

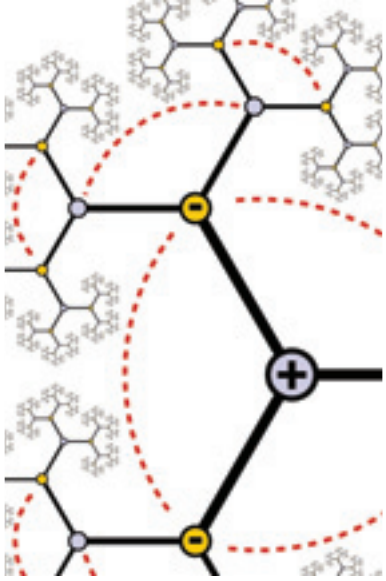

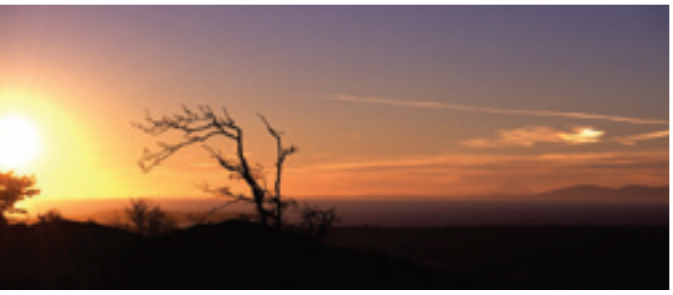

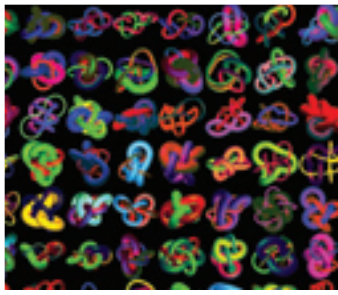

Solutions
for a Complex Age

Long Range Plan for Mathematical and Statistical Sciences Research in Canada 2013–2018

2013–2018 | Report of NSERC's Long Range Plan Steering Committee for the Mathematical and Statistical Sciences

Acknowledgements: The Long Range Plan Steering Committee for the Mathematical and Statistical Sciences is pleased to present our Long Range Plan for 2013–2018 and beyond. This plan—the first for our disciplines—was prepared at the request of the Natural Sciences and Engineering Research Council (NSERC). Details about the Steering Committee, its terms of reference and consultations with our research communities are provided in Appendix A. NSERC funding for the preparation of the plan is gratefully acknowledged.

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Long Range Plan for Mathematical and Statistical Sciences Research in Canada 2013–2018

Executive Summary

The mathematical and statistical sciences are essential to discovery and innovation in Canada and throughout the world. A key source of transformative breakthroughs in science, they provide both new ideas and fundamental tools for scientific and technological innovation.

Advances in mathematics and statistics are vital to the growth and smooth functioning of the Canadian economy, and to our society as a whole. As the 21st century progresses, they will play a crucial role in helping to understand and solve many of the energy, environmental and health challenges that are priorities for Canadians.

Mathematics and statistics are everywhere—from the way we manage our investments to the way we track our transportation systems or explore the outer reaches of space. The theories, models and methods of the mathematical and statistical sciences are part of an almost invisible foundation that supports the way we interact with one another, transact our business and construct the world around us.

Mathematics and Statistics—Advancing Discovery and Innovation

Canada aims to be a top global performer of science, technology and innovation in order to thrive in a global knowledge economy and to maintain the quality of life that Canadians cherish. A strong capacity in mathematics and statistics research and training in Canada is central to achieving this goal.

The Power to Transform Science and Technology

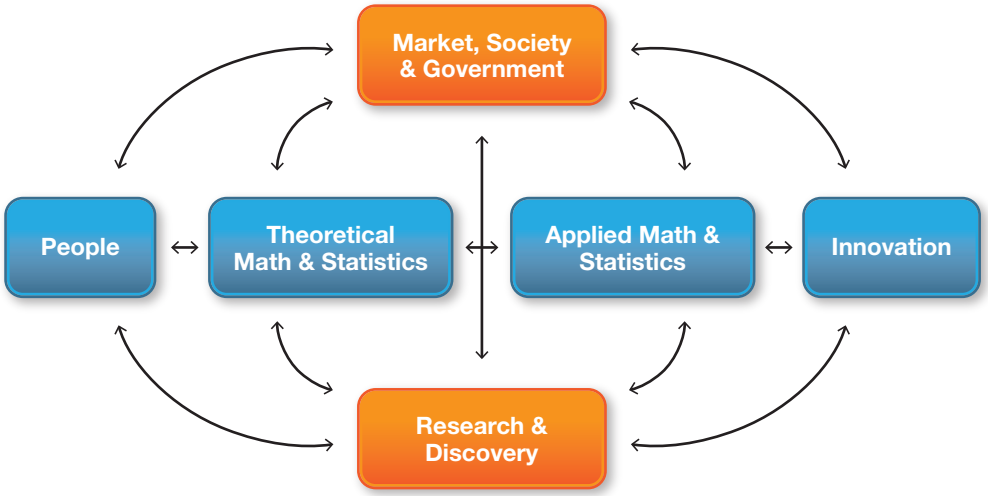
The mathematical and statistical sciences are fundamental to the advancement of science. Researchers across the physical, health and social sciences depend on ideas from mathematics and statistics to explore new concepts, analyze their data and verify their findings.

The mathematical and statistical sciences—both pure and applied—can be found at the heart of almost every effort to push the boundaries of science and related innovation, powered by technological advances and the ubiquity of data. Mathematical and statistical methods enable us to model complex ecological systems, assess new materials and crack the codes of nature. They also drive advances in computer science, with application to most scientific and technological advancements.

There is no "best before" date on a theorem in mathematics, and the deep and beautiful foundations of the subject have inspired thinkers for many centuries. Mathematics has also shown, time and again, an uncanny ability to cross boundaries between the sciences and to drive forward great leaps in scientific understanding and countless technological applications. This power to transform

Accelerating Innovation and Discovery—Engaging Mathematics and Statistics

Collaborations with research teams from across science, industry and government enable mathematicians and statisticians to explore themes linked to real-world problems and to use the ideas needed for these collaborations as inspiration for their own research. Strategic feedback of this kind is advancing the mathematical and statistical sciences at an unprecedented rate and contributing to S&T solutions for important global challenges and Canadian priorities.



has been particularly notable in physics, where mathematics has laid the groundwork for revolutionary breakthroughs in areas as diverse as quantum mechanics and string theory.

The impact of statistical science can also be observed across almost all fields of intellectual enquiry. The force of the oncoming "data tsunami"—as information and communications technologies enable business, governments and individuals to collect and manipulate ever-increasing amounts of data from diverse sources —will only accentuate the demand for statistical expertise.

Accelerating Discovery and Innovation in the 21st Century

Many see the 21st century as a Golden Age for the mathematical and statistical sciences around the globe. Already, the first decade has brought an unprecedented level of research activity in both mathematics and statistics, generating important theoretical breakthroughs and spinning off new areas for exploration and surprising possibilities for application.

Both sciences are bursting with new ideas as the borders between mathematical and statistical sub-disciplines fall away and many of the world's most talented people are attracted to study or practice mathematics and statistics. Add to this the ever-evolving range of high-power computational and graphical tools now available to the research community, and breakthroughs in almost any area of the mathematical and statistical sciences—and related discovery and innovation—are possible.

In a world increasingly characterized by complexity, the ability to tease apart difficult problems and work with multifaceted systems is essential. Mathematical and statistical scientists have the expertise and the advanced theoretical and computational tools available to help generate game-changing technologies and ideas that can drive the global economy, and to implement innovative solutions to many of the world's most pressing problems.

Changing Relationships—Mathematics and Statistics as a Strategic Investment

Researchers with mathematical and statistical expertise are increasingly sought after to contribute to projects of all kinds across the sciences, government and industry. This collaboration has unleashed a wave of creative thinking and new experimental approaches that have had an extraordinary impact on discovery and innovation in all areas. The influence on mathematics and statistics has been similarly profound—the testing of mathematical and statistical theory in the real world has raised new and interesting questions for mathematicians and statisticians to pursue and solve.

As the link between scientific discovery and innovation tightens—and the global research enterprise becomes more interdisciplinary and fast-paced—the strategic importance of the mathematical and statistical sciences only grows. The ability to explore theories and to model situations using mathematical insights and statistical methods is becoming ever more essential to science and engineering, reducing risk and cost by enabling faster, more responsive feedback loops between theory, discovery and application.

The value generated by investments in the mathematical and statistical sciences is exceptionally high. Both sciences are relatively low-cost in terms of their capital infrastructure requirements, yet their influence on talent, discovery and innovation—the three key building blocks of a knowledge-based society and economy—is both broad and deep.

Our Vision

Canada will be a world leader in the mathematical and statistical sciences, and a driving force in interdisciplinary research and innovation that contributes solutions to important Canadian and global challenges.

Vision for Canadian Mathematics and Statistics

Canada is well placed to make important contributions to the evolution of the mathematical and statistical sciences at the international level—both by pushing the boundaries of pure mathematics and theoretical statistics, and by excelling in linking these ideas to the grand challenges that will define human progress in the 21st century. Our communities of researchers have the vision, talent and expertise to achieve international excellence and, in particular, to be at the leading edge of interdisciplinary research and innovation. The Council of Canadian Academies (CCA) report, *The State of Science and Technology in Canada, 2012* (Council of Canadian Academies, 2012), shows Canadian mathematics and statistics as having improved in both relative citation rates and numbers of publications since 2006. Our mathematical and statistical sciences research base is ranked 9th in the world by Average Relative Citation rates, and 5th in the world in a survey of top-cited international researchers.

Notably, our research communities are already at the forefront of integrating mathematical and statistical expertise into interdisciplinary teams. Mprime (formerly Mitacs[1]) and other collaborative initiatives have built a strong capacity for interdisciplinary work with industry and other sectors of society.

The CCA's 2012 report on the state of S&T noted the high rate of international collaboration among Canadian researchers in the mathematical and statistical sciences. Using new bibliometric indicators designed to reflect the increasing interdisciplinarity of research, it also pointed to some of the hot spots where interdisciplinary research is most intense. From the report: "Canada's most rapidly growing research clusters are associated with networking and wireless technologies, information processing and computation, advanced data analysis, digital media technologies, speech and image recognition, carbon nanotubes and graphene, fuel cell technology, and space and planetary science." Canada's mathematics and statistics research communities are actively engaged with discovery and innovation in many of these areas. Indeed, Mprime has supported projects in six of the eight emerging research clusters mentioned above.

1 Prior to May 16, 2011, the Network of Centres of Excellence (NCE) in the mathematical sciences was known as MITACS Inc. Effective May 16, 2011, the mathematical sciences NCE assumed the name Mprime Network (Mprime Network © 2011). In this document, we use Mprime for convenience to refer to the NCE both before and after the restructuring in 2011.

Our goal for our research communities over the next five to ten years is to build on this expertise to bring the mathematical and statistical sciences to the fore in finding solutions to issues that really matter to Canadians and to the world—from energy to security to environment to health care.

Achieving Our Vision—Three Fundamentals

Our vision for building this capacity rests on three fundamental pillars:

- **People** Ensuring Canada's researchers are among the best in the world, and that Canada has the highly qualified personnel available to meet the demand for the mathematical and statistical sciences in a knowledge economy and complex society.
- **Research and discovery** Maintaining a vibrant, world-class, basic and applied research base that can drive discovery and innovation.
- **Innovation and connections** Fostering innovative approaches that advance interdisciplinary research, embed researchers in industry, and facilitate the flow of ideas between researchers and their potential partners across science, industry and government.

Realizing this vision—and its many potential benefits for Canadians—will require a strong commitment to continued investment in mathematical and statistical sciences research, and a willingness to find new ways to collaborate with Canada's research community and its funders.

For Canada to have the mathematics and statistics capacity it needs to advance discovery and innovation over the coming decade, all three of these fundamental pillars must be robust and be well connected to each other.

This Long Range Plan describes the opportunity and challenges that cut across all three of these pillars, and makes interrelated recommendations aimed at strengthening all three.

What We Heard—Community Concerns and New Initiatives

Canada's researchers in the mathematical and statistical sciences have the expertise, drive and momentum to bring real innovation to the most challenging and complex problems of importance to Canada and the world. However—despite these considerable strengths—there are challenges that may limit our ability to move this vision forward. Some of these are being actively addressed at the community level with the launch of new initiatives. Others will need to be addressed in collaboration with the Natural Sciences and Engineering Research Council (NSERC), the primary source for funding of mathematical and statistical sciences research in Canada.

Maintaining the pipeline Demand for skilled researchers and instructors is outstripping supply in our universities, as our faculty attempt to provide training in the mathematical and statistical sciences for the next generation of scientists, engineers and business professionals. Enrolment at the graduate level in both the mathematical and statistical sciences has more than doubled over the past decade. Discovery Grants are an essential resource for funding the pipeline for highly qualified personnel: researchers use most of their grant funding to support students at the undergraduate, post-graduate and post-doctoral levels. A well-resourced system for research and training is essential if Canada is to have ready access to the talent, knowledge and innovation we will most certainly need to sustain a strong economy in the years to come.

Levels of investment Canada has forged a record of high achievement in the mathematical and statistical sciences with comparatively modest investment in international terms. The research community has been resourceful in leveraging the basic support it receives from the federal government with funding from other sources, including the private sector and international funding agencies. Nevertheless, current gains and future advances will be in jeopardy without further and continued investment in Canada's mathematical and statistical sciences research capacity.

Flexibility and diversity Maintaining breadth, depth and diversity is essential to the health of mathematical and statistical research. This means maintaining capacity to support research and training at the individual researcher levels at both large and small institutions. It means encouraging and building diversity across geography, gender and culture. It means actively supporting programs of basic research, not only to meet future needs for innovation in the mathematical and statistical sciences, and the sciences that rely on their findings and advances, but for their important contributions to knowledge. And it means actively supporting interdisciplinary research, thematic and collaborative resources, and partnerships and innovation.

Interdisciplinary research Research in the mathematical and statistical sciences is often inherently interdisciplinary in nature, and many exciting research advances are occurring in collaboration with other disciplines, and in the creation of new

hybrid disciplines. This is especially true in applied mathematics and in statistics, although researchers in pure mathematics also find themselves involved in such collaborations. Our communities expressed concern that interdisciplinary research proposals can be difficult to evaluate, and may fall between the cracks of two or more Evaluation Groups at NSERC, or between the cracks of the three granting councils. The problem is particularly acute in biostatistics, but affects other areas of research as well.

Thematic and collaborative resources Canada is home to three international mathematical sciences institutes: the Centre de recherches mathématiques, the Fields Institute for Research in Mathematical Sciences and the Pacific Institute for the Mathematical Sciences. Canada also hosts the Banff International Research Station, a unique and inspiring international collaboration with the US and Mexico. A new Canadian Statistical Sciences Institute is in development.

Research institutes are established assets for the mathematical and statistical sciences research communities around the world. Canada has been an important contributor to this trend: international experts rated Canada's infrastructure for the mathematical and statistical sciences very highly in *The State of Science and Technology in Canada* report (Council of Canadian Academies, 2012). The Long Range Plan endorses close cooperation among the institutes through the development of a Canadian Network of Mathematical and Statistical Sciences Institutes. The Long Range Plan also recommends investment in these resources by ensuring that funding for the institutes and for the Banff International Research Station is preserved under the envelope model for funding mathematics and statistics.

Together—and individually—these thematic and collaborative resources are key supports for our communities' vision: for Canada to be a world leader in the mathematical and statistical sciences, and to be a driving force in interdisciplinary research and innovation that contributes solutions to important Canadian and global challenges.

Partnerships and innovation The mathematical sciences community created a vibrant and uniquely successful Network of Centres of Excellence for the Mathematics and Information Technology of Complex Systems, since renamed Mprime. The participation of Mprime in the Network of Centres of Excellence program ended, under the rules of that program, on March 31, 2012. The loss of this federal funding, about $5.4M per year, will impact hundreds of companies, professors and students who all came together under the Mprime umbrella to address some of the most pressing challenges the country faces. The loss also jeopardizes hundreds of linkages between Canada's industrial base and the mathematical and statistical sciences research communities.

The mathematical and statistical sciences are assuming new and important roles in Canada's innovation agenda. Research in mathematics and statistics provides a conceptual framework and a quantitative language for describing and measuring phenomena, and students trained in the mathematical and statistical sciences bring problem-solving skills to bear on pressing industrial problems.

The Long Range Plan envisions a future role for Mprime as an over-arching national network, serving to bring together mathematical and statistical scientists from businesses, universities, research centres, and financial and technology organizations to stimulate innovation. Mprime will serve as a resource for both industry and academia in providing a platform for developing research proposals to NSERC's Research Partnerships Program.

Key Directions and Recommendations

This Long Range Plan is the first of its kind for the mathematical and statistical sciences research community in Canada. It is the product of more than a year of consultation and discussion within our communities. It is also informed by the Government of Canada's Science and Technology strategy: *Mobilizing Science and Technology to Canada's Advantage.*

The Long Range Plan Steering Committee has identified the following key directions and areas for investment in the Canadian mathematical and statistical sciences. Individual chapters of the report outline community initiatives aimed to advance the mathematical and statistical sciences in Canada over the next five to ten years, and give more detailed recommendations from the Steering Committee. A complete list of all the recommendations can be found in Chapter 8 of the report.

We recommend that NSERC:

- Invest in Canada's mathematical and statistical sciences research via Discovery Grant levels that reflect the importance of the research base to Canada, and that acknowledge that the costs of research are similar to those in several related science and engineering disciplines.
- Invest in Canada's network of thematic and collaborative resources in the mathematical and statistical sciences, including the newly developing Canadian Statistical Sciences Institute, and ensure that the funding envelope has a boundary between Discovery Grant funding and funding for these resources, to enable both to flourish and support each other.
- Augment the funding envelope to include the Research Partnerships Portfolio, enabling the mathematical and statistical research communities—working through the institutes and through Mprime—to provide a platform for a wide range of successful partnerships between the mathematical and statistical sciences and industrial partners.
- Establish a committee of leading mathematical and statistical scientists, chosen in consultation with the research communities, to oversee the implementation of this Long Range Plan, represent the research communities to NSERC, and develop research linkages among the mathematical and statistical sciences and allied science disciplines.

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Contents (continued)