography, from medical imaging to movie graphics, and from large data set algorithms to the calculus of infinitesimals. That is why mathematics is often at the center of multidisciplinary initiatives large and small. Compared with laboratory scientists, for example, mathematicians can also accomplish much with grants of relatively modest size involving a small number of experts and students working on special-seeming problems with relatively little equipment. When awarding such grants, detailed priorities and targets set in advance are less crucial than when decisions must be made between large and mutually exclusive projects. Indeed, curiosity-driven, investigator-initiated, and peer-reviewed funding mechanisms work especially well in this field, where the applications of research to areas both within mathematics as well as in other disciplines, whether immediate or not, tend to be surprising and significant.

Most research on mathematics takes place at institutions of higher education and in government laboratories. Mathematicians also do valuable work throughout the economy, yet few private firms can afford to invest in research whose payoffs, while great in total, are distributed too widely in space and time to be adequately rewarded by the market.

Three federal agencies supply the vast majority of funding for mathematical research in the United States: 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 is able to focus more on basic

research than 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. DOE's Mathematical, Information, and Computational Sciences (MICS) 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 of Standards and Technology (NIST), the Department of Transportation (DOT), and the Environmental Protection Agency (EPA) are also involved with mathematics. For example, NIST mathematical research 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. 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 chapter therefore focuses on explicit expenditure plans at NSF, DOD, and DOE.

HIGHLIGHTS

- The Division of Mathematical Sciences (DMS) at NSF requests $130.3 million, an increase of $23.9 million (22.5 percent).

- Basic research at the Department of Defense would receive an increase of 4.9 percent above the FY 2000 level to $1.2 billion.

- DOE's Mathematical, Information, and Computational Sciences (MICS) program would increase by $50.6 million (42.5 percent) for a total of $169.7 million. The MICS request includes $33.1 million for applied mathematics research, an increase of $9.7 million or 41.5 percent.

FY 2001 R&D FUNDING REQUESTS, BY AGENCY

Table 1 shows the FY 2001 budget request for mathematical research programs at NSF, DOD, and DOE. Below are brief descriptions of each of these programs and the funding levels requested by the President.

Table 1. Federal Support for the Mathematical Sciences (in millions)

Agency	FY 2000 Estimate	FY 2001 Request	%Change FY 00-01
National Science Foundation			
DMS	106.29	130.2	122.5
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	1.7
Department of Energy			
MICS	119.1	169.7	42.5

NATIONAL SCIENCE FOUNDATION (NSF)

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. The FY 2001 budget request for the DMS is $130.2 million, an increase of $23.9 million or 22.5 percent over FY 2000. In its budget materials, NSF states that "in FY 2001, mathematics will receive high priority within MPS. The mathematical sciences continue to play essential roles in both independent discovery and in support of other fields of research; indeed, mathematics is the foundation and vital backbone of both today's and tomorrow's science, engineering, computation, and technology." Of the increase, $17.0 million would be allocated to research grant awards, and $6.9 million would enhance support both for the Vertical Integration of Research and Education in the Mathematical Sciences (VIGRE) program and for research institutes.

DEPARTMENT OF ENERGY (DOE)

The Mathematical, Information, and Computational Sciences (MICS) Division 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, Dynamic 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 $169.7 million, an increase of $50.6 million or 42.5 percent. Applied Mathematics research within MICS would receive $33.1 million, an increase of $9.7 million or 41.5 percent. 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 (DOD)

Because of the size of the Department of Defense (DOD) 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 Defense Advanced Research Projects Agency (DARPA). The vast majority of mathematics-related DOD research is funded in these accounts.

The Administration's FY 2001 budget request for DOD Research, Development, Testing and Evaluation (RDT&E; all categories) would be $37.9 billion, a decrease of approximately $500 million.

Most university-based research is funded through the Department's "6.1" or basic research accounts. Agency-wide, these "6.1" accounts would receive $1.2 billion, an increase of 4.9 percent over FY 2000. Among the services' basic research programs, the Army "6.1" account would receive $201.0 million, a decrease of $3.4 million or 1.7 percent (see Table II-5). The Navy, which sponsors the largest basic research program, would receive $397.5 million, an increase of $23.2 million (6.2 percent). The Air Force basic research program would be cut to $206.1 million in FY 2001, a decrease of 3.6 percent. 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 percent).

The much larger applied research accounts at DOD—the so-called "6.2" programs—would receive a 7.8 percent decrease in FY 2001, from $3.4 billion in FY 2000 to $3.1 billion in FY 2001. Within these funds, the Army applied research program would be cut drastically, from $790.9 million to $602.5 million (down 23.8 percent); Navy applied research programs would decrease from $622.4 million to $527.1 million (down 15.3 percent); the Air Force applied programs would decrease from $596.8 million to $590.3 million (down 1.1 percent); and Defense-wide applied programs would increase slightly to $1.4 billion (up 1.7 percent).

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 in mathematics, including: optimization and discrete mathematics, including linear and nonlinear programming and computational geometry; physical mathematics and applied analysis, including non-linear optics, the mathematics of materials, inverse problems, and theoretical fluid dynamics; and signal processing, probability, and statistics, drawing on wavelet methods and reliability analysis.

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, some promising approaches to

computer vision for automatic target recognition (ATR) 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.

Office of Naval Research (ONR)*:* The Mathematical, Computer, and Information Sciences Division, part of 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)*:* NSA is one of the largest employers of mathematicians in the U.S., and perhaps the world. Since 1987, the NSA Mathematical Sciences Programs 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.

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