Declining Mathematics Funding at the DoD

In the past five years the landscape of federal funding for mathematical sciences research has changed a good deal. While funding from the National Science Foundation (NSF) has steadily increased, there have been steep declines in the research funding agencies of the Department of Defense (DoD). The agencies of the three branches of the armed services used to account for around a third of total federal funding for mathematics; today they account for only about a quarter. The mathematical community has become more active in pressing the government for increases for research. However, such efforts sometimes have little effect on the DoD funding agencies, most of which are embedded in a military bureaucracy that can be hard to influence.

Mathematics Funding at the DoD

The main DoD agencies funding scientific research are aligned with the three branches of the armed forces: the Air Force Office of Scientific Research (AFOSR), the Army Research Office (ARO), and the Office of Naval Research (ONR). The Defense Advanced Research Projects Agency (DARPA), which also funds research in the mathematical sciences, reports directly to the Pentagon rather than to any specific branch of the military. The National Security Agency (NSA) performs much of the mathematical research it needs by hiring its own staff, but it also has a small program of grants to fund outside research, mostly at universities.

The mathematics programs at these agencies all have a common mission, which is to support mathematical sciences research in areas of interest to the DoD. The military designates research as 6.1 (basic research), 6.2 (applied research), and 6.3 (advanced technology development). AFOSR and ARO fund only 6.1 work, while ONR and DARPA fund 6.1, 6.2, and 6.3 work. The NSA does not use this classification, but the 6.1 designation applies to its mathematics grants. Generally the mathematics program officers at the defense agencies act as intermediaries between researchers and the military and have a large role in setting the agenda for what kinds of mathematical sciences research the agencies will fund. For this reason, there is often less reliance on the kind of peer reviewing of proposals one finds, for example, at the NSF and more reliance on the judgment of program officers. In the case of DARPA, proposals are usually refereed only by government employees. The mathematics divisions of the DoD agencies have sometimes been criticized for not doing more peer reviewing of proposals and also for funding the same researchers year after year.

The DoD agencies fund applied mathematics, including such areas as control theory, robotics, dynamics, decision theory, operations research, optimization, discrete mathematics, numerical analysis, probability, and statistics. Signal and image processing, visualization, and computer vision are also important areas. Some of the agencies support parts of analysis that have applications to physical systems in which the military is interested, and all except the NSA support research in computational mathematics and computer science. Because of its interest in cryptography, the NSA concentrates its support in algebra, number theory, discrete mathematics, probability, statistics, and the design and analysis of cryptographic

systems. Grants from the DoD agencies go primarily to principal investigators at universities and laboratories. There is also some support for conferences, workshops, and a few small centers. In mathematics the DoD grants can be more generous than NSF grants and in some cases provide academic-year salary support.

Why Did the Declines Occur?

When the threat of the Soviet Union disappeared, the entire U.S. military budget shrank, research included. Mathematics research was not singled out for cuts; rather, it took part in the stringent declines felt across the DoD. Overall, the budget of the DoD has declined nearly 30% in constant dollars since the end of the cold war. At the same time, the U.S. military has become more active, and its deployments around the world have increased in number, with the most recent example being the conflict in Kosovo. When these deployments occur, they tend to monopolize the attention of high military officers and to eat into funds intended for other DoD functions. Between 1989 and 1998 DoD funding for research and development declined 23% in constant dollars; in the same period, DoD funding for basic research fell 16% in constant dollars. These declines are less severe than they might have been under the circumstances and in fact seem to indicate a substantial commitment to research on the part of the DoD.

Among the mathematics divisions at the defense agencies, the worst hit was the Mathematical, Computer, and Information Sciences Division at ONR. In fiscal year 1995 its budget for mathematics grants had reached a peak of $21.4 million after several years of increases. By fiscal year 1998 this amount was slashed by nearly one-half, to $11.2 million. At ARO the budget for mathematics within the Mathematical and Computer Sciences Division decreased 26%, from $23.0 million in 1995 to $17.0 million in 1998. The Directorate of Mathematics and Space Sciences at AFOSR fared a little better, as its budget for mathematics rose slightly from $16.4 million in 1994 to $18.0 million in 1998 (though when inflation is taken into account, the increase disappears). One place where the downward trend did not hold is in the Applied and Computational Mathematics Program at DARPA, which has become the DoD leader in funding mathematics; its budget rose from $18.4 million in 1994 to $22.5 million in 1998. Ten years ago DARPA accounted for about 20% of DoD funding for mathematics, and by fiscal 1998 that figure had risen to around 30%.[1] The Mathematical Sciences Program at NSA is quite a bit smaller than the others, hovering around $2 million to $2.5 million for the last several years. The declines at AFOSR, ARO, and ONR can be contrasted with the growth in the budget for the NSF's Division of Mathematical Sciences, which rose from $78.0 million in 1994 to $93.6 million in 1998.

How did the mathematics divisions in these three agencies deal with the cuts? Inevitably, the process was painful. At ONR, where the cuts ran deepest, the director of the Mathematical, Computer, and Information Sciences Division, Andre van Tilborg, followed the ONR's general policy for handling such decreases, which calls for cutting whole grants rather than shrinking grant size. In addition, he said, "We eliminated entire areas rather than reducing all areas" equally. For example, at one time ONR had a substantial program in discrete mathematics, combinatorics, and graph theory. "We've just about eliminated that program," he said. Figuring out which areas to cut and which to retain was not easy. The decisions were based on judgments about which areas would be of greatest importance to the Navy in a decade or two, said van Tilborg, as well as judgments about which mathematical areas are especially dynamic and innovative. Another factor in the decisions was whether another agency, such as NSF, is funding a particular area. If so, it might be less important that ONR also fund it. Van Tilborg stressed that, as at other agencies, the ONR mathematics budget was not targeted for cuts, but rather decreased in proportion with the decrease in the budget for the agency overall.

At ARO the cuts were spread across all areas. Julian Wu, associate director of the Mathematical and Computer Sciences Division at ARO, said that his division eliminated some grants and reduced the size of others. It also sharpened its focus on grants having the clearest connection to Army needs. For example, ARO can no longer fund theoretical areas of functional analysis, because in the present climate the payoff is less clear and the proposals do not review well among Army scientists. Sometimes the ability of the principal investigator to explain the payoff can be a factor. According to Wu, one well-known mathematician who had an ARO grant was uncomfortable with the additional burden of providing such an explanation and decided to withdraw a renewal proposal. Said Wu ruefully, "When money is tight, we are forced to make these kinds of decisions."

At the AFOSR mathematics several years ago was paired with geosciences when a reduction in senior personnel forced elimination of AFOSR's physics directorate. The Mathematics and Geosciences Directorate, as it was called, has now been renamed the Mathematics and Space Sciences Directorate. Since becoming head of the directorate in October 1998, Clifford E. Rhoades Jr. has had to deal with a 15% budget cut. He decided to eliminate support for a few areas, such as software construction, artificial intelligence, and atmospheric sciences.

[1] *Budget figures for DARPA come from annual reports on federal funding for mathematical sciences research prepared by the Joint Policy Board for Mathematics.*

Cuts to the last of these "drew several expressions of concern," Rhoades said, "particularly with respect to lightning strikes on shuttle launches at Cape Canaveral, where the Air Force retains responsibility for range safety" (to meet this concern, he retained some research on lightning strikes). The reductions in those three areas accounted for about one-half to three-quarters of the necessary cuts. The rest were distributed uniformly across the other areas the directorate supports, in a difficult exercise of determining which grants were most valuable to the Air Force. Although the mathematics divisions at all three agencies have tried to shrink their grants as much as possible, none seems to have instituted blanket measures such as decreeing, say, that all principal investigators get one month of summer support rather than two.

Overall the budget cuts have meant that the mathematics divisions at these agencies have had to focus yet more narrowly on funding research that is of clear and immediate military usefulness. The cuts have reverberated across all of applied mathematics; included among the hardest hit areas are control theory and numerical analysis. Some investigators who have been cut turned to interdisciplinary collaborations, particularly with researchers in areas that have won funding increases in the last few years, such as materials science and biology. Many have also tried to migrate to the NSF, and this has increased pressure on the NSF's Division of Mathematical Sciences, particularly its programs in applied mathematics and computational mathematics.

The Difference at DARPA

One of the reasons mathematics fared better at DARPA than at the service-branch agencies has to do with the way DARPA operates. Rather than being given a set budget, DARPA program managers come up with a collection of projects they would like to support and then compete against each other for funds for the projects. The budget for a given program therefore depends greatly on the effectiveness of its program managers. Many credit Anna Tsao, who was a manager for DARPA's Applied and Computational Mathematics Program from 1994 until 1998, with working well in the DARPA environment to improve funding for mathematics. Also contributing to this effort is Dennis Healy, who has served as a manager in this program since 1996 (at the time of this writing, DARPA was still searching for a replacement for Tsao). One of the program's achievements was an unprecedented collaboration between DARPA and the NSF's Division of Mathematical Sciences to support interdisciplinary research in materials science.

A perennial difficulty for the DoD research agencies is the possibility that their budgets will be "swept". When the U.S. enters into a military conflict and the DoD needs money immediately, any unobligated funds in the research agencies can be "swept" out of the agencies and put toward supporting U.S. activities in the conflict. Sometimes funds that have already been awarded in a research grant but have not yet been spent by the grantee are vacuumed up. Other forms of "budget raiding" can be a problem in the service-branch agencies, though DARPA is less susceptible because it is not embedded in the kind of bureaucracy one finds in the three branches of the military. Big-ticket military hardware can also siphon funds from DoD research. During budget negotiations for fiscal year 2000 there were battles over the F-22 fighter plane, which many feared could endanger increases for DoD research. At the time of this writing the question of whether the F-22 would be funded in fiscal 2000 was still unresolved.

The budgets for AFOSR, ARO, and ONR are buried within the much larger budgets of the military branches they serve. "When military people make their budgets, research is an afterthought," explained Samuel M. Rankin III, director of the AMS Washington Office. "These people think about troops and materiel, not research, even though they are the recipients of that research when they go to war." There are people within the military who serve as advocates for increased funding for research, Rankin said, but the part of the budget with which they are concerned is relatively small, so they lack influence. The situation is not much better in Congress. What looms large in the mind of a member of Congress concerned with DoD budgets are things like whether a base in his or her home district is going to be closed. There is much more "pork barrel" politics and protectionism surrounding DoD funding than there is surrounding funding for, say, the NSF. "For members of Congress on the Defense Appropriations Committee," Rankin observed, "their sense of what the appropriation is for is very different from those overseeing the NSF."

In efforts to increase funding for the DoD research agencies, Congress is an important pressure point. But, according to van Tilborg, it is not the only one. In the case of ONR, for example, "you have to convince the Navy management to put more money into science," he said. He contrasted this situation with that of the NSF, which is an independent agency with no department between it and the Congress. Therefore, if one wants to influence the NSF budget, one goes directly to the relevant congressional committees. But with ONR, van Tilborg maintained, "we need the support of the management chain inside the Navy to get any budget increases." Understanding and influencing this bureaucracy is no easy task. Mathematics might have an especially hard time getting a hearing, van Tilborg predicted, because "one finds almost no mathematicians or computer scientists anywhere in the executive management structure" of the

DoD. On the other hand, van Tilborg noted that the number two uniformed official in the Navy is a mathematician: Admiral Donald L. Pilling, vice chief of naval operations. Pilling is a member of the AMS and of the Society for Industrial and Applied Mathematics.

Whither the AMS Referendum?

It was almost twelve years ago that the AMS membership passed a referendum concerning support for mathematics from the DoD agencies. Motion 2 of the referendum expressed concern about the "tendency to distribute this support through narrowly focused (mission-oriented) programs and to circumvent peer review procedures." The motion warned that this tendency "may skew and ultimately injure mathematics in the United States," and ended by saying, "Therefore those representing the AMS are requested to direct their efforts towards increasing the fraction of non-military funding for mathematics research, as well as towards increasing total research support." The referendum also included motions about the Strategic Defense Initiative and other, less controversial, matters of funding policy. The referendum drew about 7,000 votes, and motion 2 passed by a wide margin, with about 74% in favor and about 19% against (there were some abstentions).

At AMS meetings and in the pages of the *Notices*, passions flowed so hot that it is surprising to see how cool they are today. In retrospect the referendum seems like a quaint reminder of a less practical, more idealistic time that has since passed. The referendum's main effect seems to have been to alienate, at least temporarily, certain segments of the mathematical community from the AMS. Some mathematicians were deeply offended by the referendum; one was James Crowley, who at the time was the head of the mathematics program at AFOSR and is now the executive director of SIAM. Today AMS representatives do not seem constrained to focus their attention only on "increasing the fraction of non-military funding for mathematics research." As one observer put it, the AMS referendum is "not on the radar screen" of anyone concerned with funding for mathematics or science.

Indeed, the AMS has been active on a variety of fronts to try to boost funding for science and mathematics by all federal agencies, including those in the DoD. The AMS Committee on Science Policy, chaired by Arthur Jaffe, has invited to its meetings a number of key people from the DoD, including Robert J. Trew, director of research in the office of the secretary of defense. The AMS is active in the CNSR (Coalition for National Security Research), a group of sixteen scientific societies, university groups, and industry representatives who are advocates for increased support for research by the DoD. Perhaps their voices are being heard: The fiscal year 2000 defense appropriations bill, signed into law by President Clinton in October 1999, contains a 7.3% increase for DoD research. Consistent advocacy for all of science and mathematics, bolstered by alliances with other scientific groups, is what is likely to improve the funding picture for mathematics at the DoD agencies. As Rankin put it, "It is in the interest of mathematics to have all agencies that fund science be healthy."

— *Allyn Jackson*

Mathematics Budgets for DoD Agencies, FY 1994–1998
Millions of Dollars

	1994	1995	1996	1997	1998	Change 1994–98
AFOSR	$16.4	$17.5	$16.7	$17.1	$18.0	9.8%
Constant Dollars*	11.1	11.5	10.6	10.6	11.0	-0.9%
ARO	20.0	23.0	22.0	20.0	17.0	-15.0%
Constant Dollars	13.5	15.1	14.0	12.5	10.4	-23.0%
ONR	18.0	21.4	20.2	14.0	11.2	-37.8%
Constant Dollars	12.1	14.0	12.9	8.7	6.9	-43.0%
DARPA	18.4	21.0	22.9	18.5	22.5	22.3%
Constant Dollars	12.4	13.8	14.6	11.5	13.8	11.3%
NSA	2.5	2.5	2.1	2.1	2.0	-20.0%
Constant Dollars	1.7	1.6	1.3	1.3	1.2	-29.4%

*Constant dollars are computed using the Consumer Price Index, based on prices during 1982–84.