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13. ABSTRACT *(Maximum 200 words)*

The Board on Mathematical Sciences (BMS), National Research Council was established in 1984. The Board has one standing committee, the Committee on Applied and Theoretical Statistics (CATS). The Board, CATS, and other *ad hoc* committees, panels, and working groups established by the Board typically comprise at any one time over 200 mathematical scientists, other scientists, engineers, and medical personnel. The major activities of the Board involve: annual mathematical sciences department chairs colloquium, annual national science and technology symposium, health of the mathematical sciences, articulating emerging research directions, mathematical sciences interacting with other areas, mathematical sciences education, recommendations to federal agencies on research directions, international representation.

The BMS is a catalyst, convener, coordinator, and consensus builder for the mathematical sciences on the national level. It follows a policy of inclusion. It undertakes to do those activities that are necessary for nationwide reform and revitalization but are unlikely to be carried out effectively by other organizations.

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Core Support for the
Board on Mathematical Sciences

BOARD ON MATHEMATICAL SCIENCES

FINAL REPORT

U.S. ARMY RESEARCH OFFICE

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ARO MIPR'S 145-89,137-90

NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL
COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND APPLICATIONS
BOARD ON MATHEMATICAL SCIENCES

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1. INTRODUCTION

In response to the recommendations of the 1984 David Report, the National Research Council ((NRC) established the Board on Mathematical Sciences (BMS) in December 1984 to oversee activities formerly conducted by the Office of Mathematics and the Committee on Applied and Theoretical Statistics (CATS). From its inception in 1984 until the end of 1985, the Board was chaired by Prof. Michael Artin of the Massachusetts Institute of Technology. From January 1986 to May 1991, it was chaired by Provost Phillip Griffiths of Duke University (currently Director of the Institute for Advance Studies). Since June 1991, Dr. Shmuel Winograd of IBM Corporation has been the chair of the Board. The Board consists of 14 members representing the areas core mathematics (5 representatives), applied mathematics (3), statistics (2), operations research (1), health-sciences mathematics (1), social-sciences mathematics (1), and industry (1). The Board has one standing committee, the Committee on Applied and Theoretical Statistics (CATS), currently chaired by Prof. William Eddy of Carnegie-Mellon University, who serves as *ex officio* member of the Board. Additional *ad hoc* committees and panels are formed as needed to carry out individual projects. The Board, CATS, and the *ad hoc* committees, panels, and working groups established by the Board typically comprise at any one time over 200 mathematical scientists, other scientists, engineers, and medical personnel, including many members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The BMS reports to the Commission on Physical Sciences, Mathematics, and Applications (CPSMA) of the NRC.

Three characteristics of the Board on Mathematical Sciences distinguish it from previous undertakings in the mathematical sciences:

- The direct interaction of the BMS with all major players in the mathematical sciences from government, academia, industry, and the professional societies.

- The sustained attention that the BMS provides over many years to research and higher-level education in the mathematical sciences.

- The unity that the BMS brings to the mathematical sciences viewpoint at the national level.

Board activities are described below.

2. BOARD ACTIVITIES

The Board on Mathematical Sciences holds regular meetings of the full Board and its Executive Committee to discuss projects, mission, strategy, and operations. Representatives of federal policy institutions, funding agencies, academia, industry, the professional societies, and the professional communities are often invited to attend. As needed, they are invited to speak on how the areas they represent have an impact on and are affected by the mathematical sciences as well as on their concerns, needs, or problems involving mathematical sciences.

The activities supported exclusively by core funding are the annual Department Chairs Colloquium, the National Science and Technology Symposium, specific reports, the initiation of all projects, and continuing oversight of all BMS committees and panels. Other activities of the Board include projects on the health of the mathematical sciences, interactions between mathematical sciences and other areas, education, and emerging research directions. The activities of the Board fall into eight categories as described below.

A. Department Chairs Colloquium

Each October in Washington, DC, the Board organizes and sponsors the Mathematical Sciences Department Chairs Colloquium. The theme of the 1989 Colloquium was "Chairing the Mathematical Sciences Department of the 1990s." The program included sessions on curriculum, funding, fostering undergraduate programs, and BMS projects (including MS 2000 and David II). Proceedings of this Colloquium were published. The theme of the 1990 Colloquium was outreach of mathematical sciences departments to other university departments, industry, and secondary schools. The theme of the 1991 Department Chairs Colloquium was "Encouraging Talent into the Mathematical Sciences Pipeline," and included sessions on changing U.S. demographics, the Ph.D. job market, and the statistics pipeline. Women, minorities, and smaller non-research departments were in the main stream of that Colloquium. The theme for 1992 will be "Chairing the Changing Mathematical Sciences Department of the 1990s." Each Colloquium includes one or more sessions organized by ICEMAP. Attendees are responsible for their own expenses. Direct meeting costs are recovered through a registration fee. Staff and development costs are borne by core Board funds. The conference draws over 160 department chairs and representatives.

In the future, the Department Chairs Colloquium will continue to be held annually. The content of the Colloquia will shift further in the direction of covering the needs of both research and teaching departments. Starting in 1992, the Mathematical Sciences Education Board (MSEB) will work with BMS on the Colloquium program.

B. National Science and Technology Symposium

The BMS organizes and sponsors an annual National Science and Technology Symposium. This Symposium informs federal policy makers and agencies and the scientific, engineering, and technology communities of important issues in the mathematical sciences and of the relation of the mathematical sciences to other areas and to national interests.

The 1989 symposium *Number Theory* focused on the applications, trends, and future directions of number theory while amplifying its history, intellectual beauty, and role in the rest of mathematics. The proceedings of the 1989 Symposium were published. The 1990 symposium *Partial Differential Equations* focused on the interplay between mathematical theory for partial differential equations and the benefits derived from this theory in applications. In 1991, the Board highlighted in the symposium a recent highly successful report, *Mathematical Sciences, Technology, and Economic Competitiveness*. Each symposium was attended by approximately 150 persons concerned with scientific and policy issues in the mathematical sciences as well as by journalists writing on science and technology.

In the future, the Board will continue to hold annual symposia on science and technology. The symposia will highlight the contributions of the mathematical sciences or the mathematics community to the economy, health, social well-being, and security of the Nation.

C. Health of the Mathematical Sciences

The 1984 NRC David report (*Renewing U.S. Mathematics: Critical Resource for the Future*) is credited with giving rise to an 84 percent increase (in current dollars) in total funding in the mathematical sciences in the period 1985-1988. However, this progress fell far short of the goals recommended by the David I Report. In 1990, the Board issued a report of a second panel headed by E. David entitled *Renewing U.S. Mathematics: A Plan for the 1990s* ("David II Report"). This report examines the state of U.S. mathematics research and recommends additional steps to be taken by the government and universities to ensure the continuing health of the mathematical sciences. A companion document, *Actions for Renewing U.S. Mathematical Sciences Departments*, guides department chairs and others in implementing the recommendations of the David II Report.

In the future, the Board will continue to monitor and report on progress toward balance between support given mathematical sciences and that given other sciences. The Board will assist in creating a unified approach by the mathematical sciences to issues of scientific and technical policy and ensure that this unified approach is taken into consideration by policy makers when making decisions.

D. Articulating Emerging Research Directions

The Impact of Mathematics: Nonlinear Mathematics, Chaos, and Fractals in Science, the proceedings of the 1988 National Science and Technology Week Symposium, was published by the BMS in 1990. This report highlighted how nonlinear mathematics provides explanations of phenomena that were previously not understood. The proceedings of the 1989 National Science and Technology Week Symposium, *Number Theory*, was also published in 1990.

In the future, the Board will continue to stimulate research in critical areas in the mathematical sciences, identify breakthroughs, and make known their significance for mathematical sciences and applications. The Board is considering future studies on core mathematics topics and on the synergy between theory, computation, and experiment.

E. Mathematical Sciences Interacting with Other Areas

Another fundamental area of BMS activities is the interaction of the mathematical sciences with science, engineering, and technology. In May 1991, the report, *Mathematical Sciences, Technology, and Economic Competitiveness*, which articulates the continuing contributions of mathematics to industry, was completed. This report, developed entirely under core funding, has been disseminated to over 800 mathematical sciences departments, 300 colleges of engineering, 50 companies, the mathematical sciences professional societies, and many federal agencies, research laboratories, and policy institutions. The Chinese translation of this report, to be published in the People's Republic of China, is currently in press. This report was featured at a symposium, organized by the BMS and the NRC's Academy Industry Program for October 1991, at which 20 industry executive representatives and an equal number of representatives of the mathematical sciences community discussed how the mathematical sciences can be more responsive to the needs of industry.

Statistics: A Guide to Assessing Societal Risk was published by the Committee on Applied and Theoretical Statistics (CATS) in 1991. The role of statistics in decision making in public health and the environment was featured in this document, which is the proceedings of a symposium sponsored by CATS at the National Academy of Sciences during November (National Statistics Month) 1989 to commemorate the Sesquicentennial of the American Statistical Association. CATS also produced proceedings from a public forum, *The Future of Statistical Software*. One of the objectives of the guidelines for statistical software project was to identify and articulate a suitable scientific basis and performance objectives for statistical software.

The report *Spatial Statistics and Digital Image Analysis*, published by the Board in 1991, is a report that can be used by program officers in the federal agencies as a reference for the applications of spatial statistics to computer vision, oceanography, meteorology, the environment, ecology, and speech recognition. The report *Applications of the Mathematical Sciences to Materials Science*, also published in 1991, surveys the interface between the mathematical sciences and materials science in work on metals, semiconductor materials, nonlinear optical materials, polymers, ceramics, glasses, and biomolecular materials. A follow-up study of Applications of the Mathematical Sciences to Materials Science, one that emphasizes areas such as statistics, which were not emphasized in the first report, is under way.

Also in 1991, the Board published, *Mathematical Foundations of High-Performance Computing and Communications*. This report identified the role of mathematics in the Grand Challenges for HPCC. *Mathematical Opportunities in Nonlinear Optics*, produced exclusively with core funding in 1992, describes the role of the mathematical sciences in creating optical computer and communication systems.

Studies currently under way include Statistics and Oceanography and Mathematics and Molecular Biology. Statistics and Oceanography will point out the pressing need for research in statistics to support certain areas of oceanography. Mathematics and Molecular Biology will highlight recent mathematical work in molecular genetics and evolution and mapping of the human genome.

Motivated by the national need to enhance productivity, CATS is currently conducting studies on Statistical Quality Control Procedures, Probability and Algorithms, and Statistical Issues in the Combination of Information.

The Quality Control project will conduct a review of statistical quality control methodologies and assess their applicability to the measurement of performance in non-routine, white collar tasks. Probability and Algorithms will highlight the advantages in speed and structural insight that can be provided by probabilistic algorithms and probabilistic analysis of deterministic algorithms. Combination of Information explains to a general scientific audience how information from different sources can be correctly combined and points out applications in medicine, social sciences, physical sciences, and national statistics.

A project on Statistical Methods in Software Engineering is currently being developed. This project will spotlight areas in the rapidly emerging field of software engineering to which modern statistical methods can be fruitfully applied. Other projects under consideration include Mathematical Sciences and Computational Chemistry, Language Processing, and Mathematics and Manufacturing.

The Board plans to continue to create expository reports on cross-disciplinary research opportunities for the mathematical sciences. Expanding opportunities for involvement of mathematical science in other sciences, engineering, and technology.

F. Mathematical Sciences Education

Improving university education in the mathematical sciences is an important strategic direction of the Board's activities. In 1988, the Board on Mathematical Sciences, jointly with the NRC's Mathematical Sciences Education Board, launched a major project, Mathematical Sciences in the Year 2000 (MS 2000). This project has issued three reports: *Everybody Counts* (in 1989), *A Challenge of Numbers* (in 1990), and *Moving Beyond Myths* (in 1991). These reports provide a national assessment of the current serious situation in mathematical sciences education at all levels; articulation of standards for curricula, faculty, resources, quality, and productivity of collegiate mathematical science departments and faculty; identification of the forces that drive toward change; and recommendations for sweeping change by colleges and universities, federal agencies, state governments, foundations, and professional societies.

The project on Doctoral and Postdoctoral Study in the Mathematical Sciences was recently completed, and the report, *Educating Mathematical Scientists: Doctoral Study and the Postdoctoral Experience in the United States*, was presented at a public briefing in April 1992. The study found that successful programs possess (1) a focused, realistic mission; (2) a positive learning environment; and (3) relevant professional development. *Chairing the Mathematical Sciences Department of the 1990s*, the proceedings of the 1989 Department Chairs Colloquium, were published by the Board under core funding in 1990 to inform department chairs on curriculum, funding, fostering undergraduate programs, and BMS projects (including MS 2000 and David II).

In the future, Board will continue to provide leadership in post-secondary education. Specific areas of Board interest are attracting and retaining new talent in the mathematical sciences, improving mathematical sciences education of scientists, engineers and K-12 teachers, and broadening access to the mathematical sciences to all individuals regardless of race, gender, or physical ability. A study on the Professional Masters' Degree in the Mathematical Sciences and another on Modern, Interdisciplinary University Statistics Education are being planned.

G. Recommendations to Federal Agencies on Research Directions

During 1988-91, the Board supervised the work of several advisory panels to federal agencies. The Panel on Applied Mathematics Research Alternatives for the Navy (PAMRAN), formed in 1977, provided expert advice to the mathematical sciences program at the Office of Naval Research (ONR), and, through ONR, to naval research laboratories and programs. PAMRAN issued an advisory report *Selected Opportunities for Mathematical Sciences Research Related to the Navy Mission: An Update* in 1990. The Advisory Panel to the Mathematical Sciences Program of the National Security Agency (NSA) provided advisory and peer-review services for NSA's unclassified mathematical sciences research funding program until 1991. In 1989, 1990 and 1991, the number of proposals reviewed was 150, 150, and 130, respectively.

The Board will continue to maintain a responsive presence for the federal government for expert assessments and advice on matters pertaining to the mathematical sciences.

H. International Connections

The U.S. National Committee for Mathematics (USNCM) is responsible for representing the U.S. at meetings of the International Mathematics Union (IMU) and at the International Congresses of Mathematicians. In August 1990, the USNCM participated in the International Congress of Mathematicians (ICM) in Kyoto, Japan. Two of the proposed resolutions of the USNCM were adopted at the meeting of the IMU in Kyoto.

The U.S. Commission on Mathematical Instruction nominates the U.S. delegation to the International Congress on Mathematics Education, and will head-up the official delegation to ICME-7 in Quebec in August 1992. USCMI organized a session at the Joint Mathematics Meetings in Baltimore, January 1992, on the topic of ICME-7 to inform and encourage U.S. participation in this and future congresses. The USCMI also supported the Eighth Inter-American Conference on Mathematics Education held in August 1990 in Florida.

In the future, the Board will continue to ensure representation and participation of U.S. mathematical scientists in international programs and research programs. The Board will create ties with the Division of International Programs at the National Science Foundation as well as with the State Department. Since these agencies require information on geographic areas rather than technical disciplines, the Board expects to participate in these projects as part of the Commission on Physical Sciences, Mathematics, and Applications. Direct contacts with government, quasi-government, and private organizations representing the mathematical sciences in other countries will be created.

3. RELATIONS WITHIN THE NRC AND WITH OTHER ORGANIZATIONS

The BMS works cooperatively with the other units of the NRC, especially the other Boards of the Commission on Physical Sciences, Mathematics, and Applications (CPSMA), the Committee on National Statistics (CNSTAT), and the Mathematical Sciences Education Board (MSEB). The BMS is increasing its direct contact with the National Academy of Engineering (NAE) and the Institute of Medicine (IOM), the Academy Industry Program, the Manufacturing Forum, and other NRC/NAS/NAE/IOM organizations.

NAS: The BMS presents information on Board activities to the two NAS mathematical sciences sections (mathematics and applied mathematics) at the NAS annual meeting in April of each year.

Other CPSMA Boards: The project Mathematical Sciences and Computational Chemistry is under consideration as a joint project by the BMS and the Board on Chemical Sciences and Technology. Joint projects with other CPSMA Boards are under discussion. BMS staff frequently contact other Boards for recommendations of potential committee members and report reviewers.

CNSTAT: CATS will send representatives to the CNSTAT Workshop for the DOD on Statistical Applications in the Testing of Weapons Systems scheduled for September 1992.

MSEB: The MS 2000 Project, a joint project of the BMS and the MSEB, was conducted from 1989 to 1991. The MSEB has been invited to work with BMS on the program for the 1992 Department Chairs Colloquium.

Federal Policy Agencies: Improving the level of appreciation for the mathematical sciences in FCCSET, FCCSET/PMES and FCCSET/EHR is an objective of the Board.

Federal Mission Agencies: Ties to the ICEMAP agencies (AFOSR, ARO, DARPA, DOE, NSA, NSF, ONR), the Board's traditional sponsors, are being supplemented by ties to NASA, NIH, EPA, DOJ, DoEd, NIST, and the State Department. Representatives of federal mission agencies are invited to appropriate BMS meetings and functions.

The Congress: BMS members participated in creating a response to a request from the House Subcommittee on Science for a statement of goals, assessment procedures, and attainment of goals by the mathematical sciences community. The Board will function as a source of advice and testimony to Congress on research and education issues affecting or affected by the mathematical sciences.

Mathematical Sciences Professional Societies: The Board does strategic planning and speaks for the whole mathematical sciences community, and maintains close ties to the professional societies. Representatives of the professional societies are invited to appropriate BMS meetings and functions and BMS representatives attend professional society meetings and functions upon invitation.

Academic Departments of Mathematical Sciences: The BMS works through the Department Chairs Colloquium, direct dissemination of reports, and the professional societies to identify and assess problems in mathematical sciences research, education, and manpower that academic departments are experiencing.

Industry: The BMS works through symposia and direct dissemination of reports to industry to identify and draw attention to areas in which increased use of the mathematical sciences will enhance competitiveness. The BMS recommends ways to prepare students for non-academic careers.

Foundations: The BMS works with foundations to identify topics of mutual interest, including mathematical sciences education, and provides assessment and recommendations.

Individual Mathematical Scientists: Through its publications, colloquia, and symposia, the BMS addresses the needs of the some 3,000 mathematical scientists active in research and the larger number engaged in education. The Board promotes mainstreaming of underrepresented groups (women, racial minorities, the disabled).

The Public: The Board produces books and booklets of a popular nature to encourage public understanding of the benefits of the mathematical sciences in everyday life. The Board writes articles or assists reporters in writing articles for newspapers and magazines that present mathematics as useful, interesting, and worth studying.

International Relations: The Board ensures representation and participation of U.S. mathematical scientists in international programs and research projects through the U.S. National Committee for Mathematics and the U.S. Commission on Mathematical Instruction. The Board works with private and governmental organizations in other countries to identify common interests and provide mutual support in addressing problems that are international in scope.

4. CONCLUSION

The Board on Mathematical Sciences is a catalyst, convener, coordinator, and consensus builder for the mathematical sciences on the national level. It follows a policy of inclusion. It undertakes to do those activities that are necessary for nationwide reform and revitalization but are unlikely to be carried out effectively by other organizations.