What Is the BMSA and What Does It Do?

Scott Weidman

Government policies should rest on a solid foundation of analysis, and increasingly that analysis consists of mathematical models. But mathematical scientists, with their in-depth understanding of how to construct and analyze mathematical models, and of the limitations of mathematical models, have often not been involved in the discussions leading to those policy decisions. The Board on Mathematical Sciences and Their Applications (BMSA) exists to increase the involvement of mathematical scientists and their perspectives in policy decisions that depend on, or affect the practice of, mathematical research.

The BMSA is a standing committee of the National Research Council (NRC), a nongovernmental, nonprofit entity that conducts studies on behalf of the National Academy of Sciences (NAS) and the National Academy of Engineering (NAE). The NAS, NAE, and NRC, along with a sister organization, the Institute of Medicine, are collectively known as The National Academies. National Academies studies, some 200 per year, address issues such as the proper use of computational models in setting environmental regulations, the validity of biometric security technologies, priorities for supercomputing investments, and many other topics with mathematical relevance. The common theme in such studies is that of distilling lessons from the scientific, engineering, and medical communities to guide federal policies and decisions. The National Academies are considered the premier source of objective technical advice in the United States, both because of the quality of people recruited for these studies and because of the processes in place to ensure that those studies are conducted independent of bias or conflicts. Increasing the involvement of mathematical scientists in studies such as these is a great opportunity to improve policymaking while increasing the visibility of mathematical scientists, and those are the goals that motivate the BMSA.

In order to maintain its understanding of the needs of federal agencies, BMSA has in the past year engaged in discussions with the heads of the National Science Foundation, the National Institute of General Medical Sciences, and the Air Force Office of Scientific Research, with leaders in the Federal Reserve System, and with many other highly placed officials. Members have also had discussions with leading figures in computer science, biology, medical informatics, economics, defense, intelligence, and so on. This access allows the board to raise issues of importance to the mathematical sciences, contribute perspectives of our community to high-level policy discussions, and generally raise the community's profile so it is less likely to be overlooked during policymaking. In many cases, these discussions are one of the few occasions where the high-level decision-makers have a chance to interact with mathematical scientists, and they welcome that involvement. The board's interactions in this way spread the word that mathematical scientists are engaged, interested, and contributing professionals.

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What Is the BMSA?

The BMSA consists of nineteen members who serve pro bono; a list appears at the end of this article. While they are appointed by the president of the NAS, academy membership is not a prerequisite. The board takes a very broad interpretation of the mathematical sciences and includes members from core and applied mathematics, operations research, statistics, computer science, computational science, economics, systems engineering, financial engineering, genomics, risk analysis, and decision analysis. All of the board members consider themselves mathematical scientists, and they feel strongly that there is a core mathematical foundation that unites, grounds, and strengthens their fields. The BMSA has a long-term vision of uniting these many fields under a general umbrella of "mathematics" while encouraging a similar broadening within many academic mathematics departments.

The board is not an advocacy or lobbying organization. Rather, it aims to understand many uses of the mathematical sciences—explicit or, more often, hidden—throughout the federal government, and it undertakes studies or workshops to provide two-way communication between the mathematical research community and those important application areas. Through these workshops and studies, planned by expert committees that include mathematical scientists as well as leaders of other fields and that often address nonmathematical needs (examples are below), the BMSA accomplishes at least three good goals:

1. The best mathematical thinking is brought to the subject of the study or workshop, which improves public policy;

2. The value of mathematical thinking is demonstrated, both to the non-mathematicians on the committee and to the readers of the study's final report; and

3. The BMSA (through a report or follow-on presentations) can steer mathematical researchers to open research questions that will contribute both to future advances in other fields and to the mathematical sciences, thereby strengthening that important interface.

This approach, of working with communities that need mathematics to address challenges that may be only partly mathematical, is the best way of demonstrating the value of the mathematical sciences. A long-term effect will be an improvement in the way the mathematical sciences are perceived—as essential and willing partners in problem-solving, partners whose toolkit is special and valuable—which could broaden federal support for the mathematical sciences. At the same time, this approach builds bridges that counter the isolation that hampers some mathematics at present. This is a gradual process, accomplished by long-term, consistent involvement of mathematical scientists in issues that transcend our own profession. There is no quick fix, no chance to whisper magical words to a high-ranking person who will then orchestrate a greater, widespread appreciation of (and funding for) mathematicians.

To most sectors of the nation and most agencies of the federal government, "mathematics" is nearly synonymous with "analysis" (meaning quantitative modeling, not the subfield of mathematics). There are very few people with the title of mathematician in government or industry, but many people who would readily agree they are performing mathematical tasks. In many cases, these people have difficulty staying connected to the academic mathematical sciences community because the level of work, and the types of questions addressed, are so disparate. This is the community of mathematical practitioners: those people who apply mathematical methods but generally do not carry out research. These professionals are connected to many exciting challenges that are essentially mathematical, challenges that give them an incentive to apply research advances if relevant ones can be found. In the absence of bridges to the academic mathematical profession, many of these practitioners are more likely to align themselves with other professional communities, which simply deepens the gulf between theory and practice in the mathematical sciences. That gulf is bad not only because it lessens the transmission of mathematical advances into practice and the identification of challenges to the research community, but also because it contributes to the reputation of the mathematical sciences as being of less practical value than some other fields.

The BMSA aims to overcome that gulf in several ways. First, its activities related to federal analysis and decision-making identify directly how state-of-the-art mathematics is applicable to, and necessary for, the real needs of nonresearch agencies. Second, in the course of providing such advice, the board brings together leading mathematical scientists and mathematical practitioners, broadening the knowledge base of the mathematical scientists and demonstrating to the practitioners the value of such interactions. Presumably, some or many of the practitioners will maintain those connections as new challenges arise, leading to sustainable connections among communities that depend on the mathematical science research enterprise. Third, the BMSA's access to high-level decision-makers in agencies and Congress gives it the opportunity to drive home the value of such interactions and the consequent need for a healthy mathematical sciences research base. Remember that these interactions are primarily with leading figures who are not in research agencies, so the BMSA is able to build up diverse support for the capabilities and

value of the mathematical sciences within sectors that might otherwise be unaware of our community. This will gradually improve the political support for mathematical sciences funding.

So the BMSA includes in its mission anything that improves the quality of analysis underlying public policy and federal decision-making. Improving the quality of analysis requires the board to address all of the following needs:

1. Rapid and effective sharing of ideas, skills, and methods among and within sectors. The BMSA's 2004 workshop on Enterprise Risk Management is an example that addresses this need, because it assisted in the transition of risk management capabilities from the banking sector to the public sector while alerting academia to unresolved research challenges. That subject is likely to be explored further in coming years, as more and more federal agencies adopt quantitative methods to evaluate their internal risks. Any BMSA study that applies the insights of leading scientists and engineers to advise an agency about their analytic capabilities and guide their programs would also fall within this general mission of the board.

2. Ensuring that people with the right skill sets are produced by the academic pipeline, so that the nation has the right foundation for high-quality analysis.

3. Ensuring that adequate tools—including research results, software, and analytical methods—are available and used properly. Studies that offer guidance to the research enterprise would address this need, as would reviews of how well selected federal agencies carry out their analyses.

4. Improving the health of the academic foundation of quantitative sciences—which the board agrees is centered within mathematics departments—and improving the connectivity between this base and the widespread community that performs analyses and research. This part of the mission is essential if we are to pursue items 2–3, and it helps in performing item 1. BMSA studies that help connect research disciplines, such as our recent study on computational biology, fall within this part of the mission, and almost any study the BMSA does for a federal or state agency also includes some lessons to transmit back to the academic community so as to improve the connections and make mathematical sciences research responsive to emerging needs.

5. Ensuring healthy communication between the analysis and policy communities, so that the former understands the goals and constraints of the latter, and the latter understands the value and potential of the former. This part of the mission would be addressed through the way we conduct studies—i.e., simply by getting technical people, researchers, and policy people working together on tasks—with the result that these communities have better communication and, in particular, that the mathematical sciences community becomes a more valued contributor.

What Does the BMSA Do?

The board's current program addresses four general areas at the interface of mathematical sciences research and public policy:

1. Advice for the responsible and effective use of computational models. The rapid increases in computing capabilities in recent years have increased the need for care in interpreting output from complex models and simulations.

2. Creation of knowledge from large amounts of data. Over the past twenty years, many areas of science and engineering have evolved from being data-poor to being awash in data, and there is a growing need for better methods of data analysis.

3. Advancing the mathematical and statistical underpinnings of risk analysis.

4. Leadership for the mathematical sciences. The mathematical sciences community benefits from guidance about emerging research directions and the development of policy for the discipline.

The last of these areas is probably the easiest for *Notices* readers to recognize. An example of the board's work in this area is its recent reports *Mathematics and 21st Century Biology* and *Basic Research in Information Science and Technology for Air Force Needs*. The first of these, released in June 2005, captures the results of a one-year study by an expert, cross-disciplinary committee to identify ways to best position mathematical sciences research to be of most value to biology. The committee was chaired by a leading biologist, Maynard Olson of the University of Washington, to ensure that the study and its report would have maximal credibility and not be biased toward the goals of mathematical researchers. Although the study was sponsored by the Department of Energy in order to better align its mathematical sciences research program with the DoE's research in biology and environmental science—which are fairly constrained—the committee decided that a broader scope would be critical for really strengthening the mathematics-biology interface. Therefore, it decided to examine the roles of mathematical sciences research on research in genomes, molecules, cells, organs, populations, and communities. This was a good choice, because the committee also found a great deal of overlap in the mathematical challenges for addressing biology problems from across these scales. The committee—which included six members of the National Academy of Sciences and other prominent leaders in biology, ecology, bioinformatics, applied mathematics, and statistics, most of whom work on the interface of the two fields—also made recommendations about how funding

agencies can best encourage fruitful research on this interface.

Most recently, *Basic Research in Information Science and Technology for Air Force Needs* (2006) was the first document to lay out a clear research agenda to build the foundations of information science of importance to the Air Force. That report was generated by a committee with strong credibility in both computer science and mathematical sciences communities,[1] and so its recommendation for a major increase in research funded by the AFOSR (Air Force Office of Scientific Research) with a mathematical orientation was well received. As a result of this study, AFOSR's Directorate of Mathematics and Space Sciences is slated to receive an increase of US$6 million per year.

More generally, the BMSA serves to provide highly credible advice regarding the best infrastructure for the mathematical sciences enterprise and the best use of the community's insights for improving the work of the federal government and underpinning national policy. Regarding the infrastructure for the mathematical sciences, the board's reports on research opportunities (next paragraph) contribute specific advice, distilled from the leaders of the cognizant fields or interfaces. Occasionally, the board develops reports with a more overt policy orientation. Examples include *Harnessing Moore's Law: Mathematical Science Priorities in Support of Computational Science and Engineering* (planned for 2007) and *U.S. Research Institutes in the Mathematical Sciences* (1999).

One way in which the BMSA improves interfaces between the mathematical sciences and other fields of research is by documenting fertile sources of exciting research opportunities at the interface with other fields of science and engineering. The board has a long history of doing this through reports such as *Mathematics and 21st Century Biology* (2005), *Mathematics and Physics of Emerging Biomedical Imaging* (1996), *Calculating the Secrets of Life* (1995), *Mathematical Sciences and Theoretical/Computational Chemistry* (1995), *Mathematical Research in Materials Science* (1993),[2] and others. To create such reports, the BMSA typically assembles a cross-disciplinary committee of experts that—through interactions with other experts, funders, and other involved parties over the course of a year or more—identifies some of the most exciting and promising opportunities. These committees often make recommendations to the funding agencies and the affected communities about how to improve the effectiveness of the subject interface.

In addition to reports, the BMSA organizes workshops to bring together communities performing research that is synergistic, both to strengthen those communities and to inform federal funding agencies about some of the most promising directions to support. Examples of these, some of which were organized by the BMSA's Committee on Applied and Theoretical Statistics (CATS), include:

- *Workshop on New Tools for Modeling Systemic Risk in the Financial Sector* (joint with the Federal Reserve Bank of New York), May 18–19, 2006
- *Workshop on Statistics on Networks*, September 26–27, 2005
- *Workshop on Visualization of Uncertain Information*, March 3–4, 2005
- *Enterprise Risk Management*, Jan. 14–15, 2004.
- *Statistical Methods for the Analysis of Massive Streams of Data*, December 13–14, 2002
- *Mathematical Sciences' Role in Homeland Security*, April 26–27, 2002
- *The Interface of Three Areas of Biomedical Science with the Mathematical Sciences*, April 26–28, 2001
- *The Interface of Three Areas of Computer Science with the Mathematical Sciences*, April 28–29, 2000
- *Statistical Approaches for the Evaluation of Complex Computer Models*, December 3–4, 1999
- *Large-Scale Structures in Acoustics and Electromagnetics*, September 26–27, 1994
- *Motion, Control, and Geometry*, April 12, 1994

Because of the BMSA's position within the National Academies, it has had great success in attracting leading scientists from other fields to its workshops. That allows these meetings to be truly cross-disciplinary and to have influence in multiple fields. Workshops such as the 2002 one dealing with homeland security profited from the board's ability to attract leading managers from a variety of federal agencies, including the National Security Agency, the Centers for Disease Control, the National Imagery and Mapping Agency, and the predecessor of the Department of Homeland Security. Some of those workshops are documented via proceedings (e.g., *Motion, Control, and Geometry*), web-based video (e.g., Mathematical Sciences' Role in Homeland Security, the video of which is hosted at the website of the Mathematical Sciences Research Institute, `http://www.msri.org`), and articles in professional journals (e.g., a December 2003 special issue of *Journal of Computational and Graphical Statistics*, drawn from the workshop on statistical methods for the analysis of massive streams of data).

[1] *The committee included five members of the National Academy of Engineering, one member of the National Academy of Sciences, and one of the Institute of Medicine, including well-known mathematical scientists Elwyn Berlekamp, Roger Brockett, and Prabhakar Raghavan.*

[2] *All reports cited in this article are available through the National Academies Press,* `http://www.nap.edu`, *and most may be perused online at that site.*

The BMSA is taking steps to increase its contact with the broader academic mathematics community, for example with an article about recent work that appeared in the September 2005 issue of the *Notices*.[3] The board has also taken first steps to present cross-disciplinary opportunities at professional conferences, such as special sessions at the 2003 and 2004 Joint Mathematics Meetings (on mathematics and computer science and on mathematics and biology, respectively) and a special session at the 2004 Joint Statistical Meetings on statistics and forensic sciences. A special session is being planned for the 2006 Joint Statistical Meetings dealing with statistics on networks.

Some Future Directions

The BMSA has seen increasing interest among a wide variety of federal agencies to receive top-quality mathematical advice. The board recently held a workshop jointly with the Federal Reserve Bank of New York to stimulate fresh approaches to modeling systemic risk in the financial sector. It is hoped that this workshop will be just a first step in a long-term effort to strengthen ties between mathematical scientists and the central banking community. The board's Committee on Applied and Theoretical Statistics will soon be involved in a major study aimed at strengthening the foundations of forensic science; statisticians are needed to deal with the many uncertainties. BMSA has nearly finished a major study on defense modeling, simulation, and analysis, which is a very broad enterprise providing input to many critical decisions affecting defense and budgets. That enterprise is only weakly coupled with the broader mathematical sciences community, and the board hopes that its report will be a first step toward reconnecting the two communities, which were very close in the 1940s and 1950s.

This is just a snapshot of the BMSA and its activities. As it explores new connections for the mathematical sciences community, we will provide updates periodically through articles like this one and at professional meetings. These are tremendously exciting times for mathematical scientists.

BMSA Membership
2005–06 academic year

David McLaughlin, Provost, New York University, chair
Tanya Styblo Beder, CEO, Tribeca Investments, LLC
Philip Bernstein, Microsoft Corporation
Patrick L. Brockett, Risk Management and Insurance Program, University of Texas
Aravinda Chakravarti, Genetic Medicine, Johns Hopkins School of Medicine
Phillip Colella, Applied Numerical Algorithms Group, Lawrence Berkeley National Laboratory
Lawrence Craig Evans, University of California at Berkeley
John E. Hopcroft, Cornell University
C. David Levermore, University of Maryland
Charles M. Lucas, Market Risk Management, AIG
Charles Manski, Department of Economics, Northwestern University
Joyce McLaughlin, Rensselaer Polytechnic Institute
Jill P. Mesirov, Bioinformatics and Computational Biology, Broad Institute
Andrew M. Odlyzko, Digital Technology Center, University of Minnesota
John Rice, Department of Statistics, University of California at Berkeley
Stephen M. Robinson, Department of Industrial Engineering, University of Wisconsin-Madison
Edward Wegman, Center for Computational Statistics, George Mason University
Detlof von Winterfeldt, Policy, Planning and Development, University of Southern California
Lai-Sang Young, New York University

[3] *What Mathematics Is Required to Make Use of Genomic Data?, by Jennifer Slimowitz and Scott Weidman, vol. 52, p. 829.*