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

Proposal to the
Department of Energy

CORE SUPPORT OF THE BOARD ON MATHEMATICAL SCIENCES

SUMMARY

This proposal summarizes activities conducted by the Board on Mathematical Sciences (BMS) during the period August 1, 1994 to July 31, 1995 and describes future plans of the Board for the period August 1, 1995 to July 31, 1998. We are requesting core support in the amount of $105,000 ($35,000 each year) from the Department of Energy for the additional three-year period. The BMS activities supported exclusively by core funding are the annual Department Chairs Colloquia, the National Science and Technology Symposia, specific reports, the initiation of all projects, continuous oversight of all activities, and partial core support of the Committee on Applied and Theoretical Statistics (CATS). Other activities of the Board include giving recommendations on research directions to federal agencies, and reports on education in the mathematical sciences, interaction of mathematical sciences with other areas, health of the mathematical sciences, and emerging research directions.

1. INTRODUCTION

In 1984 the National Research Council (NRC) established the Board on Mathematical Sciences to maintain awareness and active concern for the health of the mathematical sciences and serve as the focal point in the NRC for issues connected with the mathematical sciences. Dr. Avner Friedman of the Institute for Mathematics and Its Applications at the University of Minnesota is the chair of the Board. The Board consists of 16 members representing the areas of core mathematics (4 representatives), applied mathematics (including industry) (4), statistics (3), operations research (1), scientific computing (2), and social-sciences mathematics (1). The Committee on Applied and Theoretical Statistics (CATS) is a standing committee of the Board, and is currently chaired by Dr. Jon Kettenring of Bellcore; he serves as an 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 100 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.

For the period August 1, 1992 to July 31, 1995, BMS received $108,306 from the Department of Energy for its core activities. During this period, additional core support for BMS was received from the following members of the Interagency Committee on Extramural Mathematics Programs (ICEMAP): National Science Foundation (NSF), Army Research Office (ARO), Air Force Office of Scientific Research (AFOSR), National Security Agency (NSA), and Office of Naval Research (ONR).

Board activities are described below. Board activities done through the Committee on Applied and Theoretical Statistics have the notation "(CATS)" after their titles.

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 Colloquia, the National Science and Technology Symposia, specific reports, the initiation of all projects, continuing oversight of all BMS committees and panels, and partial core support of CATS. 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 Colloquia

Each October in Washington, DC, the Board organizes and sponsors the Mathematical Sciences Department Chairs Colloquium for four-year colleges and universities. The theme of the 1994 Department Chairs Colloquium, held on October 28-29, 1994 was "Shaping a New Contract with the University and Society." The keynote speaker was Neal Lane, Director of the National Science Foundation. The speakers and panel members at the Colloquium included chairs of mathematical sciences departments, university administrators who come from the mathematical sciences community, representatives from business, industry, and government who make use of or are concerned with the mathematical sciences, and representatives of federal research and education programs. The colloquium provided current and future department chairs with information on the changing role of the mathematical sciences both within and outside academia. Attendance, in a third year of financial restraint at universities, was approximately the same as in previous years, while evaluation comments were much more favorable than in the recent past.

The 1995 Department Chairs Colloquium, "Managing While Science and Education Evolve," will be held on October 20-21, 1995. A major figure in national science policy has been invited to be keynote speaker. For this colloquium, sessions are planned on the fundamentals of chairing a department, interdisciplinary initiatives, evolving university departments, employment opportunities for mathematics doctorates, evolving assessment of faculty teaching, successes encouraging underrepresented minorities, changes in statistics practice, successes encouraging women, issues for chairs of peer universities, and a number of other areas. People attending 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 180 department chairs and other representatives.

The Board organized the first Division and Department Chairs Colloquium for two-year colleges at the November 3-6, 1994 annual conference of the American Mathematical Association of Two-Year Colleges (AMATYC) in Tulsa, OK, on the theme "The Partnership of the Mathematics Division in Technical Education." This was done in partnership with the Mathematical Sciences Education Board. The event was so successful that AMATYC invited BMS to organize a second colloquium at the November 9-12, 1995 annual AMATYC conference in Little Rock, AR. Planning for this second AMATYC colloquium, with working theme "Addressing Critical Issues," is progressing.

B. 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 1994 Symposium on the topic of "Motion, Control, and Geometry" was held at the National Academy of Sciences on April 12, 1994. Proceedings of this Symposium are being prepared. The 1995 Science and Technology Symposium will have as its theme "The Mathematical Sciences in Seismology," and is being planned for the summer of 1995 at the National Academy of Sciences. The tentative speakers include William Symes of the Department of Mathematical Sciences at Rice University and Norman Bleistein of the Department of Mathematics at the Colorado School of Mines. BMS chair Avner Friedman will moderate, and proceedings will be prepared. Future 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 Board continues to monitor and strives to maintain the health of the mathematical sciences, and works toward the improvement of the state of the profession. In response to concern expressed by an ad hoc committee of leaders of the statistics profession, including representatives from the National Institute of Statistical Sciences, the Committee of

Presidents of Statistical Societies, and the BMS Committee on Applied and Theoretical Statistics, agreed that a comprehensive strategic review of statistics was overdue. Therefore, with support from the NRC, CATS organized an April 27-28, 1995 planning meeting for a major study addressing "Statistics in the 21st Century: Impacts, Outlooks, and National Needs." The planning meeting will: define the study, indicate what should be the report scope, task, and audience, recommend a composition profile for the study committee, and produce guidelines for performing the proposed study. The study will commence when the project receives NRC approval and support is procured.

To provide leadership for the community in a period of continuing changes in the research environment, the BMS is organizing a forum on "Actions for the Mathematical Sciences: Adapting to the Changed Environment" to explore emerging opportunities for mathematicians to have impact on science and technology, and to indicate new directions for both pure and applied mathematical research. In the context of a select number of areas such as materials science, the biological sciences, and medical science, and with the input of representatives from outside the mathematical sciences community, the forum will examine what steps mathematics should take to build upon existing connections with those areas, and what actions the community should take in response to the changed environment to benefit the way mathematical research is pursued in the United States.

The BMS is participating with three NRC units, the Board on Physics and Astronomy, the Board on Chemical Sciences and Technology, and the Office of Scientific and Engineering Personnel, in planning efforts for a project on "Career Options for Doctorates in the Physical Sciences and Mathematics: Reality, Myths, and Opportunities." NRC support was obtained for a planning meeting to determine if sufficient data and other analytical information is available to get an accurate assessment of employment conditions in physics, chemistry, and mathematics, and to describe the wide variety of different possible career paths for PhD graduates in these three disciplines. The planning meeting will be held in the summer of 1995.

D. Articulating Emerging Research Directions

In response to a request from the Office of Naval Research, the Board organized a September 26-27, 1994 National Research Council symposium on "Large-scale Structures in Acoustics and Electromagnetics" to spotlight relative merits of time-domain and frequency-domain techniques in acoustics and electromagnetics, and investigate ways in which they can be used together for enhanced progress in the analysis of large-scale structures. Participants indicated the event was very successful in constructively bringing together researchers from related areas to stimulate product exchange of insights. The proceedings are in production and will be published by the National Academy Press.

A study committee of the Board is finishing its report for the project "Group Theory: The Language of Symmetry in Science and Technology." This study, which looks at group theory in mathematics, physics, and chemistry, is being done with the Board on Physics and

Astronomy as a partner. The report will be published in 1995 by the National Academy Press.

The Chief of Statistical Research Techniques for the National Security Agency (NSA) asked the Board's Committee on Applied and Theoretical Statistics (CATS) to commence an activity on the statistical analysis and visualization of massive data sets (those that are orders of magnitude larger than can be dealt with by present statistical analysis and visualization methods). In response, CATS has planned a 2-day workshop for July 7-8, 1995 in Washington, DC, to explore statistics research challenges presented by massive data sets. The objectives of this activity are (1) to bring multi-disciplinary national attention to the statistical analysis and visualization research challenges posed by massive data sets, (2) to expose those challenges to a broader segment of the research community, and in particular the statistics research community, and (3) to stimulate ground-breaking statistics research on problems concerning massive data sets that are or will soon be confronting the research investigators in such areas as the atmospheric sciences, geosciences, astronomy, ecology, and the biological sciences. Printed proceedings and a videotape of the main sessions will be produced and made available via Internet. CATS has also planned a follow-up session on this topic for the August 1995 Joint Statistical Meetings in Orlando, FL.

The Board's Committee on Applied and Theoretical Statistics has initiated a project on "Causal Inference and Statistics" in response to serious conflict that has arisen in recent years between camps that favor different approaches to causal inference. Since there is now great disagreement in the research community about its statistical underpinnings, CATS is working to convene an impartial study panel whose task will be to produce a report that reviews current causal inference practice and thoroughly evaluates the logic of causal inference; assesses the role that statistics, probability, and computing play in causal inference methods; synthesizes and integrates views to forge a common causal inference vocabulary for the many scientific areas of its application; and recommends where existing summaries of uncertainty in causal inferences are inadequate and need to be improved. The report will delineate research frontiers in this area with respect to modeling, data collection, concepts of randomness, and inferential logic, and will include an extensive bibliography of both traditional and contemporary resources on the statistical logic of causal inference and its application.

The Board is working on plans for future studies on core mathematics topics and on the synergy between theory, computation, and experiment, and the ensuing research opportunities, as well as on improving the understanding of the mathematical sciences by decision makers and the general public.

E. Mathematical Sciences Interacting with Other Areas

In April 1995, the Board on Mathematical Sciences produced the book *Calculating the Secrets of Life: Applications of the Mathematical Sciences in Molecular Biology*, that was published by the National Academy Press. It was written by a multidisciplinary BMS committee chaired by Eric Lander. It gives a state-of-the-art view of significant

contributions, open problems, and likely future directions of mathematical sciences research and methods in molecular biology, especially recent intensive work in the areas of genome and protein structure research. Topics treated in the book include probabilistic models for mapping genes, extremal statistics for probing evolutionary origins, stochastic processes for measuring the rate of evolution, geometry to describe the coiling of chromosomes, topology for probing the action of enzymes, and computational methods for predicting protein structure.

In April 1995, the BMS in partnership with the Board on Chemical Sciences and Technology produced the report *Mathematical Challenges from Theoretical/Computational Chemistry* that identifies areas of computational chemistry, particularly those related to molecular structure and related properties, where the mathematical sciences have contributed and could contribute more. The report was published by the National Academy Press, and is also available via Internet. Three of the study committee members gave presentations on the subject at the January 1995 Joint Mathematical Meetings in San Francisco. The study committee chair also gave a presentation on the report on April 4, 1995 at the American Chemical Society meeting.

The Board project on "The Mathematics and Physics of Emerging Dynamic Biomedical Imaging," being done in partnership with both the Board on Physics and Astronomy and the Institute of Medicine's Division of Biobehavioral Sciences and Mental Disorders, is to produce a report on the links between the mathematical sciences and medical imaging. At its December 13-14, 1994 meeting, the study committee agreed on recommendations for mathematics and physics research of high value to biomedical imaging. Final changes are being made to the report, illustrations are being selected, and writing style is being homogenized. The report is expected to be available by August, 1995. At the BMS's suggestion, private NRC funds were secured to make the report available on Internet.

The BMS delivered a letter report from CATS to the U.S. Environmental Protection Agency on *Statistical Quality Control Procedures* on October 6, 1994. This letter report included a review of statistical quality control methodologies and assessed the applicability of the latter to the measurement of performance in non-routine, white collar EPA tasks. The BMS director and a CATS member subsequently met with EPA representatives in December, 1994 as follow-up and to provide additional information.

The CATS report *Statistical Software Engineering* is to be published by the National Academy Press in the summer of 1995. It spotlights software engineering problem areas to which modern statistical methodology can be fruitfully applied. Discussions are underway to have the report reprinted in a major statistics journal, and possibly also make it available on Internet.

F. Mathematical Sciences Education

Seven of the first eight papers from the Board's Committee on Applied and Theoretical Statistics (CATS) symposium proceedings *Modern Interdisciplinary University Statistics Education* were reprinted in the February 1995 issue of the journal *The American Statistician.*

The BMS is working to create educational material for high-school students based on the BMS research book *Calculating the Secrets of Life: Applications of the Mathematical Sciences in Molecular Biology.* The Mathematical Sciences Education Board (MSEB) will cooperate with BMS on this project.

The BMS is planning to produce a series of "Expositions in the Mathematical Sciences" that consists of essays based on recent BMS reports. The aim is to have these be presented at a level for the general public to understand.

Five of the sessions at the October 1994 Department Chairs Colloquium pertained to mathematical sciences education: "Interdisciplinary Initiatives: Mathematical Sciences and Their Applications Throughout the Curriculum," "Articulation of HBCU Undergraduate Programs with Non-HBCU Graduate Programs," "Systemic Initiatives of the National Science Foundation in Education," "Interacting with Other Mathematics Departments: The Mathematics and Education Reform Department Network," and "Highly Effective Statistics Programs." Three session for the October 1995 Chairs Colloquium will be addressing mathematical sciences education issues, with working titles "Successful Interdisciplinary Examples," "Evolving Assessment of Faculty Teaching," and "Project NExT Successes."

G. Recommendations to Federal Agencies on Research Directions

The Board continues to maintain a responsive presence for the federal government for expert assessments and advice on matters pertaining to the mathematical sciences. The BMS and CATS activities on Time- and Frequency-Domain Acoustics and Electromagnetics, and Statistics Research for Massive Data Sets are being done in response to federal agency requests.

H. International Connections

The Board on Mathematical Sciences is working to re-establish the U.S. National Committee for Mathematics (USNCM) as a separate BMS committee in accordance with Articles of Understanding produced at the May 4-5, 1994 Conference Board of the Mathematical Sciences (CBMS) workshop. Until that happens, BMS is responsible, in its capacity as USNCM, for representing U.S. mathematical sciences internationally at the International Congresses of Mathematicians (ICM), and at meetings of the International Mathematics Union (IMU). With the input and advice of the mathematics professional societies, USNCM appointed a five-person delegation to the July 31-August 1, 1994 IMU General Assembly in Lucerne, Switzerland. This delegation received input from the societies and the community and set up the U.S. agenda for the General Assembly. A U.S.

delegate chaired the Committee on Finances and Dues, and other U.S. delegates served on the Nominating Committee and the Resolutions Committee. The delegation participated actively in the discussion and debates concerning broadening the outlook of the mathematics community and the need for more openness in the conduct of IMU business. In response to delegation suggestion, the BMS will strive for some continuity in the delegation from one General Assembly to the next.

The Board's U.S. National Commission on Mathematics Instruction (USNCMI) met at the Joint Mathematics Meetings in January 1995. USNCMI continues to work with the National Council of Teachers of Mathematics (NCTM) to create a tax-exempt fund supporting mathematics education activities in developing countries. USNCMI advised, evaluated, and is monitoring the Third International Mathematics and Science Survey (TIMSS). USNCMI is working to better inform the community through AMS, NCTM, and MAA journals on international mathematics education activities, and has proposed that the International Commission on Mathematical Instruction (ICMI) initiate mathematics education activities parallelling those planned for mathematics under World Math Year 2000. USNCMI presented a session entitled "International Perspectives on Mathematical Education" for the April 6-9, 1995 NCTM Annual Meeting in Boston, and intends future programs for NCTM and MAA. USNCMI is working with NCTM in the application and administration of travel grants to the Eighth International Congress on Mathematical Education (ICME-8) in Seville, Spain in 1996, and on focus topics for that congress. USNCMI's chair reports on USNCMI activities at the May 6-7, 1995 CBMS meeting.

3. RELATIONS WITHIN THE NRC AND WITH OTHER ORGANIZATIONS

BMS works cooperatively with the other units of the NRC, especially the other Boards of the Commission on Physical Sciences, Mathematics, and Applications, the Committee on National Statistics (CNSTAT), and the Mathematical Sciences Education Board (MSEB). 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. The Board will be making its reports and information more widely available by the establishment of a BMS World Wide Web home page under the general one for the NRC.

NAS: 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. BMS gets NAS input on BMS activities and projects.

Other NRC and IOM Boards: Joint projects with other NRC and IOM boards are a large part of the activity of BMS (see Sections 2.A and 2.E). BMS frequently contacts other Boards for recommendations of potential committee members and report reviewers. BMS provides suggestions for committee members and reviewers to other boards on request. BMS and CATS are cooperating with the Board on Biology and the Committee on National Statistics on the project "DNA Forensic Science: An Update" that is producing a report assessing new information that has appeared since publication of the 1992 NRC report *DNA*

Technology in Forensic Science, and its implications for the validity of current and proposed practices for the use of DNA evidence. BMS is working with the Commission on Behavioral and Social Sciences and Education on a proposed study of "The Application of the Science of Complexity to Issues in the Behavioral and Social Sciences."

Federal Policy Agencies: Improving the level of appreciation for the mathematical sciences in all federal policy agencies with science and technology concerns is a continuing 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 agencies are invited to appropriate BMS meetings and functions.

The Congress: The Board will function on request as a source of advice and testimony to Congress on research and education issues affecting or affected by the mathematical sciences, and provides relevant information as warranted to the community from Congress.

Mathematical Sciences Professional Societies: The Board maintains close ties to the professional societies and does strategic planning in concert with them. Representatives of the professional societies are invited to appropriate BMS meetings and functions and BMS representatives attend professional society meetings and functions upon invitation. The BMS director participated in the September 1994 meetings of the AMS Committee on Education, the AMS Committee on Science Policy, and the Joint Policy Board for Mathematics, and the December 1994 Conference Board of the Mathematical Sciences meeting.

Academic Departments of Mathematical Sciences: The BMS works through the Department Chairs Colloquia, direct dissemination of reports, and the professional societies to identify, assess, and address problems in mathematical sciences research, education, manpower, and management 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, and brings industrial perspectives to the attention of academic departments both through its reports that include this dimension, and Chairs Colloquia sessions on this sector of the mathematical community.

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) both nationally and internationally.

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. National Commission on Mathematics 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, re-inventing, and revitalization but are unlikely to be carried out effectively by other organizations.

Attached are rosters for the Board and its committees and panels. The Board staff currently consists of the director, a program officer, financial and administrative manager, and administrative assistant.

A report on the activities of the Board connected with this grant will be submitted annually.

Presidential Executive Order 12382 of January 19, 1993 amends Executive Order 2859, which established the National Research Council (NRC), reaffirming and clarifying the NRC's relationship with the U.S. Government. Of particular relevance to this proposal, the Executive Order directs the NRC to disseminate to duly accredited persons and the public the scientific and technical information it gathers and collates. Further, the actual expense of such reports shall be paid to the Academy through grants-in-aid and contracts by executive departments and agencies. The Academy's acceptance of an award by a department or agency of the U.S. Government, is conditioned upon adherence to the letter and spirit of the Executive Order which provides the framework within which the NRC and the Government are expected to interact. The Government printing and binding regulations intend that contractors do not become prime or substantial sources of printing for departments or agencies. The Executive Order requirement that the NRC disseminate its reports is interpreted as not being primarily or substantially for the purpose of having such findings printed for the use of a department or agency and therefore outside the limitations of the printing and binding regulations. Accordingly, included in the attached estimate of costs is an amount projected to cover the cost of reproducing reports for this activity. Reports resulting from this grant shall be prepared in sufficient quantity to ensure their