Joint Policy Board for Mathematics Testimonies

The Joint Policy Board for Mathematics regularly arranges for representatives of the AMS, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics to testify before Congress on issues of importance to the mathematical sciences community. What follows is the text of testimony presented to the Senate subcommittee concerned with scientific research funding through the Department of Defense, and testimony presented to the House subcommittee concerned with the budget of the National Science Foundation.

The Notices *will on occasion publish such testimony, in order to keep the community abreast of these important exchanges with Congress. Related issues are discussed in the Forum article, "A New Paradigm for Mathematics: Publicity or Perish," by Leon Seitelman, in this issue of the* Notices.

JPBM Testimony on the FY 1997 National Science Foundation Budget Request

Rep. Jerry Lewis, Chair
Subcommittee on VA, HUD, and Independent Agencies Committee on Appropriations
United States House of Representatives

May 10, 1996

Good afternoon, Mr. Chairman and Members of the Subcommittee. I am Arthur Jaffe, president-elect of the American Mathematical Society and Landon T. Clay Professor of Mathematics and Theoretical Science at Harvard University. Thank you for this opportunity to comment on the FY 1997 budget request of the National Science Foundation. I speak on behalf of the Joint Policy Board for Mathematics, a joint effort of the American Mathematical Society, the Mathematical Association of America, and the Society for Applied and Industrial Mathematics. With a combined membership of over 57,000 mathematical scientists and educators, our members' concerns span fundamental and interdisciplinary research on mathematics; the applications of mathematics to science, engineering, industry, and business; and mathematics education at all levels.

Mr. Chairman, the Joint Policy Board for Mathematics urges you to provide full funding for the National Science Foundation's research and education programs. We believe that the national impact of these programs warrants the small, 3.3 percent increase the NSF has requested for FY 1997.

Support for research and education in mathematics, basic sciences, and engineering ranks among the most productive investments Congress can make in the future of our country. The mathematicians, scientists, and engineers supported by the NSF today develop new ideas and make new discoveries which become the building blocks for our society and for our economy tomorrow. The United States spends less as a percentage of GDP on civilian research than our major competitors. The federal government remains the major source of support for fundamental research and education, as the private sector continues to emphasize short-term payoffs over building long-term strength.

Working with less than 5 percent of the total federal R&D budget, the NSF plays a central role in the funding for fundamental advances in mathematics, science, and engineering and assumes major responsibility for many critical components of science and technology. The NSF is the only federal agency that supports basic research across the broad spectrum of traditional fields underlying our leading position in science and technology. In doing so, it also facilitates bridging the interfaces between different scientific disciplines. The NSF works diligently toward the achievement of excellence in education in science, mathematics, and engineering, and it is strengthening its programs to promote the integration of research and education at U.S. universities. Furthermore, the NSF pursues part-

Arthur Jaffe's e-mail address is jaffe@math.harvard.edu.

nerships and encourages the participation of other federal agencies, of the states, and of industry in its activities, thereby leveraging its comparatively small budget.

The NSF supports only the most promising ideas for research among the many fine proposals that emerge from the nation's colleges and universities. Furthermore, it provides a key to our future predominance in science by encouraging our most brilliant and original undergraduate, graduate, and postdoctoral students to pursue productive scientific careers. For these reasons, the NSF is particularly deserving of the limited funds which you have to distribute.

Let me now offer a few examples demonstrating the national value of the NSF.

NSF Support for Research in the Mathematical Sciences

We are in the midst of a golden age of mathematics research, and today American mathematics is the envy of the rest of the world. The spectacular advances made in recent years are the consequence of NSF support for many areas of mathematics over the past forty-five years. The NSF and its Division of Mathematical Sciences (DMS) play a central role as they provide virtually the only federal support for fundamental mathematical research. This research provides the underpinnings of our understanding of nature; it provides the fundamental framework to enable a broad range of advances in science, engineering, and business; and it contributes to the future of our technology-based economy. Some of the most revolutionary applications of mathematics emerge in completely unexpected ways from basic research by the most talented and original mathematical scientists supported by the DMS. In addition, DMS provides effective mechanisms for connecting mathematical scientists with fields and problems of immediate national importance, including those of industry.

We have witnessed two exciting themes in this recent progress. One theme is the flourishing of mathematics focused on classic questions generated from within the field. The second theme is the flourishing of work connecting mathematics with science. In both these areas we observe torrents of new ideas and results.

Three years ago Princeton mathematician Andrew Wiles announced a solution to the 350-year-old Fermat problem. Today insights emerging from this work have opened up a floodgate of new results and possibilities both in number theory, where they originated, as well as in several other related fields. In fact, number theory lies at the heart of modern cryptography. It is hard to believe that the basis of a company valued at more than $250,000,000 is the following observation: you can quickly multiply very large numbers together on a computer, but if someone presents you with a 200-digit number that was made by multiplying together two 100-digit numbers, then all the computers in the world working together may not be able to figure out what the original numbers were. The company is RSA Data Security, and its encryption algorithm is the basis of all secure commerce on the Internet. Today we believe that the 200-digit RSA codes on the Internet are still secure. But who knows? A dramatic breakthrough could immediately change the rules of the game. Future mathematical research will make or break these codes.

Other amazing progress has come about from various connections between mathematics and physics, an area in which I myself work. Most of us have heard of Newton's apple, which symbolizes the marriage between mathematics and physics. This ancient, traditional relation has suddenly blossomed in the past few years, with the work of physicists and of mathematicians fueling a minor revolution in mathematics. For example, a new mathematical theory has been discovered which incorporates the quantum nature of physics directly into our view of space and time; this is called quantum geometry. In another direction, particle physicists have conjectured that their equations expressing the laws of nature can be modified in a new way; amazingly, these ideas touch base with exciting current problems in mathematics. This raises the possibility of a new level of understanding at both the frontiers of mathematics as well as at the frontiers of cosmology and particle physics. The early harvest has been exciting, but only the surface appears to have been scratched in these areas. The dream of workers in this area is to discover new laws of nature whose importance rivals quantum theory and relativity found early in this century.

Other connections to science and to engineering also hold the potential for having great impact. One such problem that DMS is seeking to address involves large data sets. Some impressive tools exist for collecting large amounts of scientific data, and often it is being collected faster than it can be analyzed. For example, the Human Genome Project will accumulate a database of 3 billion base pairs of human genetic code; an earthquake study in Los Angeles generates data at 35 billion different points; and satellites in one remote earth sensing project can amass 200 billion characters of information in just one scan.

Finding the best ways to organize large amounts of data so it can be distilled and interpreted is hindered by a lack of basic knowledge and structural models of databases. Basic research in core mathematics and computer science is needed to build the models and devise efficient techniques for extracting useful information. These questions arise in a variety of scientific fields including astronomy, communications, computer science, ecology, meteorology, molecular biology, particle physics, and geography; they also occur in record keeping in government and in business, such as in banks, in the Census Bureau, in the Social Security Administration, and in records of telephone and credit card use. The problem is inherently mathematical and one of many in this field being attacked by NSF-supported researchers.

Another connection highlights the commitment by the NSF to build productive partnerships with other government agencies. Recently DMS established a collaborative program with DARPA to support the mathematical modeling and simulation of advanced materials processes, with a focus on prototyping of thin films (a layer of lubricant oil is an example of a thin film). The program was motivated by the needs of materials science researchers for advanced mathematical tools that would enable computational experimentation with designs and scale-up strategies. The predictive capabilities of the sought-after tools will reduce the need for expensive trial-and-error methods that now hinder the development of new materials and their processing equipment.

The Leadership Role of NSF in Mathematics Education

It is impossible to separate science education from scientific research. The NSF also provides most of the federal funding that enables the mathematical community to work toward the improvement of mathematics education at all levels. The Education and Human Resources Directorate, sometimes in collaboration with DMS, maintains an integrated set of programs that promote more effective and more inclusive mathematics education in schools, colleges, and universities throughout the country.

For instance, the NSF Systemic Initiatives program promotes partnerships among schools, universities, state and local governments, teachers, business, and policy leaders in an effort to improve K–12 mathematics and science education. Mathematical scientists are involved in many of the initiatives; for example, they work to improve the preparation of K–12 teachers.

While the K–12 programs of NSF attract much deserved applause, I'd like to emphasize that the Division of Undergraduate Education (DUE) is also essential to collegiate educators with innovative ideas for expanding student access and learning in mathematics, science, and engineering. The core programs of the DUE curriculum development, laboratory improvement, and faculty enhancement are especially important in these efforts.

As a follow-on to the remarkably successful calculus education program that JPBM has discussed in this forum in previous years, DUE is now sponsoring a program called "Mathematics Across the Curriculum". Because mathematics pervades all fields of knowledge and all modern technological jobs, it has become imperative to demonstrate the integration of mathematics into all fields of study and to enable students to make appropriate use of mathematics. With funds from this program, Dartmouth College leads a consortium of colleges and universities in undertaking a project to integrate the undergraduate study of mathematics into courses in some sixteen different fields, ranging from art, music, and philosophy to physics, engineering, and the social and biological sciences. Overall, ninety faculty from the consortium institutions are working to design twenty-two new interdisciplinary courses and revise ten others. This unprecedented cooperation among faculty from diverse departments is expected to enrich the entire collegiate curriculum.

Conclusion

Mr. Chairman, there are many other projects I could describe to demonstrate the extraordinary impact NSF programs have on science, technology, and education. None of them, of course, would change the fact that you face very difficult choices about dividing the federal budget. We are not asking you to stray from your commitment to balance the budget by 2002, but we are asking that as you make your decisions you keep in mind that the National Science Foundation is about discovery. Discovering new ideas and exploring their potential provides a key to solving many problems we face in the United States. I hope that you will keep sight of this investment in our future as we work through these difficult budgetary times.

In conclusion, I again urge the subcommittee's continued support for the research and education activities of the NSF. Thank you for this opportunity to express our views for the record regarding FY 1997 appropriations for the National Science Foundation.

JPBM Testimony on FY 1996 Appropriations for the Department of Defense

The Hon. Ted Stevens, Chairman
Subcommittee on Defense
Committee on Appropriations
United States Senate

July 18, 1995

Good morning, Mr. Chairman and Members of the Subcommittee. I am James Crowley, executive director of the Society for Industrial and Applied Mathematics (SIAM), and I appreciate this opportunity to comment on FY 1996 appropriations for the Department of Defense. I speak on behalf of the Joint Policy Board for Mathematics, which represents three associations of mathematical scientists whose concerns encompass fundamental and interdisciplinary research, the applications of mathematics to science, engineering, and industry, and mathematics education at all levels. Today I would like to address DOD's support for research and development. I might note that prior to joining SIAM a year ago, I was the director of ARPA's Applied and Computational Mathematics program.

Mr. Chairman, JPBM urges Congress to recognize DOD's investment in basic research at universities as an integral and foundational component of R&D efforts undertaken to meet the nation's defense needs and to provide full funding for that investment, which enables DOD to employ the brightest researchers and the latest discoveries in pursuit of its R&D objectives.

Since World War II the United States has relied on the superiority of its military technologies to achieve its national security objectives. Basic research is absolutely essential to the process of developing new technologies, improving existing ones, and employing them as effectively as possible, and therefore maintaining superiority over the long term. The origins of many key defense technologies can be traced to DOD support for basic research conducted in the nation's universities.

The defense agencies that have traditionally funded scientific research have an excellent track record for making decisions about which research areas are vital to DOD's technology goals and which researchers are best able to mine the scientific opportunities for contributions to national security. They use innovative approaches to develop research programs that match relevance with scientific excellence. They take full advantage of the robust U.S. research system, supporting work at a mix of universities, governmental laboratories, and sometimes in cooperation with industry.

Rigorous internal decision making processes guide these investments and ensure they represent scientific excellence and are consistent with DOD's mission and strategic priorities. These agencies—the Army Research Office, the Office of Naval Research, the Air Force Office of Scientific Research, and the Advanced Research Projects Agency—must continue to rely on university-based researchers to stimulate new technologies and adapt emerging technologies to meet national security needs. In many mathematical areas of interest to DOD, university-based researchers are in an excellent position to make very productive advances.

Mr. Chairman, we recognize that military readiness must be the primary mission of DOD. However, Congress should exercise extreme care before disrupting DOD's thoughtfully planned investments in basic research with budget cuts that will curtail the scope of promising research that DOD has identified as relevant to its mission.

Moreover, if cuts are to be made in defense R&D, they should be guided by defense priorities and objectives and scientific excellence and not directed arbitrarily at any particular category of researchers, such as those based at universities. R&D funding decisions should be made in a way that maximizes the potential to protect and enhance national security. It would be counterproductive to restrict DOD's ability to work with the most appropriate institutions on those areas of research that it has decided to support.

Let me demonstrate the significance of basic research to DOD's mission with some examples from the mathematical sciences. In general, DOD's support for research in the mathematical sciences enhances the effectiveness, efficiency, and reliability of U.S. defense hardware and capabilities, especially communications systems, cryptographic capabilities, and smart weapons technology. It also underpins key technological areas of crucial importance to national security, like materials, robotics, and information technologies.

One area in which mathematical achievements are leading to very useful results is the handling and analyses of large volumes of data, which, as you might imagine, are something defense personnel and technology are faced with every day. For instance, observational satellites take pictures of the Earth's surface, but those images have to be conveyed somehow back down to Earth so we can use them. The image data is compressed into digital form and a signal is beamed to a receiver. It is imperative that the data is compressed in a way that allows the receiver to decompress it in usable form and without significant loss of accuracy.

In the mid-1980s mathematical scientists at invented a mathematical method to represent and convey signal and image data in a very efficient way. That is, data can be retrieved as needed very quickly at different scales and with little loss of accuracy, allowing use of the best and most appropriate data in real-time situations. DOD scientific personnel recognized early that this was a breakthrough that would lead to significant improvements in defense operations. The Air Force and ARPA continue to support research into these mathematical techniques, which go by the

James Crowley's e-mail address is `jcrowley@siam.org`.

name of "wavelets", and DOD is putting them to work in a variety of ways.

It is believed that one day the methods can be used for automatic detection and recognition of targets, which is simply not possible with older methods. That is, the analysis of data while it is still compressed can be automated, so that when, say, a satellite finds something that might be of interest to DOD, the appropriate personnel can be instantly alerted to its existence. Presently, separate and cumbersome processes must be used to analyze collected data after it is decompressed.

Incidentally, it turns out that the FBI found wavelets to be the ideal technique for compressing fingerprint images, because it preserves the fine detail of the images so well.

Another example shows how powerful new techniques, when used in combination with advanced computers, can yield dramatic results. DOD needs to be able to predict the scattering of radar signals from aircraft so their vulnerability to detection can be analyzed and so that new aircraft with low radar visibility can be designed. Current computational codes for this task can only resolve small components of an aircraft in a reasonable amount of time. New mathematical techniques would make it possible to compute the scattering over major components or entire aircraft. With older methods, if the length of the object being studied grows by a factor of 10, the time it takes to compute the radar signals increases by a factor of 1,000. The newer, faster algorithms would increase that time by only a factor of around 10.

The above examples represent only a small sample of new mathematical concepts and techniques DOD is supporting to improve the effectiveness and efficiency of its technology and to facilitate the development of revolutionary new technologies. Attached to this testimony is an article that describes how investments in the mathematical sciences paid off during the Gulf War.

In conclusion, let me just reemphasize that basic research yields valuable returns that ensure our long-term national security and lead to new and improved technologies on which the military relies for its success. We urge your continued support for DOD's basic research programs. Thank you for this opportunity to express our views for the record regarding FY 1996 appropriations. I would be pleased to answer any questions you might have.