compute canada

Compute Canada’s Response to Canada’s Fundamental Science Review

About Compute Canada

Compute Canada's mandate is to serve advanced research computing (ARC) and research data storage needs at any scale, for any discipline, for all of Canada. Compute Canada supports projects ranging from a single faculty member, up to the largest "Big Science" projects in the country. The facility enables world-leading research in many disciplines, including digital humanities, engineering, computer science, physics, astronomy, chemistry, neuroscience, bioinformatics, and mathematics. The national platform also supports researchers from large and small research institutions from coast-to-coast, across many sectors. The diverse community needs are met through Compute Canada's delivery of services, which include traditional tightly coupled High Performance Computing (HPC), serial High Throughput Computing (HTC), cloud computing and storage, visualization and other technology solutions as required.

Compute Canada is the national advanced research computing (ARC) facility of Canada. We are a not-for-profit corporation and a federation of 37 member universities and research institutions. The 37 institutions collectively own the infrastructure and employ the 200 experts that serve researchers across the country. Compute Canada's skilled team members are themselves an essential resource for Canada, working together to help Compute Canada's users accelerate and amplify their own research achievements. The federated Compute Canada team has been assembled from long-standing institutional consortia that now participate in Compute Canada as partner Regional Organizations: ACENET, Calcul Québec, Compute Ontario and WestGrid. Together, we support more than 10,000 researchers including more than 3,000 faculty.

Are there any overall program gaps in Canada's fundamental research funding ecosystem that need to be addressed?

The Advanced Research Computing (ARC) needs of the Canadian research community continue to grow and are essential as the next generation of scientific instruments are deployed and as new datasets are gathered and mined in innovative ways. Software and common advanced research computing services require robust, professional and scalable services. More and more researchers require common software services, as well as specific software funding for their projects. There is no current funding mechanism for national research software services. Current funding is for teams or individual researchers who may or may not be working toward a scalable, reusable, sustainable model, and in many cases only have access to short-term funding. Future research software funding should consider whether existing offerings are available to meet their need to avoid duplication, are mature enough to offer production quality service and are able to scale on shared infrastructure. The current mix of software and related interoperability-focused infrastructure funding to researchers and to digital research infrastructure providers generally is not directed at solving common broader problems, nor on spanning national common services. Coordination is not sufficient to create the necessary interfaces among the common services and tools. Focused expertise must be brought to bear, with goals beyond single research projects or research group goals. Current research software development for advanced research computing and data intensive research benefits from those computational scientists and developers experienced in creating production-quality software. Compute Canada supports more than 200 experts across the country to directly support research teams. However, the current funding model does not provide national software solution support.

Are there elements or programming features in other countries that could provide a useful example for the Government of Canada in addressing these gaps?

"Sustainable software for the 21st Century" is a program operated by the US NSF that demonstrates one approach to this problem.

Are granting councils optimally structured and aligned to meet the needs of the current research community in Canada? Are the current programs the most effective means of delivering the objectives of these organizations? And are they keeping pace internationally? The review should take into account the several reviews and evaluations that were performed in recent years on the councils and on science and scholarly inquiry in Canada.

Compute Canada is the only provider in Canada funded to enable excellence in research and innovation for the benefit of Canada by effectively, efficiently and sustainably deploying a state-of-the-art advanced research computing platform supported by world-class expertise. We use this platform to support a growing base of excellent researchers. Compute Canada recommends increased coordination and planning between Compute Canada and those government agencies that fund research; as well as any major science projects that require access to advanced research computing resources (regardless of funding source). Compute Canada's investments must align with strategic program investments by these funding agencies and by major science projects.

Today, Compute Canada provides expert advice in connection with CFI-funded projects that require advanced research computing support. This model could be strengthened and extended to other agencies, such as NSERC/CIHR/SSHRC, Genome Canada, as well as to high-impact programs such as the Canada Research Chairs (CRC), Network Centres of Excellence (NCEs), and the Canada First Research Excellence Fund (CFREF), as well as key initiatives funded by these programs. Such coordination has already benefited researchers through the use and evolution of shared infrastructure.

Requests for ARC investment (above a certain level) are ineligible under Tri-Agency and Genome Canada rules, as well as ineligible under programs such as the Canada Research Chairs and CFREF. However, recognizing these investments require the use of ARC needs to be coordinated.

Are students, trainees and emerging researchers, including those from diverse backgrounds, facing unique barriers within the current system and, if so, what can be done to address those barriers?

The Government of Canada's multi-billion dollar investment in research support across a wide range of disciplines and many application areas rely on access to ARC. However, there is currently no coordination between federal investment in research, and investment in this key enabling infrastructure. As a result, capital investment in the national ARC platform has been irregular and inadequate to support the growing needs of the research community.

In 2016, Compute Canada could only fulfill an average of 54% of technically reviewed and validated resource requests from academically funded researchers (down from 84% in 2012). This represents a serious shortfall that inhibits the success of existing funded projects, and disproportionately impacts students, trainees and emerging researchers. Canadian researchers have to look elsewhere to find ARC resources they need, and in Canada this means using facilities in other countries or decreasing the scope and ambition of their computationally-based scientific inquiries. In some cases, our best researchers may take their brilliance, innovations, teams and investments to competing jurisdictions, possibly creating a brain drain for Canada in many important research sectors. There are already documented examples of "star" Canadian researchers choosing jobs in other countries, motivated by superior ARC facilities.

Per estimates of the researchers we serve today, computational requirements will increase 7x over the next five years and storage requirements will be see a 15x increase. (These estimates do not reflect the needs associated with significant investments in research, for example through CFREF and the TMT.) Currently, in Canada, we have a growing community of funded researchers and research groups that cannot access computing and storage services from Compute Canada and have in most scenarios no other service option.

Is there an appropriate balance between funding elements across the research system, i.e. between elements involving people and other direct research costs, operating costs, infrastructure and indirect costs? What are best practices for assessing and adjusting balances over time?

Canada's ARC funding has been concentrated with Compute Canada in order to minimize duplication and maximize capacity available to researchers. As indicated above, coordination between research investments and availability of ARC services should be coordinated and appropriately accessible to ensure national science and research investments have access to the required advanced computing infrastructure. There is strong evidence to demonstrate Canadian researchers, large research groups and major science investments in Canada are being significantly hampered due to lack of ARC resources.

Is the Canada Foundation for Innovation optimally structured to meet the needs of the current research community in Canada? What are the strengths and weaknesses of the current model in delivering the objectives of this organization, including its ability to work complementarily with the granting councils? What is the appropriate federal role in supporting infrastructure operating costs and how effective are current mechanisms in fulfilling that role?

Canada's major science facilities are national in scope, providing leading edge infrastructure that addresses critical scientific questions of such complexity and size that they require facilities outside normal University capabilities. These facilities develop and operate over many years and involve many stakeholders from the private, public and international communities. In order to sustain these efforts, Canada needs to consider the development of new policy tools and frameworks to develop and support such major science facilities over the long term.

Many of Canada's international competitors in science, technology, and research assess and support their large-scale science facilities through comprehensive planning processes that encompass the full life-cycle of a facility, including justification, development, commissioning, and operations. For ARC, the lifecycle of the infrastructure is 4 to 6 years, but service is required on an ongoing basis. Compared with the current project-based funding approach, this holistic approach ensures delivery of appropriate research infrastructure to the scientific community. It would improve efficiency in delivery and operations, and enable stability and predictability for the facilities, thereby enabling the ability to attract and sustain research and industrial partners, optimize investments, maximize opportunities, and attract and retain top talent, not only across the research community. Over the past two decades in Canada, a series of programs have evolved in almost patchwork form to develop and support major science facilities. Today, a large-scale science initiative may apply to one program for capital and another for operations, while researchers apply to entirely separate programs for funding to support their use of the infrastructure. By not addressing and coordinating the full facility life-cycle, this piecemeal approach increases the risk associated with managing a large-scale science initiative. The situation would benefit from a more coordinated approach within the federal government.

This life-cycle coordination needs to include other levels of government and stakeholders. At present, federal funding comes with an expectation of securing matching funding, often from provinces and territories. Several provincial governments have come to question the validity of investing resources in an entity that is national in scope. In addition, provinces are seeking a demonstration of local value and impact, which can become a barrier to collaborations or consortia across provincial jurisdictions.

To improve the environment for provincial/regional and national collaboration we recommend national services be funded 100% federally. The operations of Compute Canada's counterparts internationally (e.g. XSEDE, PRACE, EGI) are largely, if not 100%, funded by national (NSF) or international (EU) funding sources.

To address these mounting pressures, significant resources and efforts are often required to align and coordinate stakeholders. In some cases, such obstacles result in substantial project delays. Put simply, the system supporting national big science research infrastructure needs to be aligned across all stakeholders, enabling Canadian facilities and researchers to continue to compete and excel at the global level.

Stewardship of large-scale research within the federal government is currently fragmented between a number of departments and agencies. At present, each facility acts independently to secure resources for operations and development for the future. A clear stewardship model for each facility would ensure coordination of big science in Canada and ensure maximum value is extracted from these investments.

At present, there is no clear champion for big science within the federal government. The proposed national science advisor will provide leadership to the overall science enterprise within federal departments; however, this alone may not be sufficient. Additional requirements are to improve the coordination between various levels of governments, and to engage non-governmental stakeholders, including industry, research communities, and civil society. Through better coordination with these partners, Canada could unlock new capacities and efficiencies within our large-scale research facilities.

Finally, centralised coordination for big science could help guide Canada's interactions with the global research community, and support the delivery of national participation in international research initiatives.

What are best practices (internationally/domestically) for supporting big science (including, inter alia, international facilities and international collaboration)?

As indicated above we recommend the holistic approach employed by many of Canada's international competitors in science, technology, and research to assess and support their large-scale science facilities, through comprehensive planning processes that encompass the full life-cycle of a facility, including justification, development, commissioning, and operations. This approach ensures delivery of appropriate research infrastructure to the scientific community, improves efficiency in delivery and operations, and enables stability and predictability for the facilities, thereby attracting and supporting research and industrial partners, optimizing investments, maximizing opportunities, and attracting top talent.

Many requests for government support for research are not tied to the cycles of the four major research agencies, but they have economic or competitive relevance nationally or regionally, or major non-governmental financial support, or implications for Canada's international standing as an active participant in big science projects or major multi-institutional projects. How can we ensure that the Government has access to the best advice about funding these types of projects in the future?

We recommend the creation of a Digital Research Infrastructure Advisory Council of digital infrastructure and service experts, which would improve coordination of investment and interoperability of technology among current providers, and provide advice to the Government of Canada on publicly funded digital research infrastructure technology. This could be in partnership with or a committee of the Leadership Council on Digital Infrastructure (LCDI).

What types of criteria and considerations should inform decisions regarding whether the Government should create a separate funding mechanism for emerging platform technologies and research areas of broad strategic interest and societal application? Are there any technologies that would appear to meet such criteria in the immediate term? When there is a rationale for separate funding, how to ensure alignment of funding approaches?

Advanced research computing (ARC) infrastructure and services are essential infrastructure for personalized medicine, advanced materials, genomics, engineering, environmental science and many other key strategic areas for growth in Canada. Nations around the world are creating strategic policies and funding support to ensure they are leaders in future scientific discovery that is increasingly fuelled by big data analytics and scientific computing.

Like the Trans-Canada Highway, this infrastructure requires a national strategy and national leadership to realize its benefits. It is larger than any one province or region can support, and it is fundamental to becoming an innovative nation. This is the infrastructure that is being used in Canada to develop new alloys for next generation aircraft, mapping environmental systems and infectious disease patterns and creating a platform for innovative new products. These needs cannot be met by current commercial computing systems. Like other countries, Canada needs to build, sustain, and continually improve its own advanced research computing delivery model to ensure the right systems are in place for the research community so that we can achieve our goals in research and innovation. As noted above, the funding of platform technologies, such as advanced research computing and DNA sequencing, should allow optimization of capital and operating costs, encourage efficient and reliable operations, prudent innovation and experimentation, and above all reward efforts that enable increased productivity for research users.

Today's emerging platform technology may rapidly become a standard tool used tomorrow by a wide variety of researchers. If such technologies are initially given stand-alone support via a dedicated program or agency, what factors should inform decisions on when it would be appropriate to "mainstream" such funding back into the granting councils?

Advanced Research Computing is an essential service for all disciplines yet we have not evolved the funding mechanism to reflect this reality in Canada. Here, the economies of scale and scope argue for consolidation and concentrated investment in a national platform, ideally with funding guided by the criteria and considerations noted above. Pooling investments in ARC that are currently separated into economic development and science investments to purchase larger leadership quality systems would greatly increase Canada's ability to compete as innovative nation. Scale and size are key competitive factors in ARC. Larger systems supporting more than one community would allow for more world-class larger scale usage.

"We need Infrastructure that supports change" – PM Trudeau, Davos, January 20, 2016

Are Canadian research facilities keeping pace internationally? If not, what changes or new programs are needed to close the gap?

Compute Canada has analyzed public data on high performance computing systems around the world (the “Top 500” list, top500.org), aggregating computational capabilities found in the academic and research sectors by country, and comparing the total computational capability with the total number of researchers in higher education, as reported by UNESCO. Using the metric, gigaflop/s per researcher (unit of measure compute resources), we can see a portrayal of national resources that is not distorted by the scale of the different countries involved. On this basis, in 2009, Canada was 6th in the world. Canada’s international rank (as of 2015) was 24th, out of roughly 34 countries for which data is available. Since 2009, Canada has fallen steadily and is not keeping pace with other G20 countries.

Is the federal funding ecosystem meeting the needs of facilities? Is it meeting the needs of the researchers who use your facilities? As the needs change, is the ecosystem able to adapt and accommodate?

Led by Compute Canada, the Sustainable Planning for Advanced Research Computing (SPARC) is a national consultation process to gather feedback from users and researchers on the types of investment required to enable Canada’s excellence and leadership in science and innovation. The foundation for our technology planning is based on our consultations with the research community. We know we offer more than 10,000 researchers an essential service and the requirements for capacity are increasing, as is the community we serve. The community’s input influenced Compute Canada’s proposal to the Canada Foundation for Innovation for operating funding through to 2022 as well as future proposals to the CFI for additional capital investment in the pan-Canadian advanced research computing platform.

How does your facility identify the needs of the Canadian research community? How do you adapt to meet those needs?

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Is there a need for high level oversight for Major Science Initiatives in Canada? If so, what would it look like in terms of structure, responsibilities, and scope? Would oversight be provided throughout the full project cycle to decommissioning?

Compute Canada supports a central body within the Government of Canada that specifically focuses on oversight for research infrastructure and Major Science Initiatives' full lifecycle and to move beyond project based funding.

Should the approach to oversight and funding for MSI projects be more uniform for all the projects in Canada? If so what would you suggest?

Compute Canada recognizes that science-driven oversight, governance and management are as critical to its own effectiveness as they are for other MSI projects. We also agree that a national science policy, and national science priorities, should guide and harmonize all of our efforts.

At the same time, Compute Canada's oversight and funding mechanisms should acknowledge several characteristics of our essential service and infrastructure that may warrant slightly different treatment:

- Our potential mandate as the operator of the pan-Canadian ARC service, as opposed to one of many possible infrastructure providers. Currently this is our *de facto* role; recognizing our role as an essential service might argue for different mechanisms.
- Given our support for other MSIs, competing with those endeavours for the same funds might be inappropriate. Similarly, given our support for nationally strategic investments (e.g. CFREF, Genome Canada) and international projects (e.g. ATLAS, TMT), funding for ARC services should be coordinated with commitments in these other areas.
- As operators of a national service, we provide a “national coordinating activity" that is required by our distributed nature, but funding for this activity might require different mechanisms.
- We are unique in how we handle different timescales of investment. Most other “big science” facilities have very long time horizons and at the same time would appreciate “cradle to grave” funding commitments. We on the other hand need "predictable sustained" funding since our assets have comparatively short lifespans (we need to be able to rely on announced funding opportunities at most 3 years, and ideally 2 years, apart), and we also need the ability to modify our technology plans in response to shifting science needs while still providing a reliable service to thousands of Canadian researchers.

Please comment on the coordination between the programs being provided by the granting councils and other funding organizations, provinces, and/or amongst themselves. Are there areas for improvement?

Compute Canada recommends increased coordination and planning between Compute Canada and the government agencies that fund research. Compute Canada’s investments must align with strategic program investments made by these funding agencies in order to serve the research community in Canada. Researchers would benefit from assurances that the computing resources required to complete their research are available and to not encounter delays or lack of resources after their research awards are received.

Today, Compute Canada provides expert advice in connection with CFI-funded projects that require advanced research computing support. This model could be strengthened and extended to other agencies, such as NSERC/CIHR/SSHRC, Genome Canada, as well as to high-impact programs such as the Canada Research Chairs (CRC), Network Centres of Excellence (NCEs), and the Canada First Research Excellence Fund (CFREF). Such coordination has already benefited researchers through the use and evolution of shared Infrastructure. Today, requests for advanced research computing (above a certain level) are ineligible under Tri-Agency and Genome Canada rules, as well as ineligible under programs such as the Canada Research Chairs and CFREF. We are currently funding research activities in Canada with the full understanding that Compute Canada cannot meet their needs due to lack of resource capacity; however, researchers are obliged to seek resources from Compute Canada as a sole provider.

What are the ways that your facility encourages or performs multidisciplinary research? Do you partner with other organizations, facilities or institutions to perform your research? How do these partnerships occur and how are resources allocated between partners? Are there barriers to partnerships or collaboration that your facility is facing?

We support more than 10,000 researchers in Canada including more than 3,000 faculty. We have several access and support mechanisms that explicitly encourage and enable national and international collaboration through a federated model that supports more than 200 experts at over 37 institutions across the country. Our facilities are leveraged by the researchers as in-kind support for participation in several international research endeavours including ATLAS and CANFAR. ARC research is inherently multidisciplinary combining engineering, math, computer science expertise with a suite of disciplines.

How important is international collaboration and/or funding to your organization and users of your facility? Do you face any barriers to enhanced international collaboration? Please comment on your international collaboration efforts and initiatives.

Compute Canada supports more than 8,000 international researchers who are partnering with Canadian researchers on a wide variety of international projects. For management of the national platform, collaboration internationally is a key activity that allows us to move toward global interoperability for Canadian researchers as research becomes more multi-disciplinary and more grand challenges are being addressed by international teams.

Are there international programs, structures, models, or best practices that Canada should adopt? If so, please explain why these should be considered.

At a high level, funding and oversight of advanced research computing in other jurisdictions is marked by considerably more national and international strategic vision, as well as higher levels of "central" funding.

- In the US, a cyberinfrastructure strategy has been in place for years, with regular updates, consultations with the community and consideration by learned bodies. Similarly, in the European Union, EU-wide strategies have been developed and updated and have guided funding of numerous EU initiatives. In both jurisdictions, cyberinfrastructure strategy is a clear component of overall science strategy and priorities.
- In the US, funding for advanced research computing is largely provided by the National Science Foundation, funding 100% of the costs of both XSEDE and a number of major academic system operators. In the European Union, the EU funds roughly 100% of the central operations of PRACE, the primary supercomputing initiative in Europe, as well as a high proportion of the central operations of a sister to PRACE, the European Grid Infrastructure (EGI), which coordinates and manages the operations of national facilities funded and operated within each partner country.

What should the vision be for Canadian science? If we imagine an even more successful future for Canadian science, what does success look like and how should it be measured?

Canada requires an integrated approach to big data and advanced computational infrastructure that will benefit all sectors of research and development. A comprehensive system that supports the full data research cycle (currently Compute Canada does not have the mandate to archive data, while this would be relatively simple as we store much of the active data today) will allow researchers and their industrial and international partners to compete at a global scale. With enhanced coordination of major science investments that rely on advanced research computing resources, we can ensure these major investments deliver on their promise. If resource providers are given the mandate and funding to foster interoperability among their resources, providers will create workflows that easily span different resources - from the lab or campus, to national computational resources, to analytical facilities, to publication archives, and with collaborators. The funding for various components will be organized in an improved model removing duplication and maximizing investments. Funding and oversight of the various components will be aligned and managed by organizations with the appropriate expertise.

The Government of Canada's recent science review is timely and of critical importance to Canada's ability to remain an innovative nation. Compute Canada supports the development of a national advanced research computing strategy.
Through modeling, simulation and high performance data analysis, Compute Canada services and platforms are fuelling Canadian companies, government agencies and research investments in Canada. This is encouraging new ways to conduct research and business, develop transformative products, offer services and interact in ways that improve everything from health and safety to productivity and entertainment.

The lack of advanced computational resources is an ongoing retention and attraction issue for research activities in Canada. Adopting a national strategy for advanced research computing would be a giant step forward enabling world-class activities in Canada.

Are there any other issues or questions that you would like to raise and address?

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How should Canada define Big Science infrastructures? Should the definition be strictly based on dollar figures, or do other factors need to be considered? If so, what are those factors?

Larger investments certainly argue for treatment consistent with other large investments, but the dollar value alone should not define "big science". Here are several other important considerations:

- Extreme performance metrics are required by the science:
  - Particle energy achieved in a particle accelerator (LHC is 4 TeV)
  - Calculation capacity in supercomputing (93 PF = #1 in Top500)
  - Telescopic sensitivity and/or frequency range
  - Detector noise (e.g. in LIGO)
- Unique characteristics required for the facility, e.g.
  - Natural "filtering" of ice or rock (IceCUBE, SNOlab)
  - Avoiding light pollution and atmospheric distortions (optical telescopes in remote locations or space)
  - Avoiding electromagnetic pollution (SKA)
  - Natural environment (arctic, boreal forest, volcanoes)
- Economies of scale plus shared use that create platform technologies
  - Advanced research computing

- Genomic sequencing
- Databases (CADC, PDB, BIND, DataOne)
- Data collection systems (ONC, LSST)

Clearly these factors interact -- if a particular scientific question requires a certain computational performance, other scientific questions can be addressed with the same infrastructure, so making sure it can be shared, and shared efficiently, (a platform technology) is worthwhile. You might locate that advanced research computing facility in a cold climate near a natural power source in order to reduce operating costs.

For Platform technologies, additional considerations might come into play:

- "Critical Mass" of users -- This criterion should not require that any specific investment must itself always be used by a very broad community. For example, Compute Canada serves many different "micro communities" with resources (hardware, software) optimized for the use of that community, although those resources are physically part of a larger resource that can be shared more broadly.
- "Shared access" -- again, some portions of a larger resource might be dedicated at different times to specific users or "micro communities", with Compute Canada ensuring that that investment can be used by other users at other times, and operating the dedicated as well as the more broadly shared resources using consistent best practices.
- Infrastructure and service-orientation rather than project-orientation. ARC is essential to all scientific disciplines, and Compute Canada works to enable its broad user base through regular investment in and renewal of its technology base, coupled with efficient management and operation of that technology, as well as support personnel and resources working to help users maximize their productivity and impact. Ideally Compute Canada would be treated as an essential service that must be sustained, rather than a project moving from cradle to grave.
- Serving pan-Canadian needs. This extends the "critical mass" consideration -- and some big science investments can be more effective if they have a pan-Canadian mandate, allowing more effective needs-assessment and planning. Compute Canada takes this approach already; this translates into improved needs assessment as well as a holistic approach to measuring the impact of our investments; formal recognition of a mandate of this nature would clarify our role in many national and international situations.

Decisions regarding support for Big Science should be driven by national strategic priorities and mechanisms to create national advantage (whether through knowledge, people or technology), and should be gated by full commitment to the project (either from within Canada or with international partners). Care should be taken in defining Big Science "projects" (that depend on Big Science infrastructure) as opposed to Big Science "infrastructure" (which must serve science projects, big and small). Big Science infrastructure facilities must be funded on a life cycle basis -- while Big Science projects should be funded cradle-to-grave -- with Big Science infrastructures engaged in, and funded to perform, the development of Big Science project proposals.

What is working and what is not working with the current ad-hoc model for funding large infrastructure? What are the challenges associated with the requirement for 60% fund matching? Is there a need for predictable cradle to grave funding and oversight of Big Science infrastructure? Should this cover some, most, or the entire cradle to grave life-cycle? What would be the challenges or opportunities associated with this model?

The 60:40 matching formula creates challenges for most big science investments. For Compute Canada, this formula creates challenges for funding of the national management and coordination of distributed facilities, even if those facilities are acknowledged to serve pan-Canadian needs. As Compute Canada considers investment in concentrated "national-scale" facilities at a single location, of a scale greater than required by any local region, the matching formula will make it difficult to raise both the required capital investment, and the associated ongoing operating investment.

Compute Canada has been a long advocate for predictable funding for major science infrastructure. Compared with many other "big science" investments, the useful lives of our investments are short (4 to 6 years) and must be regularly renewed. The availability and scale of future funding is an important consideration in current planning, so regular funding opportunities of a predictable nature allow us to plan, invest and operate more efficiently. For example, there was close to a decade long gap in capital funding for systems that have a four to five year lifespan.

The nature of current funding models creates tension not only between the "local" and national levels, but also between operating and capital requirements. Compute Canada makes frequent tradeoffs between capital and operating investments, where the relative availability of capital or operating funds may constrain our ability to create the best value for Canada. Flexible access to both kinds of funding would create value for Canadian taxpayers, and increase the quality and quantity of support provided to the Canadian research community.

Compute Canada's service to other science domains, including Big Science, should be considered when designing funding programs. In the most recent MSI competition, Compute Canada was competing with some of its "customers" for MSI funding.

Big Science infrastructure should be funded on a life cycle, rather than cradle-to-grave, basis, recognizing that significant costs are associated with design, startup, commissioning, operations, renewal or potentially decommissioning. Regular reviews of both operational efficiency and science relevance are required and appropriate.

What are the pros and cons of establishing an expert body or office to be the steward of Big Science infrastructure in Canada. How should it be structured? Should it be arms-length to government? What should the membership be?

Compute Canada encourages such coordination, and such a body might accomplish this objective. Clearly scientific considerations should guide decision-making by such a body. The "big science" facilities want the resulting science-driven recommendations to translate into appropriate funding, arguing that the body should sit within government.

Care is also needed when defining "stewardship" -- Compute Canada provides stewardship for the national platform it operates, and Compute Canada's independent board is accountable for this activity.

Who should speak for Canada on the international stage? How do we determine when it makes sense for Canada to build its own facility versus participating in an international facility?

Canada requires a national organization responsible for Advanced Research Computing. Compute Canada represents the nation at international discussions, meetings and technology conferences. Collaborations and partnerships in this area will allow for common services to be adopted globally enabling collaboration around the world and ensuring Canada remains competitive and its technology investments are interoperable with international trends.

Big Science infrastructures in Canada should have the ability and resources required to engage in development of Big Science projects that might rely on their infrastructure, and access to resources to allow the necessary international commitments to be supported for those projects endorsed as priorities for Canada.