Office of the
National Science Advisor

Bureau du
Conseiller national des sciences

A Framework for the Evaluation, Funding and Oversight of Canadian Major Science Investments

Draft Discussion Paper

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Canada

Preface and Acknowledgements

This discussion document responds to a generally perceived need expressed by the scientific and science policy community as well as the granting agencies for a systematic, transparent and robust decision-making framework and process for Canada's investments in major science facilities and projects.

This draft document is intended to provide a basis for commentary and ideas among key stakeholders in Canada and will be developed into a final proposal for consideration by government over the course of the coming year.

The early drafts of this document were developed by the National Research Council (Walter Davidson and Arthur Carty) and the Natural Sciences and Engineering Research Council (Tom Brzustowski and Liz Boston), with contributions from numerous individuals including John Root and Alastair McIvor (Chalk River Laboratories, NRC), Kevin Farris (NRC-Herzberg Institute for Astrophysics), Paul Dufour and Kevin Fitzgibbons (Office of the National Science Advisor), Caroline Martin (Foreign Affairs Canada), Jim Valerio (Industry Canada) and Marc Renaud (Social Sciences and Humanities Research Council).

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Executive Summary

The purpose of this paper is to present for feedback and discussion a framework for evaluating and prioritizing proposals for major science investments, and for overseeing the management of these projects once they have been approved. Major science investments are considered to be those that are of sufficient magnitude that they exceed the capacity of a single institution, department or agency to build and operate; they have scientific research as a primary objective; they have long-term financial responsibility or legacy issues; and there is a need to evaluate the non-scientific benefits.

While major science projects and facilities cost hundreds of millions to build and operate, and while they generate significant health, environmental, economic and other benefits for Canadians, the Government of Canada currently has no systematic process for evaluating, funding or overseeing them. In February 2001, the Auditor General tabled a report strongly recommending that such a framework be established. The scientific and science-funding community has also expressed the need for such a framework. Several OECD countries, including the U.S. and U.K., have promulgated such guidelines.

The framework proposed in this draft document consists of a process and mechanisms that would bring order and coherence to the management of major science investments, at a moderate cost both to government and the applicants.

In discussing and building a major science investment framework, several elements must be considered. These include all costs including those that have to date been considered only peripherally such as maintenance, upgrades, travel, risks and decommissioning. They also include factors such as economic and social benefits, a timetable to ensure that funding decisions do not remain in limbo; the type and degree of leadership and support behind the project; responsibility and accountability; and project management and oversight.

The framework consists of a process for prioritizing proposals (a flow chart of the process is presented in Appendix A) that includes a requirement for a preliminary proposal addressing a list of detailed questions (the questions are presented in Appendix B), an annual deadline for submitting proposals, and a peer review system. The process would be an accountable, transparent procedure for evaluating, prioritizing, recommending for funding, and monitoring projects through their life cycle, from creation through operation to eventual decommissioning.

The framework also proposes the creation of a Major Science Investment Panel to evaluate proposals and prioritize them for ministerial consideration (suggested criteria for determining a proposal's priority are outlined in Appendix C), and to play a continuing role in the oversight and monitoring of a project by identifying a lead federal organization for the project. The Panel would be supported by a Secretariat consisting of a small staff and Director, to be located in the Office of the National Science Advisor. Each project would have an Oversight and Management Committee to monitor the project's management throughout its life cycle.

Over the past decade, the design, development, commissioning and management of large-scale scientific projects, facilities and networks have become more complex, costly, interdisciplinary and international in scope. This trend poses important science policy challenges for governments, the academic community and the Canadian public on how we agree on priorities, how we make decisions and how we manage our investments to ensure that Canada is an active participant in leading research fields.

This framework is a starting point for addressing these and other important trends in major science projects, be they in the natural, medical or social sciences.

Table of Contents

Introduction

This draft document outlines a framework for making systematic, transparent, strategically-based decisions about federal investments in major science projects and facilities, and for overseeing the management of the initiative once funding has been approved. The purpose of the document is to generate feedback and discussion among key stakeholders.

Major science projects often have a high capital cost and a lifetime of several decades. They involve investments of hundreds of millions of dollars and reap a wide array of benefits for Canadians. Yet, in Canada, no systematic process exists for their evaluation, funding or oversight.

Proposals for major science projects and facilities arise sporadically. Each may link to a distinct subsection of Canada's knowledge community, and contribute to different elements of Canada's strategic goals. To date, the projects have been brought forward as *ad hoc* investment items with no systematic, technically based assessment supported by a commonly agreed management framework within a well-articulated national scientific strategy.

Proponents do not know how to engage government decision makers, because no clear mechanism is in place for them to do so. The processes of proposal evaluation, assembling of funds, and governance therefore seem to be reinvented with each case. The results can lead to cost overruns, inadequate commitments for ongoing operation, confusion of mission, and lack of accountability.

Canada can do better. This paper proposes a framework to bring some order and coherence to the management of major science – sometimes referred to as *Big Science* or *Megascience* – investments. It gathers and examines many of the "infrastructure" issues, problems and tensions inherent in major science projects. It proposes a modest organizational effort that could yield great improvements in coordination among agencies and departments, and provide the scientific community with an interface with government that is transparent, constructive and consistent with federal science priorities.

Policy and international collaboration discussions on issues pertaining to large science investments entered a new era of interest in the early 1990s. This was due primarily to intense national and international policy debates on priority setting after the cancellation of high-profile projects in the United States (Superconducting Supercollider and the Advanced Neutron Source) and in Canada (KAON Proposal). International negotiations on the development of the Large Hadron Collider at CERN in Switzerland added to the debate. Such debates had become highly politicized and concerns over cost overruns and lack of project management and accountability led to a number of initiatives to ensure more rigorous and transparent priority setting and governance structures (OECD, 1993).

Canada's involvement in major science projects began more than 50 years ago with the construction at Chalk River Laboratories of the NRX research reactor (1947 to 1992) followed by the NRU research reactor (1957 to present). When completed, each facility was the most powerful in its class worldwide. Subsequent major science investments in the same genre were the Tri-University Meson Facility (TRIUMF), which began operation in 1975 and the Canadian Light Source (CLS) which officially opened in October 2004.

Each of these facilities was a unique national project, whose funding constituted a major science investment. In some cases, a major science investment can be managed by a single federal agency. The Algonquin radio telescope (1959), for example, was managed by the National Research Council of Canada (NRC). On the other hand, in the latter decades of the 20th century, the number of opportunities for Canada to participate in international partnerships, such as CERN and the Canada-France-Hawaii telescope, has increased. More recently still, large distributed projects on a scientific theme, such as high-performance computing or the human genome, are emerging to rival the large-scale facility projects that might previously have been identified as the primary major science investments.

Major science investments have generated considerable benefits and returns to Canada. The NRX and NRU reactors, for instance, generated a thriving medical isotope activity;[1] a uniquely versatile nuclear power generating technology that produces large amounts of electricity without emitting greenhouse gases; a Nobel prize in physics (B. Brockhouse, 1994); and, some 30,000 jobs and $5 billion annually. The TRIUMF laboratory, Canada's centre for nuclear and particle physics, has earned international recognition and credibility, and engages Canadian scientists with collaborators from around the world. For example, in 1995, TRIUMF was given responsibility for coordinating Canada's $30-million contribution to the Large Hadron Collider at CERN. Similarly, Canadian astronomers have played leading roles at the frontiers of their field thanks to wise investments in leading-edge astronomical facilities. Most recently, the Sudbury Neutrino Observatory (SNO) delivered epoch-making results in neutrino astrophysics.[2]

> TRIUMF is a world-class subatomic physics research laboratory located on the campus of the University of British Columbia. It is one of three subatomic research facilities in the world that specialize in producing extremely intense beams of particles. The heart of the facility is the world's biggest cyclotron. Scientists from more than 25 countries have visited TRIUMF to run their experiments.

It is estimated that the Government of Canada devotes less than 3 percent of its annual S&T funding to major science projects. This paper is not about changing that

[1] Canada now generates more than half of the world's radioisotopes and enables more than five million medical procedures annually.

[2] By demonstrating that neutrinos have mass and oscillate, the SNO introduced a huge crack in the 30-year-old "holy grail" of particle theory, the "Standard Model" – evidence of Canada's ability to make a major impact on the worldwide pursuit of understanding the nature of the universe.

ratio; it is about ensuring that the 3 percent that is devoted to Big Science is invested wisely and managed at the highest possible standard.

This draft document is presented in three broad sections. Section I provides the intended overall scope of the proposed framework, with broad criteria for when it would be applied, and a general discussion of Big Science and examples of Big Science projects either in Canada or in which Canada is involved. Section II provides the context in which the proposed framework is being discussed in terms of the issues, challenges and considerations that must be taken into account when devising a framework. Section III focuses on the components of the proposed framework. These include a process for prioritizing proposals for major science investments, a mechanism (i.e., a standing panel) for making recommendations regarding priority proposals and funding, and a mechanism for overseeing the management of a project once funding has been approved.

I. Scope of the Proposed Framework and Examples of Canadian Involvement in Major Science Projects

The proposed framework is intended only for "major science" projects or facilities as defined below. It is not directed at general science investments as these are handled through the federal granting councils and their systems. It would be applied only when the capacity of existing structures is exceeded.

A. "Major Science" in the Canadian Context

In the Canadian context, "major science" projects and facilities are those of sufficient magnitude that they require resources beyond the capacity of any single institution, funding agency or department to build and operate.[3] Assembling the necessary resources would require the collaboration of multiple institutions, and/or international partnerships, and/or the commitment of major funds from the centre of government.

> The Sudbury Neutrino Observatory uses 1,000 tonnes of heavy water to detect elusive particles called neutrinos emitted from the centre of the sun and from remote exploding stars. The SNO's findings could profoundly affect humanity's understanding of the long-term future of the universe, the energy generation processes of the sun, and the framework of the basic forces of Nature.

Although the diverse nature of major science initiatives makes it difficult to define a precise lower limit of costs, as a guideline, projects would have capital and operating

[3] In a similar vein, "Big Science" is described by the OECD (1993) as "a project that addresses a set of scientific problems of such significance, scope and complexity as to require an unusually large-scale collaborative effort, along with the facilities, instruments, human resources and logistic support to carry it out".

expenditures in excess of $100 million over 10 years. However the proposed Major Science Investment Panel would need to use its discretion on whether a project would be categorized as an appropriate major science investment.

While these criteria would suggest that most major science investment proposals will come from the fields of physics and astronomy due to the high cost of that infrastructure, projects in other fields will increasingly begin to meet the Big Science definition. Examples include large, long-term, population ageing and health studies or climate change research initiatives. These run longer than 20 years, cost hundreds of millions of dollars, are scientifically driven, and are of such a scale and import that a single "go / no go" decision would be required at a high level in government.[4]

In the following discussion, a facility will tend to be the infrastructure surrounding a single central device for the benefit of a user community (for example, the cyclotron at TRIUMF). The term "project" will be used either in the context of distributed programs or alternatively in the case of a large experiment such as the SNO project, which is not a "facility". The term "network" refers to a large-scale distributed effort of scientific research which relies on a series of investments in computers, databases and communications linkages.

B. When the Framework Would be Invoked

Four criteria define the types of projects that would be considered under the proposed framework.

1. **The magnitude and cost of the project is beyond the scope of any single federal department or agency and thus requires exceptional measures.**

The international rule of thumb regarding the cost of a Major Science endeavour is of the order of magnitude of $100 million or more. Examples of existing facilities that meet this criterion are the NRU reactor, SNO, TRIUMF and the CLS.

2. **The primary objective is to advance scientific research.**

Any kind of technology development, engineering testing or demonstration project for which the primary objective is commercial development rather than scientific research would not satisfy this criterion. This would include large nuclear, aerospace or energy demonstration projects for example.

3. **Long-term financial responsibility or legacy issues are considerations.**

This criterion would impact primarily the management of the facility or project. The time scale must be at least 20 years from genesis to decommissioning. The

[4] "Thoughts on the Nature of Big Science", M.C. Wolfson , Statistics Canada, (unpublished draft) 2004.

full life-cycle cost must be presented at the outset as an important input into the decision making.

4. There is a need to evaluate the non-scientific benefits and how this evaluation is conducted.

Ministers attach significant weight to the larger economic, health and social impacts when considering large investments such as Big Science projects.

C. Categories of Existing Major Science Activities in Canada

Some of Canada's current and proposed major science projects and facilities are briefly described below to further illustrate the types of large-scale initiatives that would be addressed by the proposed framework. They also illustrate the challenge of comparing costs, values and impacts among such projects.

1. Facilities funded and located in Canada as part of a global network of similar facilities

The NRU reactor at Chalk River Laboratories has been the birthplace of many scientific achievements. Canadian physicist Bert Brockhouse won the Nobel Prize in Physics for his seminal work at NRU using neutron scattering to explore materials. Using the same scientific approach that Brockhouse pioneered, NRU scientists today apply neutron scattering techniques in a wide range of research into materials. A modernized Canadian Neutron Facility is being proposed to continue the work started at the NRU.

Examples range from the 47-year-old NRU research reactor, to the recent Canadian Light Source, to the proposed Canadian Neutron Facility. These major facilities enable experiments and generate knowledge that would not otherwise be obtained in the home laboratories of visiting scientists. They provide for tens of thousands of individual research projects through their lifetime, and are centres that attract, train and retain thousands of highly qualified people in a multidisciplinary environment. Such facilities are available to the scientific community in most developed countries, and are essential for fostering a national competence in the application of advanced experimental techniques to cutting-edge materials sciences and technologies. Canada's investments in synchrotron or neutron facilities respond to the particular scientific interests of the Canadian community and bring a unique combination of talent and expertise to the global network of such facilities. Such facilities therefore serve as points of international scientific exchange, to which foreign scientists travel and on the basis of which Canadian scientists are welcome (and able to function effectively) at analogous facilities elsewhere.

In December 1950, Cabinet granted $60 million for the NRU reactor, the equivalent of $510 million today, making it Canada's largest investment in a single piece of research infrastructure. The funding was secured from Cabinet by C.D. Howe and then NRC president Dr. C.J. Mackenzie. Today, the direct cost to operate the NRU reactor (fuel, maintenance, and staffing), plus the neutron beam laboratory, is about $30 million annually.

The CLS, which officially opened in October 2004, cost $174 million to build and another $45 million will be required to install five additional beam lines.[5] The annual operating cost of this third-generation synchrotron source will be about $19 million. Funds for the CLS project came from many sources, including the Canada Foundation for Innovation (CFI), federal agencies and programs, provincial governments and others.

Proposals for a new Canadian Neutron Facility (CNF) range in capital cost from $400 million for a single-purpose reactor with 11 beam lines for materials research, to about $650 million for a multipurpose facility to supersede the functions of the NRU in the 21st century. Depending on the final design of the CNF, annual operating costs would range from $30 million to $50 million when the science programs are fully populated.

> The Canadian Light Source synchrotron project is located at the University of Saskatchewan. It produces extremely bright light by using powerful magnets and radio frequency waves to accelerate electrons to very high speeds and energies. This allows matter to be "seen" at the atomic scale. The CLS could lead to new drugs, more powerful computer microchips, better engine lubricants, new materials for safer medical implants and many other applications.

2. *Facilities located in Canada as a major or unique contribution to the global scientific community*

Examples include TRIUMF, as a platform through which Canadian scientists participate in the international nuclear and particle physics program at CERN, and SNO. In these examples, a major investment of Canadian science resources enables Canadian scientists to be identified with the frontiers of science and technology, leading a project that attracts foreign funding to Canada from international partners. The intent of these investments is to address a limited number of fundamental questions, and the scientific teams need to be highly focused in the discipline to which the question pertains. Such facilities are rare or unique in the world.

In 1968, $19 million in federal funding was approved for five years to construct TRIUMF. The total cost for construction over six years was about $30 million. The facility started operation in 1975. Its current annual operating budget is about $40 million.

SNO was completed in 1998 at a cost of $73 million, of which the federal government provided $54 million. This unique project was constructed in the Creighton mine and benefited from a massive loan from Canada's reserves of heavy water.

[5] The $174 million does include the construction of the first seven beam lines. Money committed toward a second suite of five new beam lines was announced by CFI on 8 March 2004. CFI is providing $18 million (40 percent of the cost) and will leverage 60 percent from other sources including provincial governments and other stakeholders.

3. International facilities located outside Canada, in which Canada is a partner

This category is the reverse of the preceding one in that Canada contributes to major science projects located in or led by other nations, giving Canadian researchers the opportunity to participate in rare or unique scientific endeavours of global interest. The Canadian contributions to these major science investments are often small enough to be managed by a single federal agency. Examples include CERN (Switzerland) and Gemini Twin Telescopes (Chile and Hawaii).

> The Large Hadron Collider is an accelerator which brings protons and ions into head-on collisions at higher energies than ever achieved before. This allows scientists to penetrate still further into the structure of matter and recreate the conditions prevailing in the early universe, just after the "Big Bang". The LHC is being built astride the Franco-Swiss border.

CERN is the world's largest particle physics laboratory. Located in Geneva and in operation since 1954, the facility has 20 member states. Canada participates as a non-member state in specific projects. Most recently, Canadians based at TRIUMF have been contributing to the Large Hadron Collider project, which is due to start operating in 2007, and to the large ATLAS experiment. Canada's support of TRIUMF is a key contribution to the CERN program of understanding particle physics and the nature of the ultimate constituents of matter. International effort, some of it in Canada, on R&D toward the proposed Linear Collider, the agreed long-term top priority of the world's particle physics community, is underway. The Linear Collider is expected to be completed around 2015 at a location in the world yet to be determined.

Gemini North (on Mauna Kea, Hawaii) had first light in 1999, followed by commissioning and a phase-in of scientific operations through 2000. Gemini South (on Cerro Pachón, Chile) had first light in January 2002. The construction budget for both Gemini telescopes was $185 million (U.S. dollars), to which Canada contributed $38 million (Cdn). The annual operating budget for both Gemini telescopes is about $18 million (US), not including the cost of new instruments. Other international astronomy projects, such as the Atacama Large Millimetre Array radio astronomy project in Chile, the Very Large Optical Telescope, and the proposed Square Kilometer Array, a new radio telescope that might be constructed between 2012 and 2020, also engage the interest of Canadian researchers.[6]

4. A distributed infrastructure that constitutes a major science investment when considered as a whole

A recent departure from "traditional" major science investment in a large facility is the type of project that depends on a distributed network of facilities and researchers working together. Examples would include a network of high-performance computers

[6] The development of Canada's participation in these projects and proposals are the result of a well coordinated international process of scientific and long-term investment priority setting led by the NRC and NSERC in collaboration with the Canadian Astronomical Society (1999). The European Astronomical Society (2004) recently released a survey of national priorities in astronomy.

distributed across the country but operated as one supercomputer, or a major geoscience project such as NEPTUNE.

From 1998 to 2002, Canada invested some $160 million in high-performing computing hardware, yet only five Canadian systems were found to be in the top 500 worldwide. The Government of Canada's Innovation Strategy recommended a major investment in computing facilities, people, applications and communications, on the order of $150 million per year for seven years, to bring Canada's high-performance computing capabilities to a world-class level. This level of major science investment could yield a competitive computational infrastructure to support research in genomics, proteomics, and fundamental molecular and nano sciences.

The NEPTUNE project is a U.S.-Canada partnership for geosciences, encompassing a network of instruments on the Juan de Fuca Plate in the northeast Pacific Ocean. The total cost to develop, install and operate the network for the first five years of a 30-year lifetime (beginning in 2007) is estimated at $300 million, of which Canada will contribute an estimated $62 million.[7]

> NEPTUNE is the world's largest cable-linked seafloor observatory. It will expand the boundaries of ocean exploration and provide a new way of studying and understanding the planet. NEPTUNE is led by the University of Victoria in Canada, and the University of Washington in the U.S.

5. A distributed research program on a strategic scientific theme

A major science project requiring coordinated but widespread field research over many years in a targeted theme also constitutes a major science investment. The recent trend toward larger and more expensive networks for climate and environmental research makes proposals for such projects increasingly likely. At some point, such a project may resemble a Network of Centres of Excellence (NCE), but the distinguishing features would be the much more focused research goal and the much larger investment of funds. For example, Genome Canada has managed about $435 million of federal funds via competitive proposals to develop genomic sciences for application in agriculture, fisheries, forestry and health. Other candidates that might constitute a major science investment are multi-agency initiatives on fuel cells and the hydrogen economy, nanotechnology, and security preparedness for terrorist activities that involve chemical, biological or radiological weapons.

[7] Canada's contribution to NEPTUNE of $62.4 million (Cdn.) through CFI and the B.C. Knowledge Development fund was announced in October 2003. A description and overview of the project and collaborative agreement can be found at http://www.neptune.washington.edu.

II. Context and Considerations

A. Investment Proposals and Priority Setting

In recent years, several OECD countries, including the United States and the United Kingdom, have established official priority-setting guidelines for the funding of large-scale science investments.[8] Canada has no clearly articulated criteria or decision-making framework for such investments.

Proposals for new major science investments are often brought forward in a "bottom-up" fashion from a group of researchers (proponents) who wish to explore new ideas and concepts at the forefront of science and who require access to major science resources to do so. The proponents may be from a single discipline (for example, astrophysics) or may represent several disciplines (for example, materials research spanning biology, chemistry, physics, geology and engineering). They may come forward from a well-organized community that has previously discussed long-range plans and priorities, such as the Canadian Institute for Neutron Scattering for the CNF, or from an informal network of collaborators. Proponents have varying degrees of sophistication in placing their request within a national strategic framework and in projecting a project's scope, impact, costs and risks. In some cases, such as the Long Range Plan for Astronomy and Astrophysics, proponents come forward with international partners whose own national priorities and operating environments add a layer of complexity to the decision making for Canadian funding.

The long-term operating and maintenance costs of major science projects in Canada can be a challenge to fund and can amount to the greater part of the funding commitment over the project's lifetime. However, a thorough accounting of the long-term operating costs has not always been fully considered in the initial decision to fund capital costs. Operating costs can vary over the life of the project and, in the case of international contributions, are subject to exchange-rate fluctuations. In the cases where Canada contributes to an international facility, the ongoing cost of participation for Canadian researchers (travel, access to data, personnel costs) must also be considered as part of the cost to Canada.

Some projects have high inherent risks which may be unforeseeable at the start of the project. A distinction should be made between a major science project which is a new experiment (such as SNO) and in which the whole project is risky, and one which serves several smaller experiments (such as CLS) where the risk lies not with the whole project but with each of the small experiments it serves. Proposals for major science investment must be carefully considered in terms of their risks and contingencies, recognizing that an analysis may be imprecise in cases where something entirely unprecedented is being proposed. A robust risk management

[8] The United Kingdom established the Office of Science and Technology in 2001; the United States created the National Academies in 2004.

system for these unique high-risk projects should be developed based on worldwide best practices. The MSIP Secretariat described in Section III would be well positioned to coordinate the design of the risk management process.

To remain technologically sophisticated, Canada must provide its scientists and engineers with opportunities to participate at the forefront of major scientific advances. Canadian researchers are currently involved in several national and international major science projects, and they will continue to want to participate in such endeavours in the future. Such activity provides benefits to Canada through the generation of new knowledge and through collaboration with the best international researchers in the field. It also benefits Canadian industry and helps to ensure a highly qualified and skilled workforce. In order to participate in major science projects at a meaningful level, with the ensuing impacts on leadership, prestige and spin-offs, a robust and coherent way to deal with the proposals must be devised. Canada needs a clear process to consider potential impacts, capital and long-term operating costs, and the potential risks of specific proposals. The process should coordinate and rationalize entry into such projects; monitor their implementation; and, oversee the effectiveness of the longer-term operation to maximize the resulting social, cultural, scientific and economic benefits to Canada through their lifetime.

B. Funding and Accountability

The issues of funding and accountability for major science facilities in Canada were examined by the Government of Canada in the mid 1990s. Under the lead of the Minister of Industry, a draft proposal entitled "Decision Making and Management Framework for Megascience Investments" was taken to a fairly advanced stage of consideration until interest was lost after the Canadian Light Source was funded.

In February 2001, the Auditor General tabled a report in the House of Commons, noting the issue of cost overruns for major science projects, and citing the SNO project as an example. The Auditor General strongly recommended that federal government decision making for major science investments be improved by considering complete and accurate information on a project's costs and risks, as well as the usual focus on scientific opportunity. The Auditor General stressed that inflation and contingency allowances need to be included in submissions for Cabinet consideration. The Auditor General further recommended that an interdepartmental framework be established for managing the approval, implementation and reporting of these projects.

Implementation of a more clearly defined management framework for investments in major science initiatives would demonstrate that the government is taking steps to resolve accountability issues related to S&T expenditures. It may also serve to reduce the political pressures placed on Ministers by scientific and political proponents. An appropriate decision-making support and governance framework could be set up to manage federal resources provided for these projects in such a way as to maximize the return to Canada. The Auditor General noted that such steps would address the perceived lack of effective management processes for federal resources once a project is approved.

C. Policy and Management Considerations

Many important elements need to be considered in building a decision-making support and governance framework for major science investments. Several of these are outlined below.

Cost:

- The high cost of major science projects requires that great care be taken in selecting projects for funding. This selection must be done in the context of other needs and opportunities for Canadians.
- Funding decisions must take into account the costs to properly instrument, operate, maintain and decommission the facility, in addition to the construction costs. Currently, operational funding support tends to be considered peripherally when estimating the project's total cost over its lifetime. Much more consideration must be given to a process of determining the operational costs and the funding scenario to be followed in the operating period. The CLS is an example of a major national facility for which capital funding was assembled for initial construction, but operational costs and funding sources were not fully considered at the initial stages. It was only later, following a drawn-out lobbying campaign that an appropriate level of operating support was secured from the federal government. A facility's operating costs must make provision for inflation, as the Auditor General noted, as well as future capital expansions or upgrades and additional operating costs if the user community grows over the facility's lifetime.
- Contingency planning and costing are particularly difficult for large-scale novel projects with complex designs, which is usually the case for major science facilities. One possibility, as suggested by the Auditor General, is to do a program management engineering analysis of the costs one year into the construction schedule when costs and scheduling estimates would be more accurate. Even then, for particularly risky projects such as SNO, a "risk cost" (perhaps as high as 30 percent) should be added to the normal engineering contingency. The money may not necessarily be allocated but funding agencies should be aware of the possibility.
- In the case of offshore international projects, the full cost of participation by Canadians, at a level commensurate with Canada's initial contribution, should be taken into account. This would include travel costs to the facility, accessing and interpreting the data, and setting up teams to run experiments using the new facility. Participation costs should also be taken into account for facilities built in Canada where researchers would require additional funds to access the facility. In the past, these costs have not been considered at the initial decision-making stage and the burden of participation expenses has fallen

largely to the federal granting agencies. Such costs should be made known and agreed upon up-front.

- Therefore, when determining whether or not a project should be classified as "major science", either for an investment in a Canadian project or for a contribution to an international project, the budget should include all of the costs described above: capital and construction, operations and maintenance, probable upgrades and expansion of operating costs, cost of access by individual users, contingencies, risks and decommissioning. When all of these costs are taken into account, it is likely that more projects than in the past would exceed the $100-million threshold.

Systematic Prioritization:

- Canada currently has no defined process for prioritizing, selecting and funding Big Science projects. To date, decisions on major science projects such as the NRU reactor, TRIUMF, the SNO experiment and the CLS have been made in an *ad hoc* manner. Establishing priorities among projects is difficult as the proposals tend to come forward on an irregular basis. Poorly-defined assessment processes can become subject to political pressures, especially when the project involves large facilities whose construction and operation could have significant local economic benefits.
- The CLS, for example, required the assembly of numerous stakeholders for review, approval and funding.[9] This daunting task was accomplished largely by the efforts of project champions, not by an agency or group of agencies executing a coherent national strategy for a large-scale research infrastructure. The presence of a national framework and a governance model would have enormously simplified the task.
- Big Science projects need to be considered in the larger context of the government's research, innovation and skills development objectives. This means that each project needs to be assessed in terms of how it will contribute to these objectives. In this context, all Big Science projects should include, at the outset, projected measurable outcomes that will provide the decision-making process with a view on the expected return on the investment. This will also help in assessing the success of the project in the future. A policy on Big Science projects and a policy on international science are closely intertwined and need to be considered in tandem.

Economic spillovers:

- Many major science projects involve the development of new technologies, which may create strategic opportunities for the industries involved. The

[9] These stakeholders included the CFI; the provinces of Saskatchewan, Alberta and Ontario; Western Economic Diversification; NSERC; NRC; Natural Resources Canada; University of Saskatchewan; and, the City of Saskatoon.

manufacture of highly specialized magnets for the Large Hadron Collider at CERN by ALSTOM Canada opened the doors to new industrial capabilities for that company.[10] Similarly AMEC Dynamic Structures Ltd. parlayed the expertise it developed when it built the Canada-France-Hawaii telescope enclosures into wider business opportunities. The participation by Canadian industries in such projects results in heightened competitiveness and economic benefit. Indeed, the technological program can be just as challenging and significant as the science program. Such participation helps to stimulate a culture of innovation in Canada.

Social and Economic Benefits:

- The social and economic benefits arising from the investment would also have to be considered. It is recognized that, given the large investments required, Ministers tend to approve Big Science projects not so much for the good of science *per se* but for the good of the country.

Training of highly qualified personnel:

- Highly trained scientists are essential in today's knowledge-based society. Nations that participate in the major scientific ventures are able to attract and retain the highly qualified personnel that are drawn to such opportunities. Trainees get the opportunity to work with leading figures, and those who are trained at world-class facilities based in Canada are more likely to remain here to help make Canada a leading nation in research and scientific development. Skilled people are required to use and operate such facilities and, in turn, the facilities are instrumental in training a skilled workforce.

Timetable:

- A timetable needs to be set and respected in the decision-making process. Timing can be a significant issue. The nightmare scenario for a big project is to never receive a decision but to be endlessly told to consider other options, make improvements, reduce the scope, attract foreign partners and/or more scientists, etc. There should be a pressure somewhere to actually reach a decision. A negative decision is better than no decision, as it releases highly qualified personnel to pursue other endeavours.

Political leadership and support:

- Not all large-scale proposals fall into the classic "major science" model with self-organizing advocacy communities behind an effective community leadership. The degree and nature of the support behind large-scale projects can differ and has to be understood. For example, the recent United Kingdom

[10] An article published in January 2004 outlines a case study of the industrial knowledge benefits accrued to private sector firms such as a university spin-off, a major engineering corporation and a medium-sized welding equipment company in the construction of the Large Hadron Collider project at CERN (Autio, E. 2004).

investment of £140 million in e-science needed strong political leadership as the requirement was difficult to organize at the grassroots science level. Although the concept was more diffuse and less well defined than "an accelerator" for example, and although it lacked a well-organized advocacy community, the e-science initiative is very likely to be just as influential. It is important therefore to distinguish between the value of a project and its apparent support. Sometimes the impetus may come from the agencies who are stewards of the national infrastructure for science and industry. Reciprocally, sometimes communities need to be coaxed into action as opposed to waiting for self-organization.

Responsibility and accountability:

- It is important that funding for a major science project flow to the most appropriate recipient, regardless of institutional location. Canada's current environment can make that difficult. For example, current CFI rules would make it impossible for a government agency to be the recipient, even if that agency were the most appropriate responsibility centre for the project. An explicit provision for directing the funding to the most appropriate responsible organization, regardless of its institutional location, is required.
- If a funding proposal for a major national science project is submitted to government through a department or agency, the department should be able to position the project as a matter of national importance, transcending the department's own mandate and mission. That is to say, stewardship of national major science investments should not be held in competition with requests for funding to serve the internal initiatives of that agency.
- It is important, as the Auditor General pointed out, to identify the most appropriate federal department or agency to serve as the lead federal oversight entity. If the proposal came from a department or agency as the responsible organization, that same department should be made responsible for its oversight as well.

Project Management oversight and control:

- Each proposal should contain clear management, audit and oversight mechanisms. It should delineate an oversight mechanism that would monitor progress on a multi-year basis and call for action if something unforeseen arises. Such unforeseen circumstances might include anything from budget changes (operations, contingency, etc.) to *force majeure* events. The monitoring mechanism should include responsibility for the project throughout its lifetime, including shut-down. These functions could be achieved by having a monitoring and oversight committee established by, and reporting to, the lead federal agency. The oversight committee would comprise external experts as well as representatives from all the relevant funding agencies.

- Since the creation of the CFI, universities, research institutions and other non-federal bodies have started to play a more significant role in managing large capital projects. However, the concentration by CFI almost solely on capital construction has indicated that its funding model is simply not sustainable for operations, long-term support and other life-cycle costs. Matching contributions are required from provincial sources for the capital phase of a CFI project, but the implications for the provinces of longer-term operating costs have often been considered only as a peripheral matter. Should the CFI funding model continue, the role of the provinces and other sources of funding for ongoing support would need to be considered and clarified.
- TRIUMF is an early example of university involvement in the governance of a major research facility where six universities formed a joint venture and the NRC funded the laboratory through a contribution arrangement.
- The agency responsible for *managing* the project should be the one with the most experts and most closely connected to the field. This might be an existing research institute, consortium or university, or, as already indicated, a federal agency or department. However, if no existing organization is appropriate, a new organization could be created specifically for that purpose. In either case, the governance of the project must involve funders, managers and users of the facilities. In addition to the agency responsible for *managing* the project, a federal agency would have *oversight* of the project. The agency charged with oversight could the one responsible for managing the project, if the proposal originated with that agency.

III. The Proposed Framework for Evaluating, Funding and Overseeing Major Science Investments

The foregoing provides the impetus to consider a new decision-making support and management framework for major science investments. If an appropriate research roadmap or master plan already exists for a given research field, that map or plan should be invoked in the framework to give the project a more strategic research context.

Section A below describes a process and mechanisms (a panel and secretariat) for evaluating and prioritizing proposals, and for making recommendations for funding. A flow chart depicting the process appears in Appendix A. An outline of the criteria that would be applied in determining a proposal's priority is presented in Appendix C. Section B outlines a mechanism for overseeing and managing a project once it has been approved for funding.

A. Prioritizing Proposals -- Process and Mechanisms

1. Process

- Proponents would be required to submit a preliminary proposal which would address a series of issues raised in a comprehensive questionnaire (Appendix B). The questionnaire explores quantitative evidence through which to evaluate the proposal's claims of opportunity and benefit, and to identify risks that might arise after a funding commitment is made. The intent is to provide a vehicle for proponents to provide the facts for an objective analysis and recommendation, rather than leaving them with little recourse but to apply political pressure. The current version of the questionnaire arises from experience to date and has been validated by applying it in hindsight to existing projects such as the CLS and to anticipated proposals such as the CNF.

- Respecting an annual deadline for the submission of preliminary proposals, proponents would submit the completed questionnaire to the Secretariat supporting the Major Science Investment Panel (see sections 2a and 2b below). The Secretariat would meet with the proponents to refine the responses to the questionnaire. During the ensuing feedback and discussion, the proponents would have the opportunity to proceed with minor revisions only, to resubmit an improved proposal for the next deadline, or to withdraw the proposal entirely. Assuming that only minor changes are required, the complete proposal would be forwarded to the MSIP Secretariat for review.

- The Secretariat would send the completed proposal to Canadian and international experts for peer review. The proposal would then be forwarded, with the reviewers' comments and recommendations, to the standing Major Science Investment Panel.

2. Mechanisms – Major Science Investment Panel and Secretariat

a) Major Science Investment Panel

- The Major Science Investment Panel (MSIP) would be coordinated through the Office of the National Science Advisor to the Prime Minister. The membership would consist of: the presidents of NRC, NSERC, CIHR, SSHRC, and CFI; the deputy ministers of four science-based departments or agencies; and, two international experts with experience in major science projects. It would be chaired by the National Science Advisor to the Prime Minister.

- The primary function of the MSIP would be to produce a list ***in priority order*** of all active proposals for major science projects that have been submitted and that have completed the peer-review process. The criteria for determining a proposal's priority are outlined in Appendix C. The prioritized list would be made public on an annual basis as a report to Parliament, or in some other appropriate format. The National Science Advisor would provide briefings on the top-ranked proposals to Cabinet committees, as necessary.

- The rationale for prioritization needs to be transparent so that proponents know their proposal is receiving due regard as to its merits, costs, risks and balance within a general framework of national goals and values. Proposals may remain on the priority list until funding is approved. A mechanism would be required for proponents and managing agencies to respond to the outcome of the prioritization process, in consultation with the MSIP Secretariat, so that there would be a possibility for the proposal to be repositioned in the priority list in subsequent years.

- An initial task of the MSIP would be to complete a roadmap that would help establish or reconfirm major science priorities within an overall vision for science in Canada.[11]

- The MSIP would then play a continuing role in the oversight and monitoring of funded major science projects. It would be responsible for defining the lead federal agency for the funded projects and delegating to that agency the responsibility for establishing an Oversight and Monitoring Committee (OMC) for that project (see section B below).

b) Secretariat to the MSIP

The cost of implementing this framework would be moderate, both to government and the applicants. No new agency would need to be created. However, a small Secretariat of experienced staff and a Director would need to be added to the Office of the National Science Advisor to serve as a permanent secretariat to the Major Science Investment Panel. The Secretariat would serve as a single interface between project proponents and government, and coordinate the engagement of appropriate partners in federal, provincial and/or international partners. The Secretariat would require consistent contacts with the review-capable agencies, such as NSERC and CFI, and, for those projects requiring coordination with foreign partners, linkages to international science organizations.

More specifically, the role of the Secretariat would be to:

[11] Such a roadmap could be modelled on the *Large Facilities Strategic Road Map*, first published in 2001 as a strategic management tool by the UK Office of Science and Technology for the Research Councils UK, and updated in June 2003. A statement of government funding priorities based on the roadmap was announced by the British government in June 2004.

- serve as the liaison point between proponents and government;
- coordinate the evaluation process, informing proponents of the process and deadlines, providing proponents with advice and feedback, identifying a suitable managing agency, coordinating the flow of initial discussions, and implementing the peer review;
- coordinate MSIP activities, provide additional financial planning and scenarios to the MSIP, and prepare briefs for the MSIP or for the NSA to present to Cabinet;
- ensure a thorough understanding of each proposal as decisions are made about prioritization and funding;
- coordinate the establishment of an Oversight and Monitoring Committee for approved projects;
- manage the feedback processes between the MSIP, the lead managing and oversight agencies, and the funding agencies; and,
- build a strong partnership among the project's stakeholders.[12]

c) Role of the Funding Agencies in the Priority-Setting Process

As well as forming part of the membership of the MSIP, the funding agencies could assist the priority-setting process by: supplying information to the Panel about long-range planning processes or priority-setting activities within research communities; providing information as necessary to the MSIP; and, acting as facilitators between the MSIP and the proponents with the assigned managing agency. The MSIP could decide to delegate the international peer review to the appropriate funding agency or agencies.

d) Role of the MSIP and Funding Agencies in Funding Decisions

As only Ministers can present a Memorandum to Cabinet, the MSIP's role with regard to funding would be one of providing advice to Ministers rather than actually making funding decisions. This is a more realistic approach, particularly given that the development of ministerial consensus to inaugurate a funded program for Big Science projects is unlikely due to the high cost of such projects, the fact that proposals arise only occasionally, and the pressure of other funding priorities.

One option would be for the MSIP to submit its priority list to government each year recommending funding for the top-ranked projects. In this option, some funds from the funding agencies could be put on the table, but additional funding might be required from the fiscal framework. Another option would be for the MSIP to provide

[12] While the framework has been articulated primarily in the context of the federal government, it should be stressed that, where appropriate and of interest, provincial participation in this science policy evaluation is strongly encouraged. As stated above, the creation of strong partnerships among project stakeholders is an important task of the Secretariat.

the priority ranking to the potential funding agencies, which would then need to collaborate to make a funding recommendation.

The role of the MSIP in the funding process would depend on the nature of the project. In some cases, the project might be fundable by merging contributions from several funding agencies. In other cases, a Cabinet decision or other source of new money would be necessary, and the MSIP would be involved in making the recommendation for funding. In either case, the funding decision would be made on the basis of an objective evaluation not only of the science but also of all the other factors involved in such large undertakings.

The MSIP would then play a continuing role in the oversight and monitoring of funded major science projects. It would be responsible for defining the lead federal agency for the funded projects and delegating to that agency the responsibility for establishing an Oversight and Monitoring Committee (OMC) for that project. In cases where Canada is contributing to an off-shore international project and is one of several funding partners, the lead federal agency would be responsible for managing the contribution, entering into agreements with partners abroad, setting up oversight processes for the Canadian contribution if necessary, and nominating Canadian members for any relevant international oversight, management and user committees. A clear reporting mechanism back to the MSIP would be required to ensure ongoing oversight of all funded major science projects and informing Cabinet as necessary.

B. Oversight and Monitoring Committee

Once the decision to fund a project has been made, the MSIP would recommend a lead federal agency for that project. The lead agency would then establish an Oversight and Monitoring Committee (OMC). The overall purpose of the OMC would be to monitor the management of the project from its creation through operation to eventual decommissioning.

More specifically, its role would be to:

- Ensure that the partner funding agencies provide the full commitments they made at the beginning of the project;
- Respond to changes in capital and operational costs and project schedules by providing additional funding if warranted (for example, authorizing the release of previously defined contingency funds) or by recommending additional funding from other sources;
- Determine if a funded project is performing well and is properly supported to do high quality work throughout its lifetime;
- Ensure that the project management does its job or is replaced;
- Ensure that the project meets its objectives against a set of pre-established milestones and indicators, or take action as required (termination or allocation of more resources for unexpected situations);

- Ensure that the project is eventually shut down in a timely way when it has met its objectives or is no longer competitive.

If budget changes are necessary due to unforeseen circumstances, the OMC would make recommendations to the MSIP via the lead agency. If the funding agencies cannot find the funds themselves but still feel that additional funding is necessary, the MSIP may then decide to request funding from the centre for high-priority projects.

References

Autio, Erkko, Ari-Pekka Jemeri and Olli Vuola (2004), “A Framework of industrial knowledge spillovers in big-science centres”, *Research Policy*, Vol. 33, 1, January 2004, pp.107-126.

Auditor General of Canada (2000), *Report of the Auditor General of Canada*, December 2000, Chapter 34.

European Astronomical Society (May 2004), *European Survey of National Priorities in Astronomy: An Overview of National Planning Documents*.

National Academies (2004), *Setting Priorities of Large Research Facilities Projects supported by the National Science Foundation*, The National Academies Press, Washington, D.C.

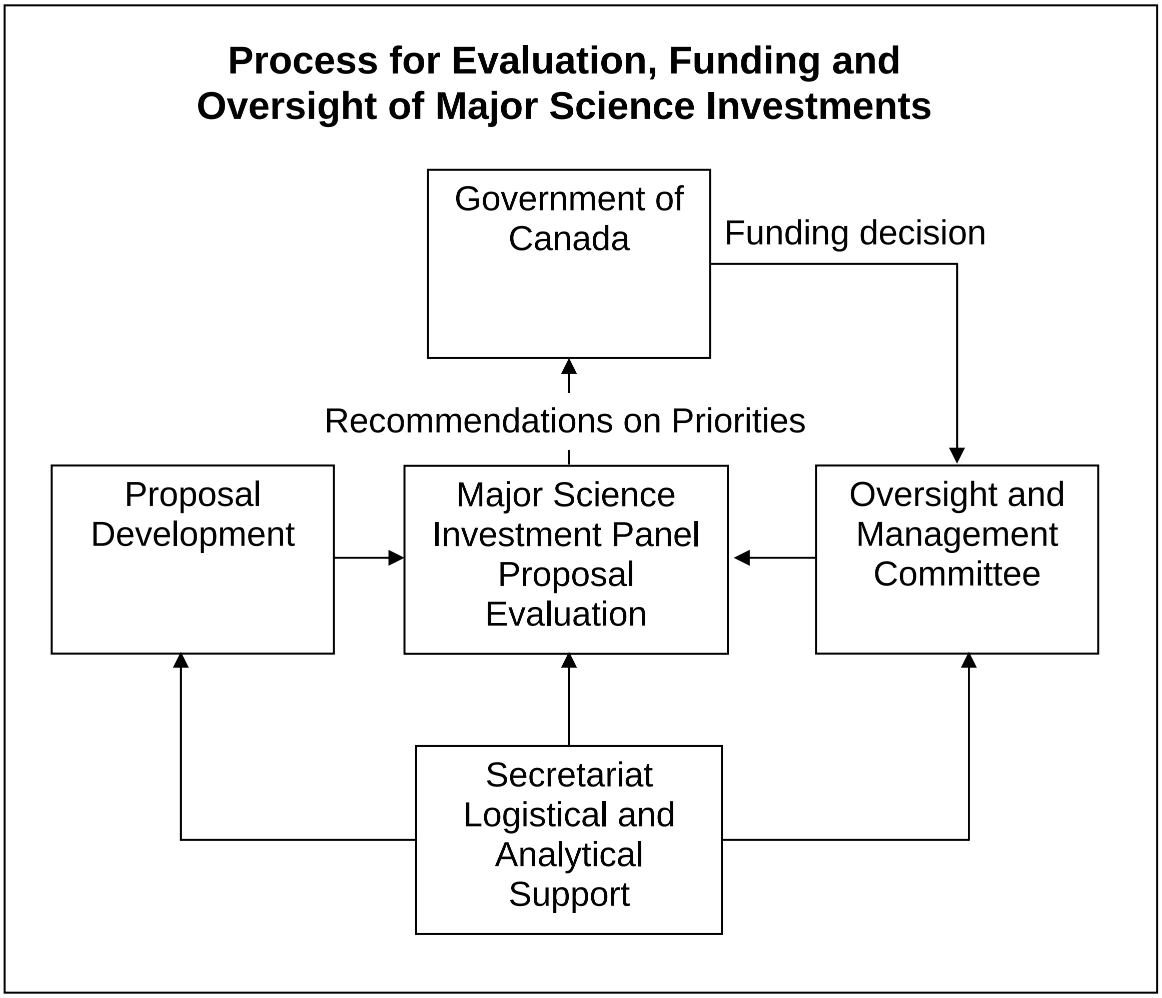
NRC-NSERC Long Range Planning Panel (1999), *The Origins of Structure in the Universe: Canadian Astronomy and Astrophysics in the 21st Century*.

Office of Science and Technology (UK) (2003), *Large Facilities Strategic Road Map*.

Organisation for Economic Cooperation and Development (OECD) (1993), Megascience and its Background

Wolfson, M.C, (2004) “Thoughts on the Nature of Big Science”, Statistics Canada, (unpublished draft)

APPENDIX A: Flow Chart



APPENDIX B: A Framework for Assessing Proposed "Major Science" Projects

The proposed framework is in the form of a list of questions, starting at a high level and descending into detail. These questions could serve two purposes. The complete list of answers could constitute the proposal or application for funding. The answers to the individual questions, or to groups of questions, could provide the basis for comparing and prioritizing different "major science" projects competing for public funding.

Project description and rationale

1. *What is the project and why is it being proposed?*
    a. Describe the project in 100 words or less, and then proceed to answer all the questions below.
    b. How does the project advance the government’s agenda in areas such as research excellence, commercialization, economic and social benefits from research discoveries as well as international objectives?
    c. Is the project unique or are there others like it in other countries? How does it complement other Canadian and international initiatives?
    d. Is this a Canadian project with possible international partners, or is it an international project with possible Canadian participation?
    e. What are the research questions to be answered? Why are they important and at the leading edge internationally? To what extent will the project have a major impact on the issues being addressed?
    f. Why is the project important or critical to the discipline(s) or research community proposing it? Is it included in the strategic plan of a discipline? How might the results impact other disciplines?
    g. Is this project included in the strategic research plan of a Canadian university or institution? Which one(s)?
    h. How will the research results be used, and for whose benefit? What receptor capacity exists in Canada for the results?
    i. Can significant technological benefits be expected? What are they? What will be their impact and can they be effectively exploited?
    j. What other benefits might accrue if Canada were to build/participate in this project (for example, international prestige, attraction of highly qualify personnel, new investment, etc).
    k. Are there social repercussions from the investment in the proposed project?
    l. Are there national security dimensions?

m. Are there potential contributions by industry?

n. For what purpose(s) would be requested funding be used?

o. If this is an international project, what form is the Canadian contribution expected to take?

p. Why should the project be funded by Canada, and why now?

q. If the project is not funded, what is the loss? To whom?

2. *What are the risks?*

   a. What are the risks involved with the project, and how will they be managed?

   b. Are new technologies required for the success of this project? How much of it can use existing technologies, and how much must be new and untried?

   c. How will any new technologies be developed and tested?

   d. Is a design/technical feasibility study required?

   e. Will an environmental assessment or other permits be required? Are there other legal or ethical issues to be considered?

   f. Do alternative approaches exist? Why is the proposed approach considered to be the best way forward?

Where

3. *Where is the project to be located?*

   a. Does the project have a fixed installation or installations (single or networked), or is it a movable activity such as field work?

   b. If a fixed installation(s), is it one big experiment (for example, SNO) or a big facility for many small experiments (for example, CLS)?

   c. If the project involves a single fixed installation, what is the proposed location of the project, and what are the reasons for locating it there?

   d. If the project involves distributed facilities, what are the reasons for the locations of the components?

   e. If there are competing possible locations or sites, on what basis should the best location or site be chosen?

   f. If the location is known (and if applicable), what will be the impact of the project at the local or provincial, as opposed to national, level? Will it build on local/provincial R&D strengths and/or infrastructure? Will it serve to correct any imbalance?

g. What are the local/provincial development implications of this project, if any?

h. What are the implications for civic infrastructure?

i. What support is there from local and provincial governments?

j. If the location is known (and if applicable), answer questions d. and e. for impacts at the global regional level (for example, North America, Asia, etc.).

Who

4. *Who is proposing this project?*

    a. Is there an outstanding group of Canadian university, government, and industry researchers committed to working on this project? Who are they, and why are they the best qualified? What reasons are there to believe that they would succeed in winning support from the federal departments and agencies to support their work in this project?

    b. If this is a Canadian project, who will have overall responsibility as its scientific leader and what are that person's qualifications for the task? What commitment of time is the leader making to this project?

    c. Who else proposes to take positions of responsibility for this project, and what are their qualifications and time commitments?

    d. What management structure has been put in place for the project?

    e. Who will provide the project management?

    f. Does an existing institution propose to provide the organizational locus for this project? If so, what services will it provide, and what resources will it commit to providing them?

    g. If no existing institution will house this project, what new organizational structure is being proposed?

    h. If there are international partners in this project, who are they and what role are they expected to play in managing the project?

5. *Who will build the project?*

    a. If the project is located in Canada, how will the project construction be managed and coordinated? Is there the technical capacity in Canada to build the project in whole or in part? If so, who are some of the qualified people (organizations, companies), and have they been involved in the development of the proposal?

   b. If Canada does not have that capacity, or if the project is located (all or in part) outside Canada, who will manage the project construction and how will Canadian interests be advanced?
   c. What will be the opportunities for Canadian suppliers to be trained and upgraded to supply the advanced components of the project?
   d. How will we ensure that as much as possible of the total project cost will be spent in Canada? ... or even of the Canadian contribution?

6. *Who will operate the project?*
   a. What will be the ongoing operational activities of the project (for example, staffing, services, supplies, maintenance, computing infrastructure, travel, field work, training, data processing and analysis, new experiments, special facilities)?
   b. What is the management structure for the operational phase of the project and who will participate?
   c. Does Canada now have the technical personnel required to operate such a project?
   d. If not, could they be trained during the construction phase to become available for the operation phase? Where, by whom?
   e. Are there Canadians abroad who might come back for this project?
   f. Could highly qualified foreigners be attracted to this project, if needed?

7. *Who will be trained as a result of the project?*
   a. What will be the impact of the project on the training and education of highly qualified personnel (for example,, postdoctoral fellows, graduate and undergraduate students, technicians)?
   b. What will be the opportunities for the enhancement of training arising from a collaborative or interdisciplinary environment?

How much

8. *How much will the project cost?*
   a. What is the best current estimate of the total capital cost of the project, including site preparation, all the permits, environmental assessments, design and construction costs, and site restoration at the end of the project?
   b. In support of the estimate, give examples of the capital costs of similar projects recently built in Canada or abroad.

c. If there are international partners, what share will they contribute to the capital costs?

d. Who are the Canadian funding partners for this project and what will they contribute to the capital costs?

e. Is an application being made to CFI for a grant to support this project?

f. What uncertainty in predicted cost could be expected for a project with this level of risk? In support of the estimate, give examples of the accuracy of initial estimates and contingencies in similar projects recently built in Canada or abroad.

g. What is the best current estimate of the operating cost of the infrastructure of this project (to fund activities described in 6a), as distinct from the direct costs of research that might be provided by Government of Canada agencies to scientists actually doing the research?

h. What share of this operating cost will the international partners provide?

i. How many Canadian scientists might be involved in using the completed project, and what magnitude of research grant would be required to support their effective use of the project infrastructure? On that basis estimate the annual incremental cost to the federal granting agencies of running this project.

j. Is there any logistical premium that would have to be provided in the research grants in order to make full use of the project (for example, travel costs and housing in a remote location)?

k. What might be the order of magnitude of decommissioning costs at the end of the useful life of the project? Again, cite examples from recent experience around the world.

When

9. What are the time scales of the project?

a. How long would the project take to build, from authorization to commissioning? Given the risk level of the project, what delays might be expected in the light of experience with related projects?

b. What would be the profile of expenditures during that time?

c. How long might the project operate until its goals have been met, or until it has run out of capacity to produce new science?

10. What are the time scales of the returns and benefits?

a. Aside from the economic activity associated with construction, are any short-term economic benefits to be expected?

   b. What medium-term economic benefits might be expected?
   c. How long might it take to begin producing data once the project has been built, and when might the first scientific results be expected?

11. *What happens at the end of the project?*
   a. What will determine when the project has come to an end?
   b. If a Phase 2 can already be visualized, is provision for it being made in the design of Phase 1?
   c. Alternatively, if Phase 2 is not visualized at this time, what is the plan for disposing of the assets of the project?

APPENDIX C: Suggested Criteria for Use by the MSIP in Determining a Proposal's Priority

Excellence of the project

- Excellence of the proposal team and of the scientific opportunity that has been identified;
- Excellence of the proposed research in terms of the impact of the results on the field; potential of the research to answer key questions and expand frontiers; potential to change how research is conducted; and, impact on other disciplines;
- Degree of support from the Canadian research community proposing the project (for example, priority placed on project in long-range planning activities, etc.);
- Extent to which the project would contribute to Canada's international leadership in areas of science and engineering;
- The project management and leadership capabilities of the team behind the proposal.

Development of highly qualified personnel

- Potential of the project to provide opportunities to train and retain outstanding researchers;
- Enhancement of training arising from collaborative/interdisciplinary/ international environment;
- Potential to create a skilled workforce with experience and capacity in managing large, complex projects.

Benefits to Canada

- Benefits to Canada's economy, social issues, health, environment and prestige;
- Impact on Canada's scientific reputation;
- Benefits in terms of the federal government's agenda.

Partnerships

- What commitments are in place from other agencies (international, national, provincial, local) or other countries?

Timing

- Is there a window of opportunity to participate in or initiate the project? How pressing is the need and urgency?
- Is the project technologically ready to be implemented in the near term, or is more R&D required?

Management Plan

- Is there a well-developed plan for the management of project construction, commissioning and operation? In the case of off-shore international projects, this criterion would apply separately to the management of the Canadian contribution.

Budgets and scheduling

- Is the budget well-justified?
- Does the budget include all life-cycle costs such as capital costs or membership, operations, cost of access to foreign facilities, cost of decommissioning, etc.?
- Are the proposed schedules reasonable and achievable?

Contingencies

- Are contingencies appropriate for the risks involved?
- An agreed methodology about contingency is required as proposed projects may come forward with very different ideas about risks and required contingency.

APPENDIX D: List of Acronyms

ALMA:	Atacama Large Millimetre Array
CFI:	Canada Foundation for Innovation
CIHR:	Canadian Institutes for Health Research
CLS:	Canadian Light Source
CNF:	Canadian Neutron Facility
MRC:	Medical Research Council
MSIP:	Major Science Investment Panel
NCE:	Networks of Centres of Excellence
NRC:	National Research Council Canada
NSA:	National Science Advisor
NSERC:	Natural Sciences and Engineering Research Council
OECD:	Organisation for Economic Cooperation and Development
OMC:	Oversight and Monitoring Committee
SKA:	Square Kilometre Array
SNO:	Sudbury Neutrino Observatory
SSHRC:	Social Sciences and Humanities Research Council
TRIUMF:	Tri-University Meson Facility
VLOT:	Very Large Optical Telescope