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# Global Research Collaboration and Infrastructure

## Government Science and Innovation in the New Normal Discussion Paper

By Ezra Miller and Dr. Jeff Kinder I December 2022

# TABLE OF CONTENTS

## ABOUT GSINN – CANADA NEEDS A NEW RELATIONSHIP WITH SCIENCE AND INNOVATION THAT REFLECTS OUR TIME

In December 2020, the Institute on Governance launched *Government Science and Innovation in the New Normal (GSINN),* a multi-year, collaborative research initiative designed to explore the impact of the pandemic on federally-performed science and innovation, to support medium-term planning for federal science and innovation departments and agencies, and to provide insights to help rebuild the relationship between science and society.

Throughout the pandemic, anti-vaxxers – joined by anti-maskers – have challenged scientific evidence and public health officials with a mandate to keep us safe and stop the spread of the disease. This is just one example that demonstrates society's relationship with science is under strain.

But society's relationship with science and innovation did not decline overnight. The governance model that underpins Canada's relationship with science is based on a report called Science: The Endless Frontier (Bush, 1945). This report outlined a basic compact in which society supports science with public funds and assures the scientific community a great deal of autonomy in exchange for the considerable but unpredictable benefits that can flow from the scientific enterprise.

Today, many of the underlying social, economic, and political assumptions in the postwar compact are outdated. This project examines the relationship between science and society and begins to imagine a new relationship, through nine specific themes:

- Equity, Diversity, and Inclusion;
- Global Research Collaboration and Infrastructure;
- Inclusive Innovation;
- Interdisciplinary Collaboration;
- Indigenous and Other Ways of Knowing;
- Mission-Driven Research and Innovation;
- Science Communications, Outreach, and Public Engagement;
- Skills and Knowledge; and,
- Trust, Integrity, and Science Ethics.

Taken together, these themes suggest elements of a new governance framework for science and innovation in Canada that embraces our current social, cultural and political realities, that recognizes the opportunities and limits of science. Perhaps most importantly, the project reinforces the role of science as part of society, and a tool ready to serve the needs of society.

Findings of the GSINN initiative were developed as a result of extensive research and engagement that included: a hindsight exercise, multiple foresight workshops, eight multisectoral roundtable discussions, and expert consultations that fed into this collection of 10 papers (one for each of the themes above and one capstone paper). Each discussion paper has been peer reviewed and explores a facet of how the relationship between government science, innovation, and society needs to be repaired in order to ensure science remains relevant in the new reality.

IOG extends its heartiest thanks to the eight federal departments and agencies that supported this work: Agriculture and Agri-Food Canada, Health Canada, Innovation, Science and Economic Development Canada, National Research Council, Natural Resources Canada, Public Health Agency of Canada, Public Services and Procurement Canada, and Transport Canada. We also wish to thank all of the individuals who participated in the workshops and roundtables whose input helped clarify and develop the project themes and findings. Finally, we want to acknowledge the following reviewers whose thoughtful feedback improved this paper: Nicole Arbour, Lindsay Copland, Doug Johnstone, Rees Kassen, David Moorman, and Kirsten Twidale.

# INTRODUCTION

The purpose of this discussion paper is to examine trends in global research collaboration and related infrastructure, and the impact of those trends on government science and innovation in the new normal.

The paper is divided into three sections. The first section examines the history and evolution of research collaboration and infrastructure and discusses some of the particular challenges for government science and innovation. The second section reflects on themes raised at the April 2021 GSINN Foresight workshop and the 2021 International Conference on Research Infrastructure, both of which addressed the challenges discussed in the first section. The final section offers several questions to guide further discussion and research.

# GLOBAL RESEARCH COLLABORATION AND INFRASTRUCTURE

## THE RISE OF COLLABORATION

Research collaboration has long been a key feature of the scientific enterprise. Through the mid- to late-Twentieth Century, international collaboration in science and technology was often focussed on large infrastructure, multi-country Big Science projects oriented toward basic research in areas such as particle physics, astronomy, genomics, and environmental and climate-related science (see text box). Big Science is "big" both because of the size of the facilities (e.g., CERN's tunnels traverse the border of Switzerland and France) and the size of their research projects, teams, and budgets, but also

**Big Science**

"The term Big Science first appeared in a 1961 article in *Science* magazine, titled 'Impact of Large-Scale Science on the United States,' by physicist and Oak Ridge National Laboratory director Alvin Weinberg. The article described Big Science as part of the new political economy of science produced by World War II, during which the U.S. government sponsored gigantic research efforts such as the Manhattan Project, the American atomic bomb program, and the Radiation Laboratory, a centre for radar research at the Massachusetts Institute of Technology (MIT). Weinberg was not only describing a new form of scientific research; his concept was an expression of nostalgia for "Little Science," a world of independent, individual researchers free to work alone or with graduate students on problems of their own choosing. Whether or not the world of Little Science as imagined by Weinberg ever existed became irrelevant; high-technology warfare had turned support of scientific research into a national security priority and promised to turn scientists and engineers into beneficiaries of Cold War largesse."

given the need for internationally coordinated effort on global challenges. In these projects, a single country often cannot afford the high costs of physical and digital infrastructure.[1] Collaboration offers pooled financial resources as well as access to large teams of highly qualified personnel from many countries to operate these facilities and maintain the momentum of scientific discovery and progress.

Fast forward to the early decades of the Twenty-First Century, collaboration across all science and technology – big and little – has become the norm around the world. According to Wagner et al (2021, p. 1), "Collaborative research has become the most common form of knowledge discovery, with teams actively linking across borders."

Research has tracked an increase in international research collaboration in recent decades. "International collaboration as measured by co-authorship relations on refereed papers grew linearly from 1990 to 2005 in terms of the number of papers, but exponentially in terms of the number of international addresses" (Leydesdorff and Wagner, 2008). Further, "patterns in international collaboration in science can be considered as network effects...Science at the international level shares features with other complex adaptive systems whose order arises from the interactions of hundreds of agents pursuing self-interested strategies" (Ibid). The Internet and modern communications technology have facilitated this network-formation process and increased the amount of collaboration. Early Nobel prizes in the sciences tended to be awarded to individuals, while more recently the Nobel Committee has recognized that it is rare for a discovery or insight to be the work of one person alone.

Collaboration is the essence of science (Rodrigues *et al.,* 2004). Indeed, the history of science is replete with significant collaborations, including but not limited to: Antoine and Marie-Anne Lavoisier; Einstein with Grossmann and Besso; and Watson, Crick, Williams, and Franklin. These are among the duos or small groups whose work together led to breakthrough discoveries even before today's era of the Internet and Big Science.

Collaboration in the conduct of science can be about sharing expensive facilities or large data sets but, above all, it is about the sharing of ideas and the creation of intellectual synergy. For example, in recent years, large teams of researchers made the most precise measurement of the mass of the Higgs boson to date, in a paper that also set a record for the number of co-authors: 5,154 (Castelvecchi, 2015). This was the result of pooling data from two teams that respectively operate detectors at CERN, the European Organization for Nuclear Research.

[1] At the 2021 International Conference on Research Infrastructures (online but hosted from Ottawa), it was proposed that large data sets be considered "research infrastructure" along with physical assets.

In 2018, the Council of Canadian Academies (CCA) noted that:

> Research is increasingly collaborative, and international collaborations are critical for major research projects. For example, at CERN, physicists and engineers from nearly 100 countries collaborate on cutting-edge scientific problems (CERN, 2015). The share of publications that Canadians authored with an international collaborator increased from 41% in 2003–2008 to 46% in 2009–2014. Switzerland had the highest collaboration rate worldwide in 2009–2014, while Canada ranked seventh. Research is also becoming an increasingly international activity; between the two periods, the collaboration rate increased for all countries except Russia, Poland, Brazil, Iran, and India (CCA 2018, p. 41 - 42).

Interestingly, the CCA noted that Canadian researchers are more likely to collaborate internationally than they are with Canadian colleagues: “Canada’s share of publications with international co-authors was about 44%. In contrast, the share of Canadian publications with domestic co-authors (from two or more provinces or territories) was about 20%” (CCA 2018, p. 119). This high rate of international collaboration may be attributed to Canada’s relatively small population, as well as a growing trend towards attracting faculty from abroad who bring their international connections with them to Canada. In 2021, Canada’s top international collaborators were the United States, China, and Switzerland (Wagner *et al.*, 2021).

Canadian researchers have had a disproportionately high impact on contributions to research worldwide. In 2018, the CCA noted that, “Measuring output of publications relative to a country’s population, Canada ranks fifth, producing about 14 publications per 1,000 inhabitants in the 2009–2014 period” (CCA 2018, p. 36). This provides a powerful research base from which to reach out to the rest of the world and incentive for researchers from around the world to engage with Canadian researchers. This is especially true in fields such as artificial intelligence (AI). According to the CCA, as “compared with their international peers, Canadian AI researchers are engaged in international collaborations far more often than would be expected by Canada’s level of research output” (CCA 2018, p. 98).

## GOVERNMENT SCIENCE

While federal researchers and scientists are reflected in the data and trends of the previous paragraphs, it is important to note that government science includes different functions from academic science. The science conducted within federal departments and agencies consists of two functions: research & development (R&D) and related scientific activities (RSA). R&D is defined by the OECD (2015) as creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge. To be considered R&D, a body of work must meet the following five criteria: novel, creative, uncertain, systematic, and transferable and/or reproducible.

RSA includes activities conducted to inform and ensure compliance with standards and regulations. These activities are driven by mandated requirements of the 33 departments and agencies that make up the Community of Federal Regulators. Of that group, the Canadian Food Inspection Agency, Health Canada, Innovation Science and Economic Development and Transport Canada have responsibility for the greatest amount of RSA activity. RSA includes tasks such as collecting data, maintaining long term data sets and specimen collections for use by researchers in Canada and around the world, and identifying and upholding regulatory standards for products and services. These activities often require close collaboration with international partners, whether for policy or trade purposes and may be categorized as follows:

- Regulation for safety across a wide range of areas including health, pharmaceuticals and medical devices, food and agriculture, explosives, transportation, environmental protection, and climate change;
- Conduct of public good science in the form of data gathering such as geophysical data, socio-economic data, and meteorological observations;
- Major national facilities (and Canada's role in international facilities) for science that require scales larger than individual institutions (e.g., universities) can provide (e.g., NRC's mandate for land-based telescopes); and,
- Support of innovation in private sector firms including the de-risking of leading-edge technologies related to, for example, clean tech, defence, health and medicine, artificial intelligence and quantum computing.

## THE PANDEMIC AND COLLABORATION

The pandemic proved the power of international collaboration as researchers from around the globe worked together to identify COVID-19 variants. The pandemic has also raised new issues for global research collaboration. These include:

- **Travel constraints** – Travel restrictions have had an impact on fieldwork resulting in gaps in datasets and the loss of experiments. A lack of travel also presents a loss of opportunities for researchers to build networks and forge new collaborations and partnerships (Morgan *et al.*, 2021).
- **Pre-prints** – Since the pandemic, many researchers now consider pre-print servers as a means to socialize ideas, with journal articles viewed more as long-term repositories.
- Increasing **interdisciplinary approaches** – Scientific collaboration often transcends traditional disciplinary boundaries. The pandemic has promoted interdisciplinary and transdisciplinary thinking including collaboration between disciplines as well as between science, business, media, and the public (Morgan *et al.*, 2021). [*See also GSINN paper on Interdisciplinary Collaboration*]

## THE ROLE OF INFRASTRUCTURE FOR GLOBAL RESEARCH COLLABORATION

What is the role of research infrastructure in facilitating and promoting global research collaboration? This varies depending on the type of research facility. In the case of Big Science projects, infrastructure can become a focal point to which country partners direct their financial resources. Countries often provide in-kind contributions in the form of technicians to operate a facility, and researchers will convene at these facilities to make use of the infrastructure. Researchers also collaborate with international partners to create enormous data sets beyond the capacity of any one team or government. There is also growing use of global infrastructure networks (e.g., the SUPERDARN network of ground-based radars that study near-Earth space systems).

Research facilities of post-secondary institutions and government departments and agencies are a second category of infrastructure. Modern universities and research facilities are usually built to promote openness and flexibility. In these environments, collaboration is often part of the culture (even while scientific competition can be fierce). Although these organizations will typically give preferential access to their own researchers, there is a constant and considerable flow of visitors to and from other institutions whether in Canada or abroad, to promote the interchange of ideas and cooperation in the pursuit of knowledge.

However, exceptions to this general openness exist where expensive equipment and research must be securely stored, or to protect users from harm. For example, government biosecurity laboratories are subject to a biocontainment level classification (1 - 4). This refers to the level of security applied to the lab, and in turn determines what types of pathogens (such as Ebola virus) can be safely handled in each. A Level 1 lab requires the lowest level of security while Level 4 requires the highest level; each level has different requirements for staff training, safety and maintenance protocols, and regulatory inspections. Canada only has one Level 4, Canada's National Microbiology Laboratory in Winnipeg.

The ability to access a lab varies according to its mandate. Labs involved in the development and implementation of regulations must be and perceived to be impartial in their application of the best knowledge available while independent of commercial or other interests, and so may be less easily accessed. In other cases, most labs aspire to maintain a high degree of openness to accommodate students, post-doctoral fellows, visiting scientists or collaborators from other governments, industry, and international organizations.

## GOVERNMENT SCIENCE AND TECHNOLOGY REALITIES

A major challenge for collaboration in government science is that each of Canada's science-based departments and agencies has a specific mandate which its science supports. As a result, government researchers tend to operate within the silos of their departments. This structure does not reflect the systemic nature and interrelatedness of the research needs. Even in the cases where there is potential for cross-governmental collaboration, researchers often have little opportunity to identify and nurture these synergies.

The siloed nature of government science contributes to a second major challenge: funding. Laboratories are expensive resources to maintain, especially when compared to per-capita costs of an office-based team. As a result, and, perhaps given a lack of appreciation for the need to provide for ongoing maintenance and upgrading of equipment, any funding set aside for the upkeep of laboratories is often the first to be cut.

## LABORATORIES CANADA AS AN APPROACH

The Liberal Government has recognized that the physical infrastructure of many of Canada's government labs are in poor to critical condition. Budget 2018 announced that Public Services and Procurement Canada (PSPC) would lead a $2.8 billion initiative to renew federal labs, an initiative called Laboratories Canada. Its long-term vision is "to create a world-class national network of modern, multipurpose, federal science and technology laboratories to support collaborative, multidisciplinary research and innovation" (Laboratories Canada 2020). Collaboration is one of

Laboratories Canada's guiding principles. Renewed federal laboratories are to serve as collaborative hubs, enabled by modern, real property approaches and appropriate connectivity. They "will support this collaboration by bringing together scientists from inside and outside of government. A culture of openness, along with the pooling and sharing of scientific knowledge and expertise across jurisdictions, will promote knowledge transfer and advance the pace of discovery" (Laboratories Canada 2020).

In 2018, PSPC commissioned the Institute on Governance (IOG) to examine whether there is sufficient commonality of fields, types of research, and types of equipment to indicate an "affinity" among scientific activities across departments and agencies. The study confirmed that there are significant affinities. Several departments have analytic chemistry labs, for example, used for various diagnostic activities.

Co-locating federal scientific activities of several departments and agencies could have multiple advantages. First, it could help avoid duplication and take advantage of economies of scale in the acquisition of equipment. Indeed, several organizations working together would be able to afford more sophisticated, leading-edge equipment than each on its own. The physical plant of such facilities could be purposely constructed to accommodate such equipment.

Second, co-locating labs could facilitate collaboration between teams and identify even more synergies. Third, because these shared research spaces are being constructed as entirely new facilities, it is possible to design collaboration into their very structures. To accommodate visiting researchers, students, and the public, labs can be designed with accessible and open spaces in one area and with secure spaces behind locked doors in another. The resident staff could have spaces to interact with authorized personnel and with others not cleared for secure areas. Finally, modular and flexible design of these new facilities could ensure the ability to reconfigure them in response to evolving needs.

Research by IOG for Laboratories Canada involved a study of shared research facilities around the world (Miller and Kinder, 2020) that offers lessons for the new Canadian model. The project included interviews with lab managers of shared facilities in Canada, the UK, the Netherlands, Germany, Australia and CERN in France/Switzerland. The study identified three types of shared scientific establishments which align with the types of federal research conducted in Canada:

- Curiosity-driven, basic research and the pursuit of knowledge, broadly defined;
- Mission-oriented and targeted research (typical of government labs); and
- Research and development for the purpose of commercialization.

The study team found few facilities where two or more government organizations share the ownership and management of a single lab. Across all labs, the lab managers were clear on the benefits of collaboration and emphasized that the development of synergies takes effort and dedication to the purpose. The physical facilities themselves can be designed to bring people from different organizations together to find commonality, e.g., create easily accessible common areas, moveable equipment, and space that can be easily reconfigured for different purposes. Leadership and governance (e.g., internal committee structures) have important roles in the creation of a culture of collaboration.

# INSIGHTS FROM THE GSINN WORKSHOP AND ICRI

In April 2021, the IOG hosted a foresight workshop focused on the topic of Global Research Collaboration and Infrastructure which brought together federal public servants from eight federal science-based departments and agencies. The International Conference on Research Infrastructures (ICRI) took place, virtually, during June 1-3, 2021. ICRI brought together people from around the world who are involved in the use and/or management of research infrastructure. This section discusses themes and issues that arose at both the GSINN workshop and the ICRI Conference, as they relate to challenges and tensions identified in the first part of this paper.

## THE IMPORTANCE OF RESEARCH COLLABORATION FOR GOVERNMENT SCIENCE

Workshop participants distinguished between international research collaboration involving Big Science projects and the global collaborations related to the on-going conduct of federal research that enable the government to fulfil its various mandates. Participants also emphasized the importance of having strong capabilities across this vast range of research areas to provide a "launch pad" from which to participate in collaborative research efforts. They noted that it is crucial for federal researchers to have links to and collaborate with their respective international communities as part of the process of science. Their everyday work requires exchanging information, insights, and data with researchers in their respective fields around the world. Participants noted repeatedly that research is a global exercise which is dependent on knowledge and know-how moving seamlessly across borders.

## HOW FEDERAL SCIENCE IS MANAGED AND FUNDED

Workshop and conference participants discussed the barriers to collaboration imposed by federal policies such as the *Financial Administration Act (FAA)*. Some noted that, ironically, it can be easier to collaborate internationally, within their field, than with other federal departments and agencies across fields, given constraints imposed by the FAA on moving money between organizations. Many science collaborations have multiple partners who contribute in different ways, not all of which can be supported by a single financial mechanism. Mechanisms that allow funds to flow between collaborators generally do not capture the dynamic, multi-player, multi-sectoral aspects of modern science collaboration.

Some participants expressed the view that departments and agencies limit scientists' freedom,[2] though they acknowledged the need for their work to fulfill departmental mandates. There was appreciation for the government taking care of aspects of intellectual property (IP) protection and

[2] The Model Scientific Integrity Policy is an attempt to address such concerns.

security as related to their work. Nonetheless, there was a clear message – by workshop participants and ICRI conference attendees – that research should be "open by default," available through open access to facilitate international research collaboration, unless determined explicitly to require protection.[3]

Funding is often a concern raised in discussions of federal science and technology. Workshop participants commented that funding for international collaboration, and emerging areas such as genomics, has not increased within the federal government, even in nominal terms in more than thirty years. As this data is not tracked centrally, it is difficult to analyze this viewpoint quantitatively.

## TENSION AT THE SCIENCE-POLICY INTERFACE

A tension exists between policy and science where two distinct cultures intersect yet fail to understand the needs and processes of the other (Snow, 1998). Inside the federal government, there is recognition that science and policy must work together, for science to inform policy and for policy to be more mindful of and support the needs of science including the importance of international and domestic collaboration. Scientists and technical staff in the government are aware of shortcomings in communicating science and technology to non-technical colleagues especially in policy. Workshop participants mentioned some efforts to improve this but noted that the challenges of bridging science and policy remain. Participants observed that international collaborations are often too technical for non-science officials to make valid contributions or to be able to interpret and report back to policy officials. This argues for the importance of embedding government scientists in these international collaborations in their research capacity (i.e., not just to provide policy oversight).

## MANAGEMENT OF THE PHYSICAL SYSTEMS AND IT THAT SUPPORT FEDERAL S&T

Workshop participants discussed the federal government's management of physical systems – which includes the physical plant, equipment, information technology systems, and networks – that support federal science. They voiced concern that federal research facilities have been allowed to deteriorate and equipment to become outdated. Participants called for a more effective means of maintaining physical plant and updating laboratory equipment, for the good of federal science and technology as well as to enable outreach for global collaboration. They expressed optimism that the Laboratories Canada program would address concerns about deferred infrastructure and maintenance. Some GSINN workshop participants are aware of their pending move to new facilities,

[3] However, multiple reviewers pointed to the increasing concerns and new policies targeting research security.

and they anticipate greater opportunity for inter-departmental collaboration and perhaps also greater opportunity for international collaboration.

Workshop participants voiced concerns over difficulties in engaging with Shared Services Canada on information management and information technology (IMIT) policies that are not developed with research needs in mind. The COVID19 pandemic has shone a new light on IMIT demands for research. Participants discussed a growing trend towards larger and larger data sets and increasing demand for storage capacity (which was already considered insufficient prior to the pandemic). Many teams are shifting away from the use of data centres towards cloud-based storage solutions. The pandemic has also created greater demand for video conferencing. Many participants expressed frustration at a lack of secure video conferencing services with regional and international collaborators. Although the situation seems to be improving, there is often insufficient bandwidth, resulting in unintelligible audio, or the inability to run audio and video simultaneously.

While Laboratories Canada is moving toward consolidated facilities that can provide shared hubs of scientific and IMIT infrastructure, the pandemic has raised many questions about the future of work. Some analysts are predicting the continuing use of home offices and the rise of neighborhood-based work centres in suburban or rural areas that would obviate or at least reduce the need for central office space (Policy Horizons Canada, 2021). How these trends might impact a science activity with requirements for specialized laboratory facilities and equipment was not fully explored in the workshop, although participants acknowledged that the accelerating digitalization is already having a great impact on scientific work.

## CAPACITY

Capacity is an interesting word in the context of global research collaboration. It has two synergistic aspects:

- Physical facilities and equipment, and
- The highly trained and experienced people capable of using those facilities in the conduct of research, discovery, and innovation.[4]

Workshop participants noted that for international collaboration to succeed, Canada must have the capacity – in both aspects – to participate. According to participants, in some areas, Canada has world-class capacity such as at the National Microbiology Laboratory in Winnipeg or the David

[4] One reviewer also identified a third aspect: “There will also be a growing need for national level funding toward international projects which will bring along governance issues.” Global Affairs Canada has requested that the Council of Canadian Academies conduct an assessment of international science and technology partnership opportunities including related governance issues.

Florida Laboratory in Ottawa. These are examples of federal scientific establishments that have attracted international collaboration and have the capacity (in both senses) to undertake important and ground-breaking research: the physical facilities are state-of-the-art, and the research staff are renowned. Participants noted that maintaining and growing capacity of this stature in other parts of the federal S&T enterprise would be a good long-term objective. In the more immediate term, they noted that it would be well to ensure that federal research staff have the tools they need to do their jobs and the financial, human resources and organizational flexibility to adapt to new contingencies as they arise.

Participants noted that, during the pandemic, travel costs have diminished due to use of video conferencing. Consequently, they suggested that a more concerted effort be made to ensure that staff have both the time and required resources to devote to international collaboration. Furthermore, they note that travel for government scientists was already reduced prior to the pandemic, and they were concerned that this is having a negative impact on networking, especially for early career researchers. Hybrid or virtual meetings and conferences are feeding into this allowing for greater participation in events but less interaction with potential future collaborators. When late-career scientists retire, workshop participants predict that departments and agencies will find themselves with reduced networks and will experience greater challenges in establishing new collaborations. It is unlikely, participants noted, that technology will be an effective replacement for in-person interaction over the long term.

# DISCUSSION QUESTIONS

- As noted at the outset, collaboration in science is as old as science itself. Yet the reach and scale of collaboration have grown significantly, especially as a result of improvements in information technology. Has the federal scientific community reached its full capacity for international collaboration? Are new threats (including geopolitical/security threats) arising that are stifling collaboration?
- Global research collaboration and infrastructure cannot be discussed without reference to Big Science. Will the costs of Big Science drive out support for individual investigator-led science or, with advances in technology, particularly computational technology (e.g., arrays of smaller radio telescopes replacing single giant ones), will Big Science become closer to “little” science? What impact will this have on global collaboration in science?
- Canada is embarked on a major experiment in the organization of infrastructure for its government science and technology in the form of Laboratories Canada. The intention is to build well-designed facilities that facilitate collaboration across federal departments and with universities, the private sector, and international collaborators. What are the greatest challenges and barriers to realizing this vision? What are the greatest strengths and opportunities? What additional changes are needed to ensure the government’s objectives are met (i.e., changes in departmental organization, reporting lines, accountabilities, location, intellectual property regulations, security regulations, etc.)?
- How might the trends toward work-from-home and neighborhood-based work centres impact the science community’s collaboration and infrastructure?

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