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TO THE NATIONAL ACADEMY OF SCIENCES

"PARTIAL SUPPORT OF THE MEETINGS OF THE BOARD ON MATHEMATICAL SCIENCES AND THEIR APPLICATIONS"

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Period of Performance: 09/01/2011 - 08/31/2014

SUMMARY

Technical Merit: The National Academies' Board on Mathematical Sciences and their Applications (BMSA) provides a broad interface between the research enterprise and federal agencies that rely on the mathematical sciences. The Board offers objective and authoritative advice on how best to apply the tools of mathematics, statistics, operations research, financial engineering, machine learning, computational science, information analysis, risk analysis, systems engineering, and decision analysis to practical problems of national importance. In so doing, the Board strengthens the policymaking process; increases the visibility of, and appreciation for, the mathematical sciences; and identifies growth areas for the discipline.

During the performance period, BMSA released the following major reports:

- *Transforming Combustion Research through Cyberinfrastructure* (2011);
- *Assessing the Reliability of Complex Models: Mathematical and Statistical Foundations of Verification, Validation, and Uncertainty Quantification* (2012);
- *Fueling Innovation and Discovery: The Mathematical Sciences in the 21st Century* (2012);
- *Aging and the Macroeconomy: Long-Term Implications of an Older Population* (2012);
- *The Mathematical Sciences in 2025* (2013);
- *Frontiers in Massive Data Analysis* (2013); and
- *Developing a 21st Century Global Library for Mathematics Research* (2014).

DOE Impacts: The BMSA helps to inform the mathematical sciences research community about high-priority research opportunities, primarily of importance to federal programs. Many of these research directions contribute fundamentally to DOE's mission. More generally, BMSA activities strengthen the mathematical sciences community by demonstrating the value of that community to a broad range of federal agencies, thereby building stronger support for research that can benefit DOE and a healthier research community.

INTRODUCTION

The BMSA serves as an interface between the many users of the mathematical sciences throughout the federal government and the broader mathematical sciences community. 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, which are carried out by committees of pro bono experts from the mathematical scientists as well as leaders of other fields, the BMSA accomplishes at least two goals:

1. The best mathematical thinking is brought to the subject of the study or workshop, which improves public policy; and
2. The mathematical sciences enterprise is linked more strongly to broader science and engineering endeavors, which contributes to the health of the mathematical sciences.

The subject grant provides partial support for semi-annual meetings of the Board and preparations for, and follow-through from, those meetings. Additional support for these meetings comes from NSF and NSA. Board meetings provide opportunities to build the interfaces noted above and to help design and oversee BMSA activities, which are funded separately. The Board membership is attached, and more information may be found at www.nas.edu/bmsa.

The Board has one standing committee, the Committee on Applied and Theoretical Statistics (CATS), which has analogous goals but is focused on the statistical sciences. CATS is funded separately by the NSF.

RECENT AND CURRENT ACTIVITIES

Accomplishments during the performance period include the following:

- Printed copies of the BMSA report *Transforming Combustion Research through Cyberinfrastructure*[1] were disseminated. That report was the product of a study funded by a consortium of federal agencies (AFOSR, DOE/NETL, NIST, and NSF) and carried out with collaboration from the Academies' Computer Science and Telecommunications Board and Board on Chemical Sciences and Technology. The report built a case for a focused cyberinfrastructure to knit together disparate communities that jointly create the technology for improved combustion. Several hundred copies of the report were disseminated by BMSA, it

[1] National Academies Press, Washington, D.C., 2011. All reports mentioned in this document have the same publisher, so that information is not repeated below.

has been downloaded over 400 times (all National Academies reports may be downloaded for free as pdf files), and 48 paper copies have been purchased.

- The BMSA committee on Verification, Validation, and Uncertainty Quantification finished its 2012 report *Assessing the Reliability of Complex Models: Mathematical and Statistical Foundations of Verification, Validation, and Uncertainty Quantification.* The report was released with a technical symposium on V&V that drew some 75 participants. Printed copies of this report were sent in June of 2012 to DOE/ASCR. This report was the culmination of a 21-month study to evaluate the concepts and tools for V&V and UQ in different communities of science and engineering, and to recommend best practices and promising mathematical science research directions. The report has been downloaded over 4500 times, and 150 paper copies have been purchased. The study, which was funded by the National Nuclear Security Administration, DOE-NE, and AFOSR, was carried out by a committee co-chaired by David Higdon, then of Los Alamos National Laboratory, and Marvin Adams of Texas A&M University. The committee included two NAS members and two NAE members. In addition to the co-chairs, many other members of the study committee were connected with DOE. Several members were associated with NNSA's Predictive Science Program, and the committee included members from Lawrence Berkeley National Laboratory (Juan Meza), Sandia National Laboratories (Charles Nakhleh), and Lawrence Livermore National Laboratory Michael Zika).
- BMSA subsequently held three meetings to disseminate the messages of that report broadly within the federal community that is concerned with validation. The first of these meetings, in June 2012, attracted three dozen federal program staff from numerous agencies and identified three important validation topics that were not directly addressed by the 2012 report: best practices for data collection to inform validation and uncertainty quantification; best practices for validation of social science models; and challenges of validation and uncertainty quantification in regulatory settings. At its October 2012 meeting, BMSA held extensive follow-on discussions with staff from NIH and the FDA about these topics. In November 2012, it held an exploratory workshop on the first of these topics, funded by internal NRC funds. Alex Larzelere of DOE/NE helped to plan that meeting, which also included experts from SNL and INEL. And in January 2013, BMSA held another forum for federal program staff to explore the topic of validation in regulatory settings. The Board continues to explore options for strengthening this field.
- In July 2012, the BMSA study on The Mathematical Sciences in 2025 issued its first report, *Fueling Innovation and Discovery: The Mathematical Sciences in the 21st Century.* This NSF-sponsored report offers accessible accounts of the impacts of recent mathematical science research in 14 different areas of science, engineering,

and medicine. Copies were sent to the mathematics and statistics departments in every U.S. college and university, including 2-year institutions. During 2014, over 10,000 copies were distributed free to secondary school mathematics teachers across the United States thanks to additional funding from the Carnegie Corporation of New York and the National Academies. The report has been downloaded almost 6400 times, and some 450 copies have been purchased.

- BMSA partnered with the Academies' Committee on Population to carry out a Congressionally mandated study on how aging of the U.S. population is affecting our macroeconomy. Funding was provided by the Department of the Treasury. The study's final report, *Aging and the Macroeconomy: Long-Term Implications of an Older Population,* was released late in 2012. The study committee was co-chaired by a leading demographer and the President of TIAA-CREF, and it included three NAS members and the former Chair of Aetna. It has been downloaded over 5300 times and sold almost 300 copies (in addition to free dissemination by the NRC). The Treasury Department subsequently commissioned a follow-on study, with which BMSA is marginally involved.
- In 2013, BMSA issued *The Mathematical Sciences in 2025,* the final report of the NSF-sponsored study of the same name. This was the first strategic study by the community since the Odom report in the late 1990s. It has sparked strong community discussion, especially with regard to its call to rethink undergraduate courses and curricula. The study committee was truly a blue-ribbon group, including 9 members of the NAS and 3 of the NAE. To maximize the study's credibility, it was led by a non-mathematician, former Caltech President Thomas Everhart. Two experts with strong ties to DOE national laboratories, Phil Colella and Margaret Wright, were on the study committee. With support from the Academies' own funds, free copies were sent to every U.S. college and university, including 2-year institutions. The report has been downloaded over 9300 times, and more than 300 copies have been purchased. It has also received international attention, garnering reviews in the United Kingdom and generating interest in the South African Academy of Sciences for an analogous study.
- Also in 2013, a BMSA/CATS committee issued *Frontiers in Massive Data Analysis*, the first report from the National Academies about the challenges and opportunities associated with "big data". This NSA-sponsored study identified the research frontiers and recommended promising directions. It has generated a great deal of interest and, in particular, led to a 2014 workshop by BMSA's CATS committee on best practices for training students to work with massive data. The *Frontiers* report has been downloaded over 15,000 times, with more than 300 copies being purchased. It helped establish the mathematical sciences as a central contributor to the subject of big data.

- In 2014, a BMSA-organized study committee issued its report on *Developing a 21st Century Global Library for Mathematics Research.* This report, sponsored by the Alfred P. Sloan Foundation, makes the case for a new sort of scientific library that uses advanced information technology to enable capabilities beyond those associated with simply being a repository. Authored by a cross-disciplinary committee of mathematical scientists and experts in library/information sciences, the report has generated a good deal of discussion internationally and been downloaded almost 2000 time.
- BMSA established a new study committee at the request of Gil Bindewald in DOE's Office of Electricity Delivery/Energy Reliability. This study will develop a long-term strategy for mathematical sciences research of importance to the next-generation electric grid. The study committee—which is co-chaired by former SIAM President John Guckenheimer and leading grid modeler Thomas Overbye—includes 6 NAE members and one NAS member and is a mix of mathematical scientists and power systems engineers, many with strong DOE ties. The committee met once during the performance period and expects to finish its work during 2015.

UNEXPENDED FUNDS

We did not have any unexpended funds left at the end of the grant.

CONCLUSION

The Board on Mathematical Sciences and Their Applications is the only forum where core and applied mathematicians, probabilists, operations researchers, statisticians, scientific computing experts, risk analysts, computer scientists, and members of other mathematically-intensive fields come together to address intellectual and infrastructural issues that affect the broad mathematical sciences community and its relationship to federal agencies. The Board and its Committee on Applied and Theoretical Statistics (CATS) undertake activities that build cohesion within the discipline, strengthen its ties to other fields of science and engineering, and demonstrate the value of the mathematical sciences to research and non-research agencies of the federal government, and strengthen the role of the mathematical sciences in attacking the problems of our time. The latter function helps to identify areas in which the mathematical sciences can grow and to improve the appreciation for, and visibility of, the mathematical sciences.

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