Academic-Facing Large Research Infrastructures in/for Canada: Mapping the Landscape and Issues

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Key messages:

- National research infrastructures (NRI) are strategic assets for Canada, playing a transformative role in fostering scientific excellence, technological innovation, and societal impact
- NRI serve national user communities, require resource commitments well beyond the capacity of any one institution and have structured governance and management
- NRI extend beyond physical research facilities to include knowledge-based resources such as collections, archives, and digital and e-infrastructures
- The Canadian NRI landscape is uncoordinated, poorly resourced and lacks an overarching strategic framework
- Current funding approaches are inflexible and can limit efforts to maximize the benefits to Canada
- Canada should learn from the approach of other countries that employ long-range planning and priority-setting for NRI as a component of their national STI strategies to frame tough choices about NRI investments, the costs of not investing, and how to best optimize returns on NRI investments

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Mapping the Landscape and Issues

A report commissioned by the Council of Canadian Academies

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1. Introduction

1.1 This Paper – Purpose and Structure

This paper is designed to describe the landscape of large, academic-facing research infrastructures in Canada – resources that serve the national research community by virtue of their strategic importance, scale, complexity, cost and/or uniqueness. It also explores Canada's approach to planning, investing in, and managing its investment in these assets in the context of how national portfolios of research infrastructures are being managed globally.

The world of research is changing very rapidly, and along with it, the demands for research infrastructure across almost all domains of research, driven by the complexity of scientific questions, new knowledge frontiers and technological progress. Canadian investment in large research infrastructures plays a crucial role in our ability to produce new knowledge and innovation, to attract and retain research talent, and to help understand and tackle the environmental, societal and economic challenges that we face.

While this document focuses only on academically-facing research infrastructures, there is significant engagement in and utilization of the suite of Canadian infrastructures by government and industry. Boundaries are necessarily blurred, and ideally as Canada moves forward will become more so. Many NRI are establishing enduring partnerships across sectors, including industry, government, and international bodies, fostering a holistic approach to research and effective means of knowledge and technology transfer.

1.2 Setting the Context - What's in a Name?

There is a diversity of naming conventions for large, nationally significant research infrastructure(s), RI. For the purposes of this paper, the author uses the term National Research Infrastructure(s) (NRI) so as not to introduce confusion with the terms Major Research Infrastructure (MRF) and Major Science Initiatives (MSI) that have specific meanings in the context of the current CFI programs, the current CFI consultation on the implementation of a new framework[1] or the recent OECD paper on very large research infrastructures (VLRI) which is more restrictive in its remit.[2]

Two definitions serve to characterize the essential nature of NRI for the purposes of this paper:

[1] CFI (2024a) Major Research Facilities Framework implementation plan development. Communication from CFI to the 19 Major Science Initiatives (MSI).

[2] OECD (2023) Very Large Research Infrastructures. Policy Issues and Options Science and Technology Policy Papers. No. 153 https://www.oecd.org/en/publications/very-large-research-infrastructures_2b93187f-en.html https://doi.org/10.1787/2b93187f-en.

A major science investment is one which "… 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."[3]

National research infrastructure (NRI) comprises a range of nationally significant assets, facilities and services that support leading-edge research and innovation. It is more than instruments and devices: a highly skilled workforce supports both the equipment and the researchers that use it.[4]

NRI have a high degree of strategic, national or international importance and include major scientific equipment (or sets of instruments); knowledge-based resources such as collections, archives and scientific data; digital and e-infrastructures, such as data and computing systems and communication networks; and any other tools that are essential to achieve excellence in research and innovation. [5] NRI extend beyond physical research facilities and include robust, sophisticated, and integrated capabilities across experimental and observational infrastructure, knowledge infrastructure, and research cyberinfrastructure.[6]

1.3 What Scale and Scope?

Key considerations in designating an initiative as an NRI include:

- National (and/or international) importance and engagement
- Uniqueness: The RI is unique or quasi unique (nationally)
- Complexity: The RI is complex in its organisational structure, technology and/or operation. Critical mass and large-scale coordination are required to plan and operate
- The magnitude, cost, opportunity and/or mandate are beyond the scope of any single organization

Internationally, the above characteristics are the prime considerations for designation as an NRI rather than reliance on a financial threshold, especially given the inclusion of knowledge and cyberinfrastructure which may entail smaller budgetary envelopes. With this being said, some nations set thresholds for designation as an NRI of $8M-$15M total capital investment and the exploitation cost over a period of 5 years. That cost threshold

[3] Carty, Arthur. Canada's first National Science Advisor, Briefing Note January 2007. Private communication.
[4] Australia (2021) National Research Infrastructure Roadmap p. 1 https://www.education.gov.au/national-research-infrastructure/resources/2021-national-research-infrastructure-roadmap.
[5] ESFRI (2021) European Strategy Forum on Research Infrastructures. Roadmap 2021 p. 17 et seq. https://roadmap2021.esfri.eu/.
[6] USA (2021) National Strategic Overview for Research and Development Infrastructure p. 2 https://www.whitehouse.gov/wp-content/uploads/2021/10/NSTC-NSO-RDI-_REV_FINAL-10-2021.pdf.

includes the human capital required to manage/operate the NRI that is recognized as being as important in achieving research outcomes as the assets and facilities.

In many countries, NRI, including adherence to international initiatives, are managed as a portfolio, indeed this is a best practice (see section 3). While necessarily being context specific, typically such an NRI portfolio would include a mix of discipline/ domain focused initiatives together with thematic/strategic priorities. The framework being used by the European Strategy Forum on Research Infrastructures (ESFRI) and the UK is a good example.

2. Large Research Infrastructure in the Canadian Research Ecosystem

2.1 The Canadian Players in NRI

Much discussion around NRI in Canada focuses on the 19 large infrastructures (see Appendix 1) funded through the CFI's Major Science Initiatives (MSI) program, six of which have now been designated as Major Research Facilities (MRF) to be supported under a new MRF framework[7] (see section 2.2). These are, indeed, critical elements of the NRI landscape, but this grouping does not convey the diversity of NRI in Canada, nor the complexity of funding and governance relationships that has grown up over time.

There is no simple way to capture the diversity of players associated with NRI – the organizations that plan, own, manage, fund and utilize NRI in Canada – in fact far from it. The Canadian landscape is messy, uncoordinated, generally poorly resourced,[8] and lacking in an overarching strategic vision/perspective.[9] [10] [11]Key players are:

Funders of NRI :

[7] CFI (2024a) OP. Cit. p. 3.
[8] See, for example, DRAC (2023) Emerging Trends in Research - Survey Findings p. 8. https://alliancecan.ca/sites/default/files/2024-04/emerging_trends_in_research_-_survey_findings.pdf and Standing Committee on Science and Research December (2024) Science and Research in Canada's Arctic in Relation to Climate Change. Pp. 29-31. https://www.ourcommons.ca/Content/Committee/441/SRSR/Reports/RP13497015/srsrrp13/srsrrp13-e.pdf.
[9] Bouchard, F. Report of the Advisory Panel on the Federal Research Support System (2023) Recommendations 10-12. ISBN 978-0-660-48161-6; https://ised-isde.canada.ca/site/panel-federal-research-support/en/report-advisory-panel-federal-research-support-system.
[10] CSPC (2023) Positioning Canada's National Research Infrastructure for Impact p. 4. https://sciencepolicy.ca/posts/cspc-2024-panel-159/.
[11] CSPC (2024) Positioning Canada's National Research Infrastructure for Impact: Implementing the Major Research Facility Policy p. 3. https://sciencepolicy.ca/posts/cspc-2024-panel-159/ .

- **CFI** that has funded much of the existing NRI (capital and operating) used by academe since the late 1990s, some of which is now supported as MRF and MSI. *Funded by the GoC.*
- **Provinces and territories** that provide much of the matching funding for NRI funded by CFI and more recently the Alliance.
- **The Tri-Council** that have supported the original capital investment in some NRI over the years (e.g., SNOLab, the Canadian Longitudinal Study on Aging). They have also supported some long-range planning, and they fund much of the research sustained by the NRI. *Funded by the GoC*
- The **Digital Research Alliance of Canada** (the Alliance) that supports Canada's digital "services".[12] *Funded by the GoC*
- **CANARIE** that supports the broadband network connections across Canada and globally. *Funded by the GoC*
- **The Government of Canada** (GoC) departments and agencies:
    - **National Research Council (NRC)** that currently supports TRIUMF and several large ground-based astronomical facilities (activities mandated by the NRC Act) and maintains a portfolio of significant RIs that may serve both internal and external users (private sector and academe).
    - **Canadian Space Agency (CSA)** that supports Canadian contributions to space research infrastructure utilized by the academic community, most recently as the Canadian partner with NASA and the European Space Agency in the international James Webb Space Telescope.
    - **Other GoC departments and agencies** that own and operate NRI in support of their missions and that may also be accessible to external user communities, e.g., the NRC wind tunnels, the Canadian Coast Guard's fisheries science vessels, agricultural research stations, Canada's Northern research stations, climate monitoring stations.

Mangers of NRI

- **Universities** that "own" many of the NRI (both incorporated and unincorporated) that have been funded through various federal, provincial and charitable programs over the years. Universities also contribute a portion of NRI funding.

Users and partners in NRI

- **Researchers** – the research community and their discipline societies – that engage in research utilizing these facilities and drive long-range planning for large NRI (in particular, astronomy and particle physics). *Funded by multiple sources, including the Tri-Agency.*

[12] ARC services are delivered through the Federation, which is a partnership of the Alliance, regional Digital Research Infrastructure (DRI)-serving organizations, and 38 academic institutions across Canada.

- **Miscellaneous players.** Other organizations play roles as funders and more frequently partners and users - e.g., not-for-profit entities, philanthropic organizations and the private sector.

2.2 The MRF Framework

As announced by CFI in an August 2024 release to the 19 MSI, the Major Research Facilities (MRF) Framework is intended to "enhance federal decision-making on MRF by introducing coordinated capital and operating and maintenance (O&M) funding and embedding a life-cycle and portfolio-based approach into investment decisions:

- Life-cycle approach: Investment decisions will be made in consideration of the full expected lifespan of a facility and reflect an understanding of the scale and scope of resources required over the long term.
- Portfolio approach: Public investments will be made with a view to sustaining a portfolio of MRF to yield maximum scientific and socioeconomic benefits for Canada. The Minister of Innovation, Science and Industry will maintain a strategic perspective of the portfolio and its alignment with federal priorities which may include considering the adequacy of overall portfolio funding and facility eligibility or divestment over time based on recommendations by the Canada Foundation for Innovation (CFI)."

2.3 Mapping the Canadian Academic-facing NRI Landscape

The complexity of the Canadian landscape of NRI reflects the diversity of initiatives that exist, the differing funding and governance regimes, and the fact that most are the product of initiatives that were developed over the years outside of any strategic framework for national research and development.

To introduce some order into the mapping of academic-facing NRI, initiatives are clustered in the following groups:

- Group #1 **Digital research infrastructure** (DRI) – the digital infrastructure service layer that serves the national R&D community as an enabling resource for all domains of intellectual activity. This critical infrastructure includes delivery of connectivity, computing power, software, and supports for managing research data. Given that e-infrastructure is now essential for almost all disciplines and research and innovation sectors, provision of effective DRI must be a central preoccupation in the development of Canada's national research strategy.[13]
- Group #2 **Major investments in infrastructures directly supported by the GoC** (NRC and CSA) for their ongoing operating costs. These are aligned with individual

[13] The 2024-25 ISED Departmental Plan projects transfer payments of $38M tor CANARIE and $203M to the Digital Alliance of Canada for 2024-25. https://ised-isde.canada.ca/site/planning-performance-reporting/en/departmental-plans/2024-25-departmental-plan-supplementary-information#s1.

agency/departmental mandates.[14] Development and funding of these initiatives is normally associated with intensive processes of long-range planning and priority setting that reflect the cost, complexity and in some cases reliance on formal international agreements.

- Group #3 The **six newly-designated major research facilities (MRF)** currently supported by CFI for ongoing operating expenses, each of which has a different trajectory in terms of its genesis and funding requirements. CFI is currently providing funding of a total of $545M over 6 years (or between $38M and $181M for each MRF including the supplemental support to CLS through budget 2024); MRF support is currently allocated at a level of 60% (the CFI portion) of the total budget.
- Group #4 The **13 major science initiatives (MSI)** currently supported by CFI, a group with considerable diversity in form, function and financial needs. CFI is providing a total of $167M over 6 years (or between $2.6M and $49M for each MSI). MSI support is currently allocated at a level of 40% (the CFI portion) of the total budget.
- Group #5 **Arctic/Northern Infrastructures** comprises a suite of infrastructures that enable scientific access to 40% of Canada's landmass/oceans. They are funded by a mix of federal departments, territorial support, CFI, universities and colleges and are supported by a major logistics hub for Arctic research (Polar Continental Shelf Program).
- Group #6. **Diverse large research infrastructures**. This category includes NRI that have been funded through diverse mechanisms and that provide capabilities and services to the national research community but are not funded through MRF or MSI. While the funding levels and approaches may differ inn relation to other large infrastructure, each delivers a unique and important service/underpinning for the national research community and are recognized by some funding from an assortment of federal sources (e.g., ISED, CIHR, NSERC).
- Group #7. **Miscellaneous.** This category includes NRI that have, in the past, been funded by the Government of Canada, but that have now migrated to a fee-for-service mode of operating that also supports academic research.
- Group#8. **International NRI accessed by Canadian researchers**. International agreements secure Canadian access to facilities outside of Canada where specialized instrumentation and beam lines are critical for our researchers, but not available in Canada. Outside of the NRC's mandate for astronomy, there is no designated source of funding for memberships in multi-national facilities (e.g. CERN, the European Spallation Source). The periodic CFI Innovation fund competitions allow capital investments in equipment that is located at, or is a contribution to, foreign NRI. In some cases, such a capital investment can be

[14] The NRC act mandate includes the charge to "operate and administer any astronomical observatories established or maintained by the Government of Canada."

traded for access to the foreign NRI for a period of time – but such one-time investments are often not at the scale needed, and leave multi-year gaps, among other problems with this approach.

An inventory of Canadian NRI in each of the above categories, spanning a wide range of disciplines and areas of application, fundamental to applied research is provided in Appendix 1. A more detailed exploration of the critical role of DRI and emerging NRI issues in four specific domains of activity that tend to fly under the radar (digital, health, social sciences and humanities and the North/Arctic) is provided in Appendix 2.

Among the above NRI, international partnerships are integral to many, including the Square Kilometre Array, the James Webb Space Telescope, the Canada France Hawaii Telescope, the Centre for Biodiversity Genomics, SuperDARN, the Ocean Tracking Network, and SNOLab, while most others have productive, and often extensive, collaborations with international partners. Canadian participation in international space and astronomy initiatives inevitably requires complex government to government agreements.

3. Planning and Managing Investments in NRI

3.1 The International Context

There is international attention to the fact that modern research facilities and infrastructures are playing a transformative role in fostering scientific excellence, technological innovation, and societal impact. They are considered, and invested in, as critical competitive advantages/vitally important national assets.[15,16]

The nature of research and the context in which it is done is changing, together with the tools and resources that support it. Research itself is becoming more interdisciplinary; more collaborative; increasingly driven by advanced technologies such as artificial intelligence, quantum computing, and digitalisation; and more responsive to national priorities and global challenges.[17] This emerging research landscape/ecosystem is increasingly reliant on collective resources than in the past – research infrastructures that themselves are shaping research.

> "As the multidisciplinary nature of research projects increases and technology develops apace, the importance of such expensive research infrastructures which

[15] G7 Conference (2024) G7 Large Conference on Large Research Infrastructures: Synergies and impact on science and society. https://www.ambrosetti.eu/en/innotech-hub/g7-large-research-infrastructures/?utm_source=event&utm_campaign=qrcode
[16] ESFRI (2020) Making Science Happen ESFRI White Paper 2020 https://www.esfri.eu/esfri-white-paper
[17] ESFRI (2024) Landscape Analysis 2024. Page 115 et seq. https://landscape2024.esfri.eu/

can be used across all research fields is increasing, as is the need for new infrastructures."[18]

Research infrastructures represent a significant investment by governments. See Section 4.1 that speaks to the change in investment levels in 57 large research infrastructures over 18 years.[19] The challenge is how best to foster a dynamic and effective portfolio of NRI that recognizes the national benefits as well as the costs of maintaining existing state-of-the-art infrastructures, pressures to invest in new infrastructures, the technological sophistication and digital/data requirements that require ongoing investments, all of which are placing pressure on the public purse.

3.2 The International Experience – Effective Practices for Investments

Internationally, long-range planning and priority-setting are being used as a component of national STI strategies to frame tough choices about NRI investments, the costs of not investing, and how to best optimize returns on NRI investments. Many countries have recognized the need to better understand the demands for specialized research infrastructures and the opportunities they represent, including the extent to which a strong NRI foundation for the research ecosystem underpins a nation's international S&T stature, as well as providing it with adaptive capability to address national challenges as they did with Covid. This has led to the rise of an approach called "roadmapping" which is built on a base of a "landscape analysis".

A **roadmap**[20] typically speaks to the role and contributions of NRI to the research and innovation ecosystem and provides guidance on actions to maintain excellence, increase innovation and address emerging challenges through the country's investments in NRI. Roadmaps take a portfolio-based approach, identifying a cluster of key scientific and thematic domains of strategic importance to the country and within those domains, specific NRI initiatives – existing and planned. A roadmap may provide insights for each domain and indicate future directions for evolution, considering the current context for research and NRI in the country and internationally. It may also identify specific research areas requiring further scoping work to better understand emerging research infrastructure needs.

[18] Switzerland (2023) Swiss Roadmap for Research Infrastructures p.5 https://www.sbfi.admin.ch/sbfi/en/home/research-and-innovation/research-and-innovation-in-switzerland/swiss-roadmap-for-research-infrastructures.html.

[19] G7 Conference (2024) Op. Cit. Highlights, page 22 and 23.

[20] See, for example, Australia (2021) Op. Cit; UK (2023a) The UK's research and innovation infrastructure: opportunities to grow our capability https://www.ukri.org/publications/ukri-infrastructure-opportunity-report/; the ESFRI list of national roadmaps in the EU https://www.esfri.eu/national-roadmaps .

A roadmap will normally be based on a **landscape analysis**,[21] an assessment of the current state of play of research infrastructure in the country. In most cases it is integrated as a part of the roadmap, although ESFRI has produced its landscape analysis for 2024 as a separate document, as did the UK in 2020. An effective landscape analysis provides the current context: the most relevant research infrastructures that are available, an analysis of the scientific needs and existing gaps, challenges and likely trends, as well as opportunities for system wide improvements. This is framed by consideration of the services vital for the research ecosystem, what is required to sustain excellence in research, resonance with national interests and needs, and the potential for larger socio-economic impacts.

3.3 The Canadian Context

Despite the history of world-class excellence sustained by their facilities and services activities, NRI face a panoply of ongoing challenges, and in the absence of change, Canadian return on existing and future investments will be sharply curtailed.

The new MRF framework will mitigate some of the challenges, but then only for some issues and only for the six designated MRF. Implementation of the lifecycle approach (e.g., moving to a long-term and away from a project-based approach for decisions on individual NRI) and the portfolio approach (i.e., set in a system-wide context) across the broader range of NRI is a priority action.[22]

There are also lessons from international experience that can inform the way in which these national assets are conceptualized, developed, funded and sustained for enhanced contribution to discovery, invention, demonstration, and commercialization. The following sections highlight some of the major barriers to maintaining Canadian NRI at a world class and productive level and approaches for change.

3.3.1 Strategic Context

Barrier – At present decisions are taken on a case-by-case basis without consideration of all relevant factors and without an overarching strategic framework. There are three missing elements: i) a national strategy for science, research and innovation, ii) an assessment of the current landscape of existing and forecast research infrastructure, and iii) a roadmap that provides guidance on NRI investments of strategic importance.[23,24]

[21] See, for example, ESFRI (2024) Op. Cit.; UK (2023b) UKRI infrastructure landscape analysis https://www.ukri.org/publications/ukri-infrastructure-landscape-analysis/ .
[22] CSPC (2024) Op. Cit p. 3.
[23] Bouchard, F. (2023) Op. Cit. Recommendations 4 and 10.
[24] Barrett, John (2023) Towards a new paradigm in Canadian Major Research Facilities Decision Making and Governance. https://sciencepolicy.ca/posts/towards-a-new-paradigm-in-canadian-major-research-facilities-decision-making-and-governance-a-response-to-the-report-of-the-advisory-panel-on-the-federal-research-support-system/.

How to address – Priorities for NRI investments should be framed with a larger strategic context that includes both a landscape analysis and road-mapping exercise that engages the research community, provinces and territories, industry and other stakeholders in a meaningful way to ensure that investments support Canada's broader science, research and innovation needs and priorities. [25, 26] In addition, sustained political ownership and commitment at all levels is needed for progress towards a functioning NRI ecosystem.

3.3.2 Development of an Initiative

Barrier - At present there is no formal mechanism for taking a new NRI initiative or upgrade through the early stages of a life cycle approach: conceptual development, full project design, implementation, taking an initiative through development to funding (or decision not to fund). There is frequently little direct engagement of the provinces.

How to address – Other countries utilize a gated approach[27] to this process – one that is divided in distinct stages or phases, separated by decision points involving expert review, critical feedback, and funding decisions that are made in the context of an overarching portfolio framework, and with engagement of all relevant stakeholders. Scoping studies to better understand emerging research infrastructure needs can also prove valuable.[28]

3.3.3 Coordination among Decision Makers

Barrier – Decisions on the funding of research infrastructure capital/ongoing operating costs are decoupled from funding of the research and research training sustained by the NRI, including the costs of access, an approach that can result in sharply reduced return on capital investments.[29]

How to address – While the criteria for consideration of infrastructure and research are distinct, decision making should be streamlined and coordinated, including improved alignment of funding cycles to ensure effective utilization of the NRI assets. [30,31]

[25] See, for example, ESFRI documents - https://www.esfri.eu/; The inventory of national RI roadmaps in Europe https://www.esfri.eu/national-roadmaps; UK (2023a and 2023b) Op. Cit.
[26] CSPC (2023) Op. Cit. p. 4. CSPC (2024) Op. Cit. p.3.
[27] For example, NSF guidance for full life-cycle oversight of Major Facilities and Mid-Scale Projects (2021) https://nsf-gov-resources.nsf.gov/pubs/2021/nsf21107/nsf21107.pdf.
[28] Australia (2021) Op. Cit p. 24.
[29] Canadian Research Coordinating Committee (2024) What we Heard report released following engagement with the research community on modernization of the federal research support system https://www.canada.ca/en/research-coordinating-committee/news/updates/2024/10/report-released-following-engagement-with-research-community-on-modernization-of-federal-research-support-system.html.
[30] CFI (2024b) Summary of Consultation on Major Research Facilities p. 5. Report released to the 19 MSI/MRF in November 2024.
[31] Bouchard (2023) Op Cit. Recommendation 13.

3.3.4 Funding Framework

Barrier - While acknowledging the importance of the proposed move to allow up to 80% federal funding for the six designated MRFs, the current matching funding regime for CFI-funded NRI is arbitrary and inflexible (40%, 60% or 80%, according to the specific NRI), and inappropriate for many national research infrastructures where the host university and province are not the major beneficiaries of the NRI.[32] In addition, the transaction costs of pursuing matching funding can overwhelm pursuit of the research mission and preclude investment in priority initiatives, representing a major inefficiency in the research system.[33]

How to address – While encouraging co-investment, implement a more flexible funding regime that would recognize the extent to which the benefits from a specific MSI/MRF/research infrastructure flow to international, national, and regional levels, as well as the proportion of "public good".[34] One size should not fit all. Involve the host province early on in the decision-making process.

3.3.5 Funded Elements

Barrier – Unlike other countries, most Canadian NRI are not funded through the O&M award for the research activities of those technical personnel necessary to ensure the effective use and further development of the NRI (TRIUMF and the astronomical facilities are current exceptions).

How to address - NRI should be funded with a core complement of technical personnel who support the continued scientific development of different/better ways to use existing facilities/equipment (e.g., explore and demonstrate new use cases) and who continue to push the envelope through research towards enhancements that would enable maintenance of the research infrastructure as state-of-the-art.[35,36]

Barrier – At present requests for routine capital investments to maintain operational capacity or that are required for health and safety of an NRI are considered in in the regular competitive programs of CFI. This approach to review and funding of such capital needs can preclude timely upgrades, compromising long-term sustainability and operational effectiveness.

How to address – Implement a bespoke approach to assess and fund core operational NRI upgrades that is not subject to the existing program cycle and/or ensure sufficient contingency funding.[37]

[32] Bouchard (2023) Op. Cit. Recommendation 11
[33] CFI (2024b) Op. Cit. p. 4.
[34] CSPC (2024) Op. Cit. p.2, p. 4
[35] CFI (2024b) Op. Cit. p. 4
[36] Bouchard (2023) Op. Cit. Recommendation 12
[37] CFI (2024b) Op. Cit. p. 4 and 5.

3.3.6 Operational Flexibility

Barrier – NRI are currently funded through a fixed funding envelope allows for long-range planning but does not provide the flexibility to respond to, or deal with, evolving circumstances that may carry a high level of uncertainty and risk for the host institution or alternatively unusual opportunities. Digital assets in particular require continuous technological upgrades to remain functional and relevant.[38] Needs can change and emerge on a very short timeline outside the funding cycle.[39]

How to address - The overall portfolio approach should provide a mechanism to consider and respond to an NRI when such eventualities occur during the course of an award and can be demonstrated as being outside the realm of the possible within existing budgets. [40]

3.3.7 Engagement in International NRI

Barrier – Financial constraints limit Canada's ability to house all research infrastructures required for a fully competitive research ecosystem. However, accessing international NRI as a partner can be a cost-effective approach to accessing key research capabilities, as well as providing technology development opportunities for Canadian firms. While Canada has been successful in leveraging access to some international facilities, this has been done on an ad hoc basis (with the exception of space and astronomy). In addition, many of the international partnerships have been based on the provision of capital funds to meet an operational need, an approach that can be short term in nature.

How to approach – A more structured approach to provision of access to world-leading RIs located outside of Canada, as well as Canadian participation in major international collaborative endeavours should be a key component of the NRI portfolio. This would entail formal agreements through which there could be both contributions to instrumentation and support for the relevant operating costs.[41]

At issue – governance and stewardship This document cannot address the ongoing questions surrounding governance and stewardship of NRI. There is considerable diversity of approach in regard to ownership, even though the dominant model in Canada has been COCO (Contractor Owned, Contractor Operated), and some diversity in governance – with some NRI incorporated as NFP and some simply managed by a host institution on behalf of the larger research community.   There is a school of thought that the federal government should acknowledge ownership of major NRI even while delegating operational responsibility to universities or university consortia. Regardless, there is a role for enhanced stewardship of NRI on the part of the federal government – whether CFI or CFI

[38] Ibid. p. 4
[39] CSPC (2024). Op. Cit. p. 4
[40] CFI (2024b) p. 4.
[41] CSPC (2024) Op. Cit. p. 4; CSPC (2023) Op. Cit. p. 4.

together with the relevant federal department or agency – a sharing of responsibility for optimizing the returns on major federal investments.[42]

4. NRI Contributions to Research and Innovation

> Research Infrastructures are key enablers of scientific and technology discoveries as well as of incremental accumulation of knowledge. At the same time, they often have considerable socio-economic impact beyond science itself. Understanding these impacts, and the capacity of Research Infrastructures to achieve them, is necessary for public authorities to make informed investment decisions aligned with broader political goals.[43]

4.1 International Perspectives on ROI

While there is a widespread understanding of the power of research infrastructures to promote scientific progress, train the next generation of research leaders and innovators, address societal challenges, drive innovation, and tackle global emergencies, all nations wrestle with the substantial knowledge gap in understanding and analyzing those influences and impacts. In this Canada is not alone.

A G7 conference on large research infrastructures was organized by INFN (Italian Institute for Nuclear Physics), under the supervision of the Italian Minister of University and Research (MUR), exploring the critical role that large research infrastructures play in advancing scientific knowledge, as well as their economic, social, and geopolitical implications. Setting the stage for that discussion was a commissioned report "G7 Large Research Infrastructures: Synergies and impact on science and society"[44] that offered insights into the economic, scientific, technological, social, and geopolitical impacts of large research infrastructures within the G7 context.

Of particular interest was an analysis of the economic return on investment on 57 very large research infrastructures identified for the study. Using a proprietary quantitative model to evaluate the capital expenditures (CapEx) and operational expenditures (OpEx) of large research infrastructures, as well as the economic impact they generate, the estimated economic impact ranged from 647.4 billion USD to 2.4 trillion USD (or multipliers of between 1.2 to 4.5).[45]

[42] CSPC (2024) Op. Cit. p. 3.
[43] ESFRI (2021) Roadmap 2021 p. 29 https://roadmap2021.esfri.eu/ .
[44] G7 Conference (2024) Op. Cit.
[45] G7 Conference (2024) Op. Cit. Conference Highlights p. 17

The analysis of capitalized[46] CapEx in this set of 57 large research infrastructures over the reference period of 1987 – 2023 revealed that the average investment has experienced significant growth after 2005, with a compound annual growth rate of investment increasing from 4.0% before 2005 to 6.6% in the years following 2005. If this trend continues, it is projected that G7 yearly investment in this scale of large research infrastructures will reach 15.3 billion USD by 2041, up from 4.9 billion USD in 2023.[47]

4.2 Economic Impacts of Canadian NRI

Capturing the contributions of Canada's NRI is enormously challenging given the diversity of platforms and the vast range of influences and impacts. At one level, the economic activity associated with each is significant. The contribution of three of our largest facilities has been reported to be as follows based on formal economic impact studies:

> "SNOLAB is estimated to have contributed approximately $358 million to the national GDP between 2017 and 2022, while CLS contributed an estimated $738 million between 2010 and 2022. From FY2018-19 to 2021-22, public investment in TRIUMF increased Canada's GDP by $489.7 million in the short-term, and British Columbia's GDP by $447.5 million".[48]

A separate economic analysis for VIDO estimated its contribution to national GDP to be $49.58 million in 2021-2022 and $322.08 million over the period 2013-2022, with GDP contributions rising sharply in 2021 and 2022 as a result of COVID.[49] [50]

But while such overview data reveals the level of economic activity associated with some of Canada's largest NRI, it does not capture the diversity of impacts from all, either on research or society at large. A more granular assessment of impacts is needed. Note, however, that there is as yet little international consensus on the pathways to impacts, the range of impacts, and how they can be measured and described.

4.3 Impacts as Revealed by Key Performance Indicators

Taken as a collectivity, NRI have had profound impacts, in some cases transformative, on Canadian research. CFI has compiled a list of standard KPIs that are tracked for each of the 19 MSI (including the six MRF) as below:

[46] Capitalized CapEx, or capitalized capital expenditure, is a cost recorded on a balance sheet instead of expensing it directly on an income statement in order to delay the full recognition of the expense.
[47] G7 Conference (2024) Op. Cit. Highlights. 19-22.
[48] Personal communication from CFI. KPMG carried out the economic studies for SNOLab (2023) and CLS (2021). The TRIUMF data are included in the formal evaluation carried out in 2023 by the NRC Office of Audit and Evaluation. https://nrc.canada.ca/en/corporate/planning-reporting/evaluation-triumf-2023-24.
[49] VIDO (2023) Annual Report 2022-2023 p. 18.
https://www.vido.org/assets/upload/pdf/annual_reports/VIDO_2023AnnualReport.pdf
[50] VIDO (2022) VIDO's economic impact over half a billion dollars: SREDA study. 2022
https://www.vido.org/news/vido%E2%80%99s-economic-impact-over-half-a-billion-dollars:-sreda-study

Data based on preliminary MSI progress reports as of October 18, 2024. As reported to, and complied by, CFI

Indicator	Definition	FY 2023-24 Total	FY 2023-24 Average per facility
Users of the facility[1]	Both onsite and remote	96,131	5,655
Contribution to training[1]	the number of students, postdoctoral fellows and technical and professional personnel who conducted research or technology development	10,384	577
Research outputs [1]	Number of knowledge outputs, including peer-reviewed publications, publications in a professional/trade journal, magazine or newsletter, contributions to conference/symposium proceedings, presentations or posters.	5,297	294
Engagement and outreach activities [2]	Number of courses, workshops, training sessions and summer schools, stakeholder or public events, media interviews, press conferences, broadcasts, podcasts and press conferences in which facility or facility staff have participated	3,242	171
Technology development and transfer [2]	Number of technology transfer activities linked to the use of the facility or data from the facility, including technical/consultancy reports, provisional patent applications filed, full patents filed and granted, licenses granted, and number of spin-off companies created.	2,473	130

[1] Values across 18 facilities

[2] Values across 19 facilities

For the purpose of this paper, and based on the Canadian experience, additional categories of impact/influence are identified below: i) the benefits/impacts intrinsic to the research ecosystem and ii) the larger socio-economic and environmental benefits/impacts. This, admittedly anecdotal, overview reveals the diversity and breadth of impact of Canada's investments in large scale infrastructure that would not happen in its absence. A separate document is available that provides more case examples of impacts in each area. Note – these examples are all drawn from information provided by each of the MSI and MRF in response to a request for inputs on "return on investment).

4.4 Influence and Impacts on the Research Ecosystem (Intrinsic Impacts)

Impacts on the research system

- Structural change
- Directional change
- Technical advice
- International profile
- Data leadership & stewardship
- Research training
- Indigenous inclusion

In addition to the well understood impact on the quality and extent of research supported as evidenced by the above KPI, seven other zones of impact internal to the research ecosystem are briefly highlighted below.

Structural change– NRI can have profound impact on how research is done by provision of services that would not be otherwise available. Examples from Canadian NRI include the transformation of modes of data collection and accessibility,[51] making available highly specialized instrumentation[52] and advanced analytics, provision of access to field sites and remote locations[53]. The structure of many of the platforms facilitates interdisciplinarity and transnational collaborative activities.

Directional change – All NRI impact what research is done, research that would not be feasible or would be more difficult in the absence of the NRI which provides unique or quasi unique capabilities. Examples from Canadian NRI include the opportunity for essential research in Canada's North/Arctic including with Indigenous peoples, research on Canadians using data from longitudinal studies and Statistics Canada that informs social and health care policy and regulation,[54] understanding space weather that entails a laboratory the size of the solar system,[55] research that requires ultra low levels of radiation or highly specialized probes of the surfaces and structures of material.

Technical advice – NRI have technical staff with unique expertise to contribute to the research and specific technical needs of the research community, including development of major instruments that may themselves constitute NRI. Those technical competencies also provide a level of competency prepared to respond to national and global challenges, for example VIDO's work on avian influenza[56] and the capabilities associated with the new

[51] CRDCN. The virtual RDC https://crdcn.ca/virtual-research-data-centre-vrdc-2/.
[52] For example, the Advanced Laser Light Source https://inrs.ca/en/research/research-facilities/find-a-research-facility/advanced-laser-light-source-laboratory/ .
[53] For example, the instrumented sites available through the Global Water Future Observatories https://gwfo.ca/instrumented-sites.php
[54] CRDCN (2023) Annual Conference highlights https://crdcn.ca/past-conferences-crdcn-2023/ .
[55] SuperDARN https://superdarn.ca/.
[56] VIDO (2023) Op. Cit p. 14.

level-4 containment facility for housing a broader range of animals, including bats and insects, which are often linked to new outbreaks.[57]

International profile – Perhaps more than any other investments in research, NRI position Canada as a major player on the international scene over and above that possible to be derived from individual or small groups of researchers or without the specialized platforms they offer.[58] NRI enable Canada to attract and retain world class researchers, they support the participation of many Canadian researchers in international collaborations,[59] and they underpin Canadian leadership in a number of high-profile global collaborations.[60] NRI play a significant role in contributing to Canada's competitiveness and international reputation.

Data leadership and stewardship– Canadian NRI have exercised national and global leadership in developing and promoting the data tools that researchers and innovators require - data that can be securely shared in accessible formats; data environments where large and complex data can be analysed, integrated, visualised and managed; data analytics; databases that allow the ready upload or download of data; and effective approaches to data standardization, data interoperability and data management. Those NRI with major data holdings exercise robust quality control on their scientific data.[61]

Research training – In addition to the massive numbers of HQP benefitting from access to NRI, they provide a particularly valuable environment for research training given their "facility" effect – the collective power of integrated suites of state-of-the-art equipment, housed in purpose-built facilities, and deliberately sited to maximize their accessibility and multi-disciplinary, multi-sectoral effects.[62] In such environments, research trainees often benefit from exposure to multi-disciplinary environments rather than environments structured by disciplines or faculties. They offer opportunities for frequent interactions between researchers and users. NRI also serve to develop research capacity in areas that would otherwise be underserved, and facilitate the development of diverse competencies, digital skills and transferable skills (e.g. project management)[63] as well as domain specific capabilities.[64] NRI are also increasingly supporting 'citizen science' and helping to build capacity in Indigenous research.[65]

[57] VIDO (2024) Annual Report 2023-24 p. 17 https://www.vido.org/assets/upload/pdf/annual_reports/VIDO_23.24%20AR_digital_single_FINAL.pdf.
[58] See, for example, the reference to TRIUMF's global reputation that attracts international partnerships to Canada https://nrc.canada.ca/en/corporate/planning-reporting/evaluation-triumf-2023-24 .
[59] SNOLab (2024) Annual Report 2023-24 p. 23 https://www.snolab.ca/about/strategic-plan/
[60] See, for example, Canada SuperDARN's leadership of the international consortium https://superdarn.ca/superdarn.
[61] See, for example, the data holdings and policies of ONC https://www.oceannetworks.ca/data/; and those of the Canadian Astronomy Data Centre https://www.cadc-ccda.hia-iha.nrc-cnrc.gc.ca/en/.
[62] KPMG Report to CFI September 14, 2028. Outcomes Measurement Study Findings: Integrated Report.
[63] SNOLab (2022). Alumni Study TVA Associates Inc. Nov 14, 2022. Personal communication.
[64] See, for example, TRIUMF's academic programs https://www.triumf.ca/academic-programs.
[65] See, for example, the work of the IISD ELA with communities https://www.iisd.org/ela/community/.

Indigenous inclusion – NRI have played a significant role in advancing Canada's approach to reconciliation. Recognizing that Indigenous ways of knowing are an integral part of valid and authoritative research, together with the direct relevance of such knowledge to address some of the research challenges that are the focus of the NRI, such as climate change and stewardship of the North, NRI are active in developing deep and trusted relationships with Indigenous partners.[66] An increasing number of the research activities sustained by the platforms partner with and engage Indigenous researchers and communities.[67]

4.5 Broader Societal Influence and Impacts (Extrinsic Impacts)

By their very nature, NRI have wide and deep socio-economic, environmental and cultural benefits, aligned with the nature of the research platform and its user base. Inevitably, many of these zones of impact overlap. The examples listed below are necessarily limited by the scope of this paper on academic-facing NRI.

Broader societal impacts

- Social capital
- Public policy
- Response to global challenges
- Health and well-being
- Agri-food and animal health
- Climate, environment & energy
- National security & sovereignty
- Science communication & outreach
- Industrial services
- External partnerships
- Spin off companies
- Patents and licenses

Social capital – NRI contribute to the development and embedding of social capital for promoting learning and research-based innovation both within the research ecosystem and in the wider community. Such social capital entails productive interactions among research organizations, communities, firms, and government. It is a key element in preparedness to respond to national and global challenges. Two phases can be considered in the development of that social capital:

1. *Structural social capital* - Setting up systemic 'infrastructure' such as partnerships and linkages between actors and among sectors.
2. *Relational social capital* - Filling those relationships with content by encouraging concrete interactions between the partners.

NRI create shared and collaborative research and innovation ecosystems through their formal and informal institutional partnerships, national and international networks, linkages among user communities and collaborative initiatives supported by the research

[66] See, for example, the partnership of OTN researchers with Indigenous communities https://news.mongabay.com/2022/02/in-canada-indigenous-communities-and-scientists-collaborate-on-marine-research/ and https://www.apoqnmatultik.ca/new-blog/a-way-forward-for-aquatic-stewardship.
[67] See, for example, CHARS https://www.canada.ca/en/polar-knowledge/CHARScampus.html.

platform. The positive and enduring relationships that form around and in association with NRI foster effective knowledge mobilization and technology transfer on an ongoing basis.

Public policy – There is a vast range of public policy issues that are informed by the outcomes of research supported by Canadian NRI, research activities that rely on the particular resources provided by these platforms. Over and above health policy addressed below, these issues include informing immigration policy, housing policies, watershed and lake management, management of what works (and doesn't) in childcare reform, managing biodiversity, whether or not to use the tax system to target benefits and much more.[68]

Response to global challenges – Building on their existing capacities and social capital, Canadian NRI have demonstrated the capacity to pivot rapidly and deploy their assets to tackle major national and global challenges. Indeed, many Canadian NRI and their research communities made major contributions to addressing Covid-19, drawing down on the availability of their technical capabilities, services and the data they hold.[69]

Health and well-being – The multiple NRI contributions to health and well-being include provision of cohorts and longitudinal datasets to inform healthy aging,[70] development of diagnostic tests and procedures, access to tools to develop strategies for addressing disabilities, drug and vaccine development,[71] identification of biomarkers for disease severity, predicting treatment response, barriers to advancing precision healthcare in Indigenous communities,[72] access to data to reveal how social determinants of health can inform the adoption of diagnostic approaches, preventative measures, and treatment, and to expose variations in health services and behaviours across time and space.

Agri-food and animal health – A number of Canadian NRI support research important to the agri-food industry such as vaccine development for high impact animal diseases,[73] tackling the sustainability and productivity of agricultural production at global, landscape,

[68] See, for example, CRDCN Knowledge Mobilization activities https://crdcn.ca/programs/knowledge-mobilization/; CBD https://biodiversitygenomics.net/news/; OTN https://oceantrackingnetwork.org/OTN10years/informing-policy/.
[69] See, for example, SNOLab's work in relation to Covid https://www.snolab.ca/news/cfi-funding-to-support-snolab-research-including-covid-19-initatives/; VIDO Annual Report 2019-2020 p. 8. https://www.vido.org/assets/upload/pdf/annual_reports/VIDO%20-%20Annual%20Report%202019-2020.pdf.
[70] See, for example, CRDCN https://crdcn.ca/publications-data/data/.
[71] See, for example, VIDO bacterial vaccine development https://www.vido.org/research/bacterial-vaccine-development/ ; GlycoNet's role in drug development https://canadianglycomics.ca/.
[72] See, for example, CGen 2023-2024 Annual Report p. 23 https://www.cgen.ca/wp-content/uploads/2024/10/CGEn-AR-2023-2024-SEP-17.pdf.
[73] See, for example, VIDO research on chronic wasting disease p. 14 https://www.vido.org/assets/upload/pdf/annual_reports/VIDO_23.24%20AR_digital_single_FINAL.pdf.

and micro scales,[74] supporting sustainable management of commercial fisheries,[75] new methods for creating meat substitutes, developing a process for turning poultry waste into a soil additive for agriculture.[76]

Climate, environment and energy – There is a diversity of activities linked to climate, environment and energy sustained by Canadian NRI, including energy efficiency of carbon conversion, new forms of rechargeable batteries,[77] understanding the Arctic ocean-climate nexus,[78] ecosystem dynamics, understanding long-term impacts of pollutants, maintenance and sharing of long-term meteorological, hydrological, water quality, and fisheries datasets for understanding impacts of climate change, protecting marine mammals,[79] effects of severe weather events on buildings and structures.[80]

National security and sovereignty – Research presence in the Arctic enabled by the Northern field stations and ship-borne platforms has the important collateral benefit of reinforcing Canadian security and sovereignty. Contributions to the coastal radar and inundation models for tsunamis and storm surge contribute to coastal community resilience.[81] Other work linked to national security demonstrated that high-frequency radars are a viable option to replace NORAD's North Warning System, overcoming the challenge of significant interference from the aurora that obscures the objects tracked by defence radars.[82]

Science communication and outreach – NRI are often uniquely equipped to educate, fuel curiosity and inspire an interest in science. Many run tours, workshops and special events for students and educators, often with a specific focus on female youth and Indigenous peoples. [83]

Industrial services - By virtue of continuing to improve their performance and keeping their platforms state-of-the-art by pushing the frontiers of science and technology, NRI

[74] GBC https://biodiversitygenomics.net/projects/farms-of-the-future/.
[75]OTN https://oceantrackingnetwork.org/OTN10years/informing-policy/.
[76] VIDO
https://www.vido.org/assets/upload/pdf/annual_reports/VIDO_23.24%20AR_digital_single_FINAL.pdf.
[77] CLS (2024) https://www.lightsource.ca/public/news/2024-25-q2-oct-dec/new-type-of-battery-could-outlast-evs-and-still-be-used-for-grid-energy-storage.php.
[78] Amundsen Science https://amundsenscience.
[79] OTN Viewbook https://oceantrackingnetwork.org/OTN10years/.
[80] WindEEE Strategic Plan 2022-2026 https://windeee.ca/wp-content/uploads/2022/03/WindEEE-Strategic-Plan-2022-2026.pdf.
[81] ONC Annual Report 2023-2024 p. 6 https://www.oceannetworks.ca/about-onc/annual-reports/.
[82] SuperDARN data used in a proof-of-concept study in a contract led by the CSA, Defence Research & Development Canada (DRDC), the US Naval Research Laboratory and NORA.D
[83] See, for example ONC's Youth Programs https://www.oceannetworks.ca/learning/youth-programs-k-12/.

have highly specialized services and unique facilities that are made available to industry, normally on a fee for service basis.[84] [85]

External partnerships – In addition to fee for service activities, to maintain their leadership role, NRI need to actively develop new technologies in collaboration with industry. Working hand in hand with high-tech companies that supply them with manufacturing capacity these collaborations have significant potential to incubate innovative spinoffs, e.g. in space and particle physics. Most NRI engage in partnered research programs and projects. Such external partnerships with private and public sector receptors for their research outcomes is an essential feature of orienting their activities to national needs and challenges and facilitating knowledge mobilization.[86]

Spin off companies – NRI frequently build on their service relationships and external partnerships to incubate innovative spin-offs that exploit their technological strengths and related competencies, with activity in high tech, sciences and life & health sectors.[87]

Technology transfer, patents and licenses – Utilizing the services of the technology transfer offices of their host universities (or in the case of TRIUMF, its own innovation unit), NRI pursue technology transfer opportunities and seek patent protection and pursue licensing agreements where appropriate.[88]

5. Concluding Comments

Canada's large research infrastructures collectively play a crucial role in Canada's ability to produce new knowledge and innovation, to attract and retain research talent, and to help understand and tackle the environmental, societal and economic challenges that we face.

They provide Canadian researchers with the ability to pursue work at the frontier of many fields of endeavour, often with strong international collaboration. There is a history of world-class excellence sustained by Canadian NRI, and an increasing reliance on them as they influence what research is done, how it is done and with whom it is done. However, they face a panoply of ongoing challenges in today’s research ecosystem as explored in this paper.

[84] See, for example https://metabolomicscentre.ca/solnul-tmic-client-success-story/.
[85] Mining technology developed using CLS - selenate bioreduction in a large in situ field trial https://doi.org/10.1016/j.scitotenv.2024.172869.
[86] See, for example https://www.lightsource.ca/industry/industry-services.php.
[87] See, for example Maritime bioLoggers spin off from OTN https://oceantrackingnetwork.org/wp-content/uploads/2018/11/OTN-viewbook-web.pdf p. 99; Amundsen-based studies on the deep biosphere microbiology and oil spill bioremediation that led to the creation of Geogenomics Inc., a Calgary based spin off (personal communication).
[88] See, for example TRIUMF Innovations https://www.triumfinnovations.ca/

The Canadian landscape of NRI is messy, uncoordinated, generally poorly resourced and lacking in an overarching strategic vision/perspective where they are supported in a manner that maximizes their impact and benefits for Canadians. The current approach is notably inefficient and restrictive in terms of institutional productivity and innovation, at an ongoing cost to Canada.

The recent government announcement of the MRF framework is a step in the right direction. However, that framework relates to only six of the current NRI, does not address Canadian access to foreign research infrastructures, and most importantly does not deal with the larger portfolio of NRI in Canada. As yet, there is no explicit commitment to invest in a larger strategic approach to the management of our NRI portfolio as is common in many other developed nations – an approach founded on landscape analyses and a roadmap of the path forward.

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Inevitably, this assessment is temporal and conditioned by the experiences of the author who takes full responsibility for the content and views expressed in this paper.

Appendix 1. Inventory of Academic-facing NRI

	Name	Description	Manger/Users	**Major Funders (operating)** Note – Host universities and the Tri-agency provide additional support
Group #1 Digital research infrastructure (DRI) – the digital infrastructure service layer that serves the national R&D community as an enabling resource for all domains of intellectual activity. This critical infrastructure includes delivery of connectivity, computing power, software, and supports for managing research data. Given that e-infrastructure is now essential for almost all disciplines and research and innovation sectors, provision of effective DRI must be a central preoccupation of any NRI strategy.				
	The National Research and Education Network	The ultra-high-speed network connecting Canada's researchers, educators, and innovators to each other and to global data, technology, and colleagues, as well as associated network services. Delivered by CANARIE and its regional and institutional partners. Established 1993 https://www.canarie.ca/	Manager – CANARIE Users – Academic researchers ; researchers in federal and provincial governments	Government of Canada (through ISED); regional and institutional partners
	Canada's digital research platform	A national service layer of digital research infrastructure incorporating advanced research computing (ARC), research data management (RDM) and research software (RS). Delivered through the Digital Research Alliance of Canda established in 2019, following a series of national consultations and related planning activities, https://www.alliancecan.ca/en	Manager - Digital Research Alliance of Canda (DRAC) Users – academic researchers	Government of Canada (through ISED); regional and institutional partners, in particular the host provinces of the ARC facilities
	The Canadian Astronomy Data Centre Research Facility (CADC)	CADC is a data archive, management and delivery organization providing data collections, along with cloud infrastructure for astronomy as a resource for data-intensive astrophysical research. CADC functions both as a provider of astronomy-specific service layers that use the Alliance	Manager – NRC Users – academic and NRC researchers	Government of Canada through the NRC and the Canadian Space Agency

		infrastructure, and as a coordinator of long-term archiving of digital data products for astronomy, e.g. it has stored all of the data from Hubble since its launch in 1990 and will be doing the same for JWST. It will also function as a home to one of the SKA's regional data centres. https://nrc.canada.ca/en/research-development/nrc-facilities/canadian-astronomy-data-centre-research-facility		
Group #2 Major science infrastructures that are supported by the GoC (NRC, CSA, ISED) for ongoing operating costs. Support for these initiatives is normally associated with an intensive processes of long-range planning and priority setting.				
	Square Kilometre Array (SKA)	A global NRI in which Canada participates. The SKA Observatory is the world's next-generation radio-astronomy observatory and will operate the 2 largest radio-telescope arrays in the world. Canada joined the SKA Observatory as a Member in June 2024, becoming the tenth country to join the intergovernmental organisation. https://nrc.canada.ca/en/research-development/nrc-facilities/square-kilometre-array-observatory ; https://www.skao.int/en	Manager – National Research Council. NRC represents Canada in the governance of the SKAO Users – academic researchers	Government of Canada through the NRC
	The Canada France Hawaii Telescope (CFHT)	CFHT is a global NRI which Canada co-leads, situated on Maunakea, Hawaii. NRC is actively involved in many of the engineering projects to further the technical capability of the telescope. https://nrc.canada.ca/en/research-development/nrc-facilities/canada-france-hawaii-telescope-research-facility ; https://www.cfht.hawaii.edu/	Manager (of the Canadian engagement – the NRC Users – academic researchers	Government of Canada through the NRC (42.5% share) with the Centre National de la Recherche Scientifique of France (42.5% share) and the University of Hawaii (15%)

	TRIUMF	TRIUMF is Canada's particle accelerator centre advancing isotope science and technology, both fundamental and applied. Founded in 1968 by three BC universities to meet research needs that no single university could provide, it is now governed by a consorium of Canadian universities and funded through NRC. https://www.triumf.ca/	Owned by a 20 member consortium of Canadian universities Users – academic researchers and industry	Government of Canada through the NRC; consortium partners That funding relationship may ultimately be changed to CFI with the implementation of the new MRF framework.
	The James Webb Space Telescope (JWST)	JWST is a global NRI in which Canada participates. Launched in December 2021, the JWST is an international collaboration between the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA) and the Canadian Space Agency (CSA). For the contribution of sophisticated science instrumentation (NRC and CSA) Canada receives access to a 5% share of Webb's competed observation time, as well as some guaranteed telescope time for the instrument teams. https://www.asc-csa.gc.ca/eng/multimedia/search/image/170 ; https://science.nasa.gov/mission/webb/	Manager of Canadian engagement – CSA Users – academic researchers	The Canadian Space Agency
	The Arthur B.McDonald Canadian Astroparticle Physics Research Institute	This is a network of astroparticle physics expertise - expert engineers, technicians, and scientists design, construct, and operate the experiments conducted in Canada's underground and underwater research infrastructure. Funded in budget 2024. . https://mcdonaldinstitute.ca/	Owner– Queen's University and managed together with 12 institutional partners	Government of Canada through ISED (see budget 2024)

Group #3 The six now-designated major research facilities (previously MSI, now designated MRF) currently supported by CFI for ongoing operating expenses, each of which has a different trajectory in terms of genesis and funding. CFI is currently providing funding of a total of $545M over 6 years (or between $38M and $181M for each MRF including the supplemental support to CLS

through budget 2024); MRF support is currently allocated at a level of 60% of the total budget, thus requiring each facility to raise 40% of its budget in partner funding.				
	Canadian Light Source Inc (CLSI)	CLS is Canada's only synchrotron with first operations in 2005 supports users across science, medical and engineering domains and serves multiple industrial sectors through an active industrial program. The CLS provides multiple experimental stations through access to 22 unique beamlines as well as accessory facilities. It is also partnered with the Advanced Photon Source (APS) at the Argonne National Laboratory (ALS) to provide Canadian researchers access to the ALS Spectroscopy Group. Received development funding of $56M in 1999 and MSI/MRF funding since then. https://www.lightsource.ca/	Owner – University of Saskatchewan and operated under licence by the CLSI which leases CLS Users – academic, government and industrial researchers	Government of Canada through CFI, Govt of Saskatchewan, NSERC, CIHR
	Amundsen Science	Amundsen Science is responsible for the scientific mandate of the research icebreaker CCGS Amundsen, maintaining the ship's pool of scientific innovative equipment and providing financial, technical and logistical support to user programs. The Amundsen operates in the Gulf of St Lawrence up the Atlantic through the Northwest passage as far north as the entrance of the Lincoln Sea and as west as the Beaufort & Chukchi seas. The broader user base comprises 12 universities, 2 Arctic colleges and more than 125 national and international institutions and organizations. https://amundsenscience.com/explore-the-icebreaker/	Owner and manager of ship - Canadian Coast Guard Manager of infrastructure - Amundsen Science Corporation Users – academic (global) and government researchers; indigenous communities	Funder – Government of Canada through Fisheries and Oceans Canada, CFI, host university and other partners (academic and governmental), QC government

	Ocean Networks Canada (ONC)	Hosted and owned, a not-for-profit established in 2007, ONC delivers ocean data from its cabled, mobile and community-based observing networks operating in the deep ocean and coastal waters of Canada's three coasts–the Arctic, the Pacific and the Atlantic. https://www.oceannetworks.ca/	Owner - the University of Victoria Manger and operator - the ONC Society Users – academic (global), government and territorial researchers, industry users	Government of Canada through CFI, University of Victoria, BC government, CANARIE, the Alliance and other partners
	SNOLab	At 2km depth, SNOLAB is the deepest cleanest lab in the world. Its program focuses on astroparticle physics, specifically neutrino and dark matter studies, though its unique location can also support biology and geology experiments. The expansion of the facilities originally constructed for the Sudbury Neutrino Observatory (SNO) was completed in 2009, with the entire lab entering operation as a 'clean' space in March 2011. https://www.snolab.ca/	Owner – Queen's University Manager – The SNOLAB Institute (formally an unincorporated Institute of Queen's University) is operated under a trust agreement among Queens University and 4 partner universities. Vale sits on the Board Users – academic (global) researchers	Government of Canada through CFI, The Ontario Research Fund's Research Excellence Program, NSERC, member institutions, city of Sudbury
	Vaccine and Infectious Disease Organization (VIDO)	Originally established in 1975 as the Veterinary Infectious Disease Organization, over time, VIDO has morphed to become a leader in infectious disease research and vaccine development for both humans and animals. In 2013 its containment level 3 facility, the International Vaccine Centre	Owner – University of Saskatchewan Manager – University of Saskatchewan (VIDO is not incorporated)	Government of Canada through CFI, SK government, and municipal governments, the livestock industry, foundations, human and animal health companies, and private and corporate donors

		(InterVac), was certified. A CL4 facility is under development that should be complete by the end of 2025 and fully operational in 2027. As an organization that is part of the University of Saskatchewan VIDO is considered a science centre that operates like a department within the university https://www.vido.org/	Users - academic, government and industrial researchers	
Group #4 The 13 major science initiatives (MSI) currently supported by CFI, a group with considerable diversity in form and function, each of which is funded at a lower level than those facilities now included in the MRF by CFI. CFI is providing a total of $167M over 6 years (or between $2.6M and $49M for each MSI). MSI support is currently allocated at a level of 40% of the total budget, thus requiring each facility to raise 60% of its budget in partner funding.				
	Advanced Laser Light Source (ALLS)	ALLS is home to Canada's most powerful laser, providing a coherent rainbow of light and cutting-edge experimental end stations to national and international users supported by a highly professional technical/research team. Opened in 2005 and fully operational in 2008 ALLS is located at the Institut national de la recherche scientifique's Énergie Matériaux Télécommunications Research Centre, located in Varennes just outside of Montréal, Que. https://inrs.ca/en/research/research-facilities/find-a-research-facility/advanced-laser-light-source-laboratory/	Owner and manager – INRS. Unincorporated, bringing together several Canadian institutions and linked with major international major laser research laboratories Users – academic (global) and industrial researchers	Governments of Canada through CFI, the Quebec government and INRS
	Canadian Cancer Trials Group/ Operations and Statistics Centre (CCTG)	CCTG is an academic cooperative oncology group established in 1980 and housed at Queen's University, the Operations and Statistics Centre (OSC) supports the research and knowledge transfer activities of the Canadian Cancer Trials Group (CCTG). The OSC is the only Canadian academic research facility that supports the	Owner – Queen's University Manager – The cooperative Group/collaborative network of more than 85 member institutions	Government of Canada through CFI, Queen's University, partners

		development and conduct of the entire range of cancer trials, from early phase (phases I and II) studies to large international randomized controlled phase III trials of all treatment methods across all cancers. https://www.ctg.queensu.ca/	Users – academic/ medical researchers, clinical trial professionals	
	Canadian Research Data Centre Network (CRDCN)	Created in 2000, with the head office hosted by McMaster University in Hamilton, Ont., CRDCN is a research infrastructure and network that provides access to confidential Statistics Canada microdata, and provides researchers in population health and the social sciences with the data, software, training and network needed to conduct advanced quantitative analyses of major socioeconomic and health issues in Canada such as labour markets, mental health, poverty, justice and education. https://crdcn.ca/	Owner – McMaster University Manager – CRDCN (unincorporated) managed by a Board of Directors Users – academic researchers	Government of Canada through CFI, SSHRC, CIHR and Statistics Canada; 33 institutional partners
	Centre for Biodiversity Genomics (CBG)	CBG was launched in 2005 to support and coordinate the major research programs undertaken by the International Barcode of Life Consortium. Located at the University of Guelph, and focused on biodiversity science, its mission is to activate a global biomonitoring system through the development of DNA sequencing, informatics, and organizational infrastructure, underpinned by the CBG's Barcode of Life Data System (BOLD), an informatics platform visited by two million users annually. https://biodiversitygenomics.net/	Host and owner – University of Guelph Manager – An unincorporated entity, CBG's operations are overseen by a U Guelph Board of Management and advised by an external Board Users – academic (global) and government researchers	Government of Canada through CFI, Tri-Council, U Guelph, Genome Canada, Ontario government, and a number of other partners, including NFP and private sector

	Canada's national facility for genome sequencing and analysis (CGEn)	Established in 2014 and led by the Hospital for Sick Children in Toronto, with nodes in Toronto, Montreal and Vancouver, CGEen provides high-throughput genomics experimentation and analysis to researchers in Canada and around the world. Massive computational and data storage infrastructure support the CGEn platform of current sequencing technologies and analysis methodologies and services. https://www.cgen.ca/	Hosted by the Hospital for Sick Children in Toronto Managed by an Exec Committee of the three institutional partners - The Centre for Applied Genomics at The Hospital for Sick Children (Toronto), McGill Genome Centre at McGill University (Montréal), Canada's Michael Smith Genome Sciences Centre at BC Cancer (Vancouver) Users – academic researchers	Government of Canada through CFI; Provincial governments of Ontario, Quebec, and British Columbia; Genome Canada; and others.
	Coalition Publica (CP)	Coalition Publica is a partnership established in 2017 between Érudit and PKP, two Canadian giants of the scholarly publishing world with a shared mission to support open-access publishing and dissemination of scholarly research outputs. Coalition Publica's infrastructure is grounded in a technology gateway that makes Open Journal Systems (OJS) interoperable with erudit.org's dissemination platform. This allows Coalition Publica to provide a wide range of integrated tools and services for scholarly publishing. https://www.coalition-publi.ca/	Hosted by the Université de Montréal. Coalition Publica is managed as a partnership between Érudit and the (Université de Montréal) and the Public Knowledge Project (PKP – Simon Fraser University) Users – academic (global) researchers in the social sciences and humanities	Government of Canada through CFI, Université de Montréal, Simon Fraser University, Fonds de recherche du Québec, associated universities, CRKN.

	Global Water Futures Observatory (GWFO)	GWFO grew from a legacy of long-term freshwater observation associated with predecessor water research networks and initiatives. Funding through the Canada First Research Excellence Fund in 2016 helped consolidate the activities as a national scientific freshwater observation network offering management of data, observations, operations of the instrumented sites, deployable systems, and water labs. Operates as a science centre within the University of Saskatchewan https://gwfo.ca/	Hosted by the University of Saskatoon, in association with eight partner universities in Ontario Managed by a Senior Management Committee including representatives from the major partner institutions. Users – academic (global) researchers and international governmental bodies	Government of Canada through CFI and other federal programs, University of Saskatchewan, partner univresities
	GlycoNet Integrated Services (GIS)	GIS is Canada's national facility dedicated to glycomics — the study of glycans, or sugars, in all biological systems, from humans to viruses and bacteria. It is one of the world's largest, most advanced academic glycomics service organizations. Launched in 2015 as a Network of Centers of Excellence, its integrated national platform includes seven sites across Canada offering a suite of glycomics services focused on developing new carbohydrate-based drugs, vaccines and diagnostics. https://canadianglycomics.ca/integrated-services/	Hosted by the University of Alberta; incorporated as a not-for-profit entity with its administrative office at the University of Alberta. Management by a Research Management Committee oversee by a Board of Directors Users – academic (global), clinical, government, industrial researchers	Government of Canada through CFI, the federal Networks of Centres of Excellence (NCE) Program (2015-2025) and the Strategic Science Fund (2024-2029)

	SuperDARN Canada	The Super Dual Auroral Radar Network (SuperDARN) is an international network of high-frequency (HF) radars located throughout the northern and southern hemispheres with partners in 10 countries synchronizing 35 radars to operate as one global facility to monitor the space weather conditions in the Earth's magnetosphere. A founding member of SuperDARN, and now leading the collaboration, SuperDARN remotely operates five radar stations in Saskatoon; Prince George, B.C.; Rankin Inlet, Nvt; Inuvik, N.W.T.; and Clyde River, Nvt. https://superdarn.ca/ ; http://vt.superdarn.org/	Hosted by/headquartered at University of Saskatchewan Managed by the University of Saskatchewan supported by an Advisory Committee Users – academic (global) researchers	Government of Canada through CFI and the Canadian Space Agency, University of Saskatchewan, Government of Saskatchewan
	The Andre E. Lalonde Accelerator Mass Spectrometry Facility for Environmental Radionuclides (AEL AMS)	AEL-AMS is the only AMS facility in Canada. Beginning operations in 2015, its national user facility has two AMS systems and supporting labs for preparing samples and measuring trace concentrations of naturally occurring and anthropogenic radioisotopes. The AEL-AMS facility measures the natural abundance of radiocarbon (^{14}C) in seawater, plants and soils to study the carbon cycle in ecosystems and monitor climate change, as well as actinides and halides for fingerprinting ore and emissions and cosmogenic nuclides to study landscape responses to human and naturally induced changes. Operates as a science centre with U Ottawa. https://www.uottawa.ca/research-innovation/national-ael-ams-facility	Hosted by the University of Ottawa in Ottawa Managed by Exec team overseen by a Board of Directors Users – academic and government researchers	Government of Canada through CFI, University of Ottawa

	The Metabolomics Innovation Centre (TMIC)	Founded in 2011, TMIC, led by the University of Alberta, is a national core facility offering a unique combination of infrastructure and personnel to conduct a wide range of cutting-edge metabolomic studies for biomarker discovery, biological studies, exposomics, clinical trials research, biomedical studies, bioproducts studies, agriproduct research, nutrient profiling, and environmental testing. https://metabolomicscentre.ca/	Hosted by the University of Alberta as an unincorporated entity Managed by the executive team overseen by a Board of Directors Users – academic (global), government and industrial researchers	Government of Canada through CFI, Genome Canada and the BC and AB Genome Centres, six partner universities
	The World's Freshwater Laboratory (IISD-ELA)	The ELA, officially opened in 1968, is characterized as "the World's Freshwater Laboratory"- the only place in the world where scientists can research and manipulate real lakes to build a more accurate and complete picture of what human activity is doing to freshwater lakes. https://www.iisd.org/ela/	Ownership assumed by the International Institute for Sustainable Development (IISD) as of 2014 (to ensure the facility's long-term operation) Management – Executive team under direction of a Board of Directors Users – academic (global) and Indigenous researchers, educators	The Government of Canada through CFI, Environment and Climate Change, Department of Fisheries and Oceans; The Province of Ontario and donors
	Wind Environment, Energy and Engineering Research Facility (WindEEE)	Established in 2011 WindEEE operates a specialized suite of infrastructure that simulates intense winds and weather that allow testing in a controlled environment of how buildings will hold up under catastrophic conditions with the goal of propelling the establishment of climate-resilient and	Hosted by Western University Managed by the facility Director , overseen by a Board of Directors	The Government of Canada through CFI, Western University

		sustainable communities. https://windeee.ca/	Users - Users – academic (global), government & industry researchers	
Group #5 Arctic/Northern Infrastructures – a suite of infrastructures that provide research support to over to 40% of Canada's landmass/oceans. They are funded by a mix of federal departments, territorial support, CFI, universities and colleges and supported by a major logistics hub for Arctic research (Polar Continental Shelf Program). Note that the Amundsen and SuperDARN could also be classified as Arctic/Northern facilities.				
	Canadian High Arctic Research Station (CHARS)	CHARS and its governing organization, Polar Knowledge Canada, were established with the CHARS Act (2014). The research station is located in Cambridge Bay, Nunavut, and works through partnerships across numerous northern and indigenous organizations. The facility is a world-class Arctic research station that works to bring science and technology and Inuit knowledge to a wide range of research needs – from ecosystem monitoring to DNA analysis, to environmental health and community wellness. The station provides researchers with accommodation and technical services. https://www.canada.ca/en/polar-knowledge/CHARScampus.html	Owned by the Government of Canada Managed by the executive team under the direction of Polar Knowledge Canada Users – academic, government and Indigenous researchers	Government of Canada
	Polar Environment Atmospheric Research Laboratory (PEARL)	Located at Eureka, Ellesmere Island, Qikiqtaaluk Region, in the Canadian territory of Nunavut, PEARL serves researchers dedicated to studying the changing atmosphere over Canada. Its facilities (Ridge Lab, Zero Altitude Lab, SAFIRE (Surface and Atmospheric Flux IRadiance Extension) are situated on the Environment and Climate Change Canada (ECCC) reserve of Eureka – a remote location socially isolated from both	The PEARL Ridge Lab is owned by ECCC; the PEARL 0PAL and SAFIRE facilities belong to the CANDAC university consortium. Managed by – the CANDAC consortium out of UofT	Initially funded by the Canadian Foundation for Climate and Atmospheric Sciences and NSERC, it has received small levels of support from ECCC and CSA, but has no ongoing federal support. UofT has stepped in to keep a minimal number of core staff members.

		northern and southern Canada. https://www.pearl-candac.ca/website/	Users – academic and government researchers	
	The Churchill Marine Observatory (CMO)	CMO is designed to facilitate multidisciplinary research on extreme weather and climate change both on land and in the ocean. CMO provides the facilities necessary for leading edge studies into the detection, impact and mitigation of oil spills and related contaminants in sea ice-covered waters. Its location in Churchill, adjacent to Canada's only Arctic deep-water port, allowing researchers access to the region's local marine and Arctic life. https://umanitoba.ca/earth-observation-science/facilities-labs-vessels/churchill-marine-observatory	Owned by the University of Manitoba Managed by executive team under supervision of a Board of Directors Users – academic and government researchers, citizen scientists	The government of Canada through CFI, the provinces of Manitoba and Alberta, the University of Manitoba and several federal and private partners
	The Centre d'études nordiques (CEN)	CEN manages a network of infrastructures stretching from the boreal to the Canadian High Arctic including the Qaujisarvik network of 9 research stations, the SILA network of 110 permanent observatories and the Nordicana D open-access platform for Nordic climate and environmental data. It is hosted and supported by https://www.cen.ulaval.ca/en/	Hosted by Laval University Managed as an official research centre of Laval University Users – academic (global) researchers	Government of Quebec - Fonds québécois de recherche Nature et Technologies (FRQNT) and partner universities
Group #6. Diverse large research infrastructures. This category includes NRI that have been funded through diverse mechanisms and that provide capabilities and services to the national research community, but are not funded through MRF or MSI. While the funding levels and approaches may differ in relation to other large infrastructure, each delivers a unique and important service/underpinning for the national research community and are recognized by some funding from an assortment of federal sources (e.g., ISED, CIHR, NSERC).				
	Bamfield Marine	The Bamfield Marine Sciences Centre (BMSC) is Canada's only year round Pacific Ocean research and education centre. In 2024, the	Owned and operated by the Pacific Marine Science Alliance Society	Member institutions provide an annual levy while the majority of

	Sciences Centre (BMSC)	BMSC hosted over 1500 students and 250 researchers from across Canada and around the world. The facility provides seawater equipped laboratories, research vessels, year round foreshore and ocean access, along with room and board. It also offers a suite of university level marine and ocean science courses and supports a range of field trip activities. https://bamfieldmsc.com/	(PMSA), established over 50 years ago by the five member universities; UVic, SFU, UBC, UofC and the UofA. https://pacificmsa.ca/ Managed by an Executive Director reporting to a Board of Directors. Users –academic and industrial researchers, and students	funding comes from researcher and student fees. Individual researchers and their programs receive support from CFI, the tri-councils and other public and private sources.
	Perimeter Institute	The Perimeter Institute is an independent institute for research, training, and outreach in theoretical physics, with a mission to advance our understanding of the universe at the most fundamental level and stimulate the breakthroughs that could transform our future. Operating since 2000, Perimeter brings together the national and international community of physicists to pursue frontier research in key topic areas including cosmology, particle physics, and quantum theory and conducts outreach to students, teachers, and schools to teach modern topics in physics. https://perimeterinstitute.ca/	Manger/operator – Perimeter Institute Users - Academic researchers; educators and teachers	Government of Canada (through ISED); Government of Ontario; private donors
	Canadian Council on Animal Care (CCAC)	Funded by CIHR and NSERC, the CCAC works to ensure that animal-based science in Canada takes place only when necessary and that the animals in the studies receive optimal care according to high quality,	CCAC is comprised of member organizations drawn from the scientific and animal welfare	Government of Canada through NSERC and CIHR; fees for program participation

		research-informed standards. https://ccac.ca/	communities, and federal granting agencies. Management of operations – through 5 standing committees under the direction of the Board	
	Canadian Longitudinal Study on Aging (CLSA)	The CLSA research platform has been envisioned as infrastructure to enable cutting-edge, interdisciplinary approaches to population-based research and empower evidence-based decision-making. https://www.clsa-elcv.ca/	Hosted by McMaster University Managed by the Executive committee/team with oversight from the larger Leadership Team Users – academic and clinical researchers	Government of Canada through CIHR, provincial governments, partner universities, multiple sponsors
	Health Data Research Network (HDRN)	HDRN is a pan-Canadian network of member organizations that either hold linkable health and health-related data for entire populations and/or have mandates and roles relating directly to access or use of those data. https://www.hdrn.ca/en/	Owned by the HDRN Board of Directors Managed by the CEO and Scientific Director Users – health researchers and health organizations	Government of Canada through CIHR
	Accelerating Clinical Trials – Accélérer les Essais Cliniques (ACT-AEC)	ACT-AEC facilitates, optimizes, and accelerates the conduct, implementation, and translation from high-quality, high-impact randomized controlled trials to improve health in Canada and around the world. https://act-aec.ca/	Owned by the Consortium of researchers from 34 networks, 11 trial units, patient-partners, the biotechnology industry, government, and experts	Government of Canada through CIHR (Canada's Biomanufacturing and Life Sciences Strategy)

			in various aspects of clinical trials X Canada	
Group #7 – Miscellaneous. This category includes NRI that have, in the past, been funded by the Government of Canada, but that have now migrated to a fee-for-service mode of operating that also supports academic research.				
	CMC Microsystems (CMC)	CMC is a federally incorporated non-profit corporation that provides microsystems researchers with industry-calibre design resources, access to state-of-the-art manufacturing technologies, and support services. Launched in 1984 through a university, industry and Natural Sciences and Engineering Research Council of Canada (NSERC) initiative, it provides access to state-of-the-art design, manufacturing, and testing capabilities to academe and the private sector and enables research, development, and the training of highly qualified personnel (HQP). https://www.cmc.ca/	Owned by the CMEC Corporation Managed by the President and CEO reporting to a Board of Directors Users –academic and industrial researchers	Government of Canada through CFI (until recently), Government of Quebec, 8 provincial governments, user fees, partners
	The McMaster Nuclear Reactor (MNR)	MNR has the Canadian Neutron Beam Laboratory in which ~$40M in capital has been invested, but operating funds have not yet been secured . While operating primarily on commercial revenues it supports academic research through irradiations, isotope production, and now positron and neutron beams https://nuclear.mcmaster.ca/facilities-equipment/facility-list/mcmaster-nuclear-reactor/	Owned by McMaster University Managed by the Director Reactor operations and Maintenance under the direction of the Scientific Director Users – academic and industrial users	Operates primarily on commercial revenue
Group#8. International NRI accessed by Canadian researchers. International agreements secure Canadian access to facilities outside of Canada where specialized instrumentation and beam lines are critical for our researchers, but not available in Canada. Outside of the NRC's mandate for astronomy, there is no source of funding for memberships in multi-national facilities (e.g. CERN, the European Spallation Source). The periodic CFI Innovation fund competitions allow capital investments in equipment that is				

located at, or is a contribution to, foreign NRI. In some cases, such a capital investment can be traded for access to the foreign NRI for a period of time – but such one-time investments are often not at the scale needed, and leave multi-year gaps, among other problems with this approach.				
	Neutrons Canada's partnership with the UK ISIS Neutron and Muon Source	Through this short-term partnership, funded solely by the UK International Science Partnerships Fund (ISPF), ISIS has awarded 20 research groups across Canada with 56 days of neutron beam time over approximately 16 months, and funds to cover travel costs for researchers to conduct their experiments. With the ISPF is at the end of its funded life and not expected to be renewed, the Canadian neutron community is looking for other funding sources to continue it. https://neutrons.ca/isis-neutron-and-muon-source/	Owner UKRI Science and Technology Facilities Council Manager - ISIS in conjunction with Neutrons Canada Users – Canadian academic researchers	The UK International Science Partnerships Fund (ISPF) has provided funds to enable the development of Canadian use of ISIS and to foster the collaboration between ISIS and Canadian researchers. This funding, for the period 2023-2025, supports Canadian PI experiments at ISIS and a workshop to promote collaboration and partnerships between ISIS and Canada.
	McMaster Neutron Source International Partnerships	Two components: (1) Access to over 100 days of neutron beam time for 6 years at the NIST Center for Neutron Research in the USA, this partnership has yet to begin, as the NIST reactor has been down for significant maintenance and is not expected to users until 2026. (2) Access to 20 days of beam time at the Spallation Neutron Source at ORNL in the USA for 6 years, limited to a few instruments. This partnership has yet to begin, but should be initiated soon. These are supported through a 2020 Innovation Fund award. https://neutrons.ca/program/	Manager – McMaster Projected users – academic researchers	The Government of Canada through CFI; NIST and ORNL in the USA
	Advanced Photon Source (APS)	Canadians access the Advanced Photon Source (APS) at the Argonne National Laboratory in the USA https://www.aps.anl.gov/ through a partnership with the Canadian Light Source.	Owner of APS – Argonne Laboratory, Illinois, USA Manager of program – CLS	The Canadian Light Source

			Users – academic researchers	
	CERN	Canadians access to some degree through in-kind contributions to the ATLAS experiment, but the Canadian particle physics community has not yet identified a means by which to pay the membership fee for Canada to join CERN, which prevents their full participation in the Large Hadron Collider along with scientists from other countries.	Owner - CERN Manager – Institute of Particle Physics	
	Other multinational facilities	There are other multinational facilities that Canadians would like to access, but cannot due to a lack of structure for decisions on, and funding for, Canadian memberships, e.g., the Institut Laue Langevin (France) and the European Spallation Source (Sweden)		

Appendix 2 – Some Critical and Emerging NRI

This appendix explores the unique features of NRI in four domains that require special consideration – DRI which underpins research in all domains of activity, and NRI in health, social sciences and humanities, and the North/Arctic, providing a somewhat more detailed exploration of issues than is possible in the main text of this report. Canada's DRI is critical for the health of the whole research ecosystem. The other three domains of activity are areas in which national research infrastructures are rapidly evolving and playing a particularly important role. Also, they are NRIs that fly somewhat under the radar in Canada.

Digital Research Infrastructure (DRI)

It is non-trivial to characterize the landscape of Digital Research infrastructure (DRI) in Canada, especially that associated with the Digital Research Alliance of Canada (DRAC). While CANARIE's remit is fairly clear cut – securing secure and reliable high-speed connectivity and cybersecurity, DRAC deals with a diversity of DRI elements - compute, research data, and software – each with differing needs and issues.

Compute – The national compute infrastructure supported by DRAC comprises five regional host-sites with differing architectures from highly parallel HPC, through general purpose high throughput systems to flexible cloud-based services. While distributed in nature, researchers benefit from a single set of login credentials for access to any computing facility. With that being said, the system is both vastly oversubscribed[1] and lagging behind its G7 peers, being last in terms of total aggregate compute capacity for research and academia. The current refresh will not meet the ever-increasing demands of forefront research. At issue is that there are no prospects for consideration of an exoscale system in Canada (whereas ~60 such systems are expected to be in place world-wide by 2028).

While Canada's compute infrastructure is struggling to meet demand, a positive attribute of the Canadian system is the over 200 highly skilled personnel who deliver services and training that constitute an essential part of the computational component of DRI.

Research Data - Building on a long trajectory of community initiatives on research data management, Canada has a suite of RDM supports that serve the research community and that are now captured within the DRAC remit, but reflecting shared responsibility in support and funding:

- Lunaris – a national data discovery service that allows researchers to find data from a single source location/portal
- The Federated Research Data Repository (FRDR) that allows researchers to publish and preserve their data for future reuse - designed to support the relatively small number of researchers working with large datasets
- Borealis – a multi-disciplinary and secure data repository delivered in collaboration with UofT's Scholars Portal, supporting institutional repositories focused on their own researcher's needs

A network of >200 RDM experts (funded by institutions; rather than DRAC) supports the national research community through the production of reference materials and ID of best practices related to RDM - again, an essential element of DRI addressing national needs.

[1] In 2024, 43% of the CPU requirements were met and 21% of the GPU requirements.

There remain significant challenges in regard to Canada's approach to RDM. There are 398 research data repositories registered in Canada, most are domain specific, with less than half having some measure of quality management and only two with formal certification. While a few have sustainable business models, most do not – being funded through short term project-based grants. While assessment of national need is critical in allocating ongoing funding, this situation risks losing valuable data; indeed there is evidence of this today. Other challenges merit highlighting – i) data sharing across regions of Canada, and even amongst researchers, is difficult especially in regard to sensitive data; ii) given the lack of clear and consistent guidelines for RDM across research silos much Canadian research data will not be interoperable for reuse beyond the original discipline.

The DRI agenda deals with our ability to handle and manage ever larger, complex and heterogeneous datasets. Data is the new currency of research and of innovation and supports researchers and other NRI in all domains of research. Our ability to steward and exploit the potential of data for impact, and indeed wealth generation, means that we need to tackle a number of fundamental issues in DRI: i) woefully inadequate computing capacity that can't be scaled to levels of global competitiveness); ii) fragmentation of storage capacity existing under a variety of ownership modes, capacity that is needed as a national research asset, especially for long-term preservation); iii) the lack of a national data platform to harmonize disconnected datasets, a platform that would enable standardized protocols, interoperability, and confidence in the quality, accessibility and reproducibility of datasets.

Health

The technological and data dependency of health research has fundamentally altered the landscape of research resources and services that underpin a vibrant health research ecosystem. Access to technological platforms such as high-capacity/throughput technology, high-cost cutting-edge analytical infrastructure, and high-fidelity imaging technology, reliance on biological resource collections (e.g., biobanks) underpins much forefront health research. But less visible are e-infrastructures and knowledge-based resources, registries, repositories, archives and scientific data developed through cohort and longitudinal studies, prospective cohort studies and clinical trials. Such data collections with demographic, life course, clinical, biomedical and/or rehabilitation information supports research to improve the prevention, diagnosis and treatment of serious human diseases. In addition, and of increasing importance, are the formal networks that have developed as a form of social capital infrastructure to support communities of practice, research, knowledge mobilization, training, health interventions and quality improvement.

Through CFI, Canada has invested in a number of NRI that provide what are primarily health-related physical platforms, including CGen that supports genome sequencing and access to high-quality omics data and VIDO with its high containment facilities focusing on human and animal health. Some different types of health infrastructure are also supported - CCTG that designs and administers cancer clinical trials, and TMIC that enables cutting-edge metabolomic studies though access to its extensive metabolomics expertise. Other funded NRI such as CLS and TRIUMF offer unique services that can be utilized in support of health research, in particular drug-related research. This mix, however, does not address how best to support many knowledge infrastructures such as major cohort studies and data registries that are currently funded through ad hoc mechanisms that do not provide adequately for long-term planning or sustainability.[2] To realize full benefit from past investments in such activities, and indeed for new investments, we need a means of providing for the long-term sustainability and continued attention to ever changing technologies and priorities for those research infrastructures that provide essential data on Canadians for research on Canadians.

> Respondents stated that the capstone organization needs to leverage, support and coordinate data platforms for health, current cohort studies (e.g., Canadian Longitudinal Study in Aging, Canadian Partnership for Tomorrow's Health), and existing initiatives for Clinical Trials Infrastructure (i.e., Biomanufacturing and Life Sciences Strategy, Canada Biomedical Research Fund and Biosciences Research Infrastructure Fund). Respondents emphasized the value of these existing infrastructures, and contributions that could be made to the new organization.
>
> What we Heard – Consultation on Capstone

Recognizing that no centralized and up-to-date inventory exists of Canada's health research infrastructure related to pandemics, the CIHR Centre for Research on Pandemic Preparedness and Health Emergencies undertook a review[3] that resulted in an inventory of 72 investments – deemed infrastructures - that were created, repurposed, or expanded in response to COVID-19. This inventory comprising networks, platforms, and hubs demonstrates the vital importance of networks in connecting research communities and the role that such infrastructures play in preparedness for national/global challenges.

The distributed responsibility for health care among provinces and territories in Canada yields other challenges for developing an effective portfolio of national health-related national research infrastructures. With provincial authority over health data, Canadian coordination and data sharing, or at the very least inter-operability, is an essential feature of an effective health research ecosystem which means that coordinating mechanisms are a vital component of the national research infrastructure. As observed in the CCA report Connecting the Dots[4], the Health Data Research Network Canada (HDRN) does just this by offering access to multi-jurisdictional data by connecting member organizations in a distributed network of data managers working together to align their data holdings in ways that enable comparative analyses and make pooling data across provinces and territories more straightforward. Yet there is no obvious source of ongoing funding for this critical component of health research infrastructure.

Social Science and Humanities

While there is a significant history in Canada of supporting infrastructure in the natural sciences and engineering and in most areas of health, the same is not true in the social sciences and humanities and the arts (SSH). SSH infrastructure is generally less costly and often less well understood. Much of it is either unfunded or relatively unknown; that which is funded, is supported at a subcritical level. Currently there are only two CFI-funded SSH MSI – the Canadian Research Data Centre Network and Coalition Publica. Others would include Canadiana (supported through CRKN), and the Canadian Writing Research Collaboratory .

[2] Canadian cohort studies include Canadian Partnership for Tomorrow's Health (CanPath), Healthy Life Trajectories Initiative (HeLTI), Canadian Longitudinal Study on Aging (CLSA), All our Families Cohort.
[3] Personal communication CIHR.
[4] Connecting the Dots https://cca-reports.ca/reports/health-data-sharing-in-canada/

National libraries, museums and archives are the most obvious NRI in the SSH and continue to be vitally important, albeit they are focused on making their collections available, rather than on explicitly supporting capacity development, research, training, and KM. At the same time, newer forms of research infrastructures founded on digital technologies are transforming what and how SSH research is done. These digital research infrastructures, typically a combination of hardware, research software, and technical experts, are frequently distributed as opposed to based at a single site.

Beyond collections of research objects, including physical resources such as historic artefacts, SSH researchers seek access to research infrastructures comprising digitized texts; highly annotated and curated corpora; longitudinal and cohort data collections; large-scale databases; virtual museums and galleries; digital libraries and repositories; survey, administrative, and other data (e.g., video, media, social media, multi-media). Those research infrastructures support data that is dynamic and continually reused, reworked, updated collaboration and provide new tools for data analysis and visualization, dissemination and sharing, data management, enhancement, linking, and reuse. Research has now become more data-driven and tool dependent, opening up new research possibilities and encouraging interdisciplinary work. This in turn is driving interests in research infrastructures that enable the creation and manipulation of large and very heterogeneous bodies of data that are both quantitative and qualitative, requiring flexibility in terms of mixed-methods approaches, more powerful infrastructures that help manage the multi-modality of born-digital scholarship.

A SSH NRI provides a technology platform but does not stop there. Many provide a range of tools and services that make and represent new knowledge and new resources, combining storage, preservation, and state of-the-art information extraction methods and services for the research community. They may provide compute power and the expertise/ competencies capable of dealing with the growing amounts of complex, multi-layered data, which needs proper curation, documentation, and evaluation. International experience with SSH research infrastructures, especially those serving a national community, demonstrates the importance of including a continuity of expertise within the infrastructure for activities such as supporting the research data lifecycle, curating historic artefacts, linking with international partners, and providing active support for researchers who typically experience a steep on ramp in regard to the technical aspects of their projects.

An issue specific to dealing with NRI in the SSH involves dealing with primary sources and raw data such as medieval manuscripts or recent administrative data sets, where digitisation, data cleaning and expert curation may be needed before objects are usable for research. As noted by ESFRI, processing and providing access to such data frequently involves working within legal, ethical and public acceptability frameworks.

SSH research infrastructures are widening access and inclusivity through their digital-forward approaches, which democratise access. When a variety of researchers from different disciplinary backgrounds and lived experiences are invited to the table, the kinds of questions that are asked in the research enterprise are broadened. Diversity of research production requires a diversity of researcher perspectives. The SSH community is increasingly active in working with Indigenous peoples and communities. As NRI emerge and evolve, especially those that capture, process and analyze complex data about people, access to the data will need to support methodologies and perspectives based on trust and respectful relationships with people, places and the natural environment.

The particular research focus and structural makeup of these SSH research infrastructures means that assessments of cost, and size and value are defined differently when compared alongside infrastructures that are equipment- and facility-heavy. The 'size' of SSH infrastructures is more usefully measured in terms of the size of the user base, but in terms of breadth of impact as measured through the diversity of users and partners across geographies, demographics, and disciplinary perspectives. Diversity in these areas leads to diversity of research questions, which is crucial for tackling complex societal challenges. Cost (both initial and ongoing) should not be the mechanism for determining 'size' nor 'value.'

A common value of many SSH research infrastructures is that they support data as a national asset, and data as the driver of further research, which puts them at the forefront of pursuits such as evidence-based decision-making, and the values behind the Open Science movement. As experts in the research data and research publication lifecycles, these particular research infrastructures can help to inform the data management practices across other disciplines and play an informed role in moving forward current demands for reproducibility and FAIR data sharing.
In its most recent Innovation Fund call, CFI has recognized that SSH researchers increasingly use new technologies to leverage large amounts of data to make new discoveries that will fundamentally change how research is conducted. As such, a separate funding stream has been introduced to incentivize initiatives in this area. This is a welcome addition to the funding landscape, and it will be useful to monitor what initiatives emerge within that group which conform to the current definition of NRI (disregarding the funding level for the moment).

The North/the Arctic

Researchers and knowledge holders working in Canada's North[5] are critically dependent on a nationally significant ecosystem of research facilities that are spread across this vast part of Canada's landmass and waters. The northern NRI ecosystem comprises several major research facilities/platforms, enhanced by numerous secondary facilities (research stations, workspaces, access to equipment, etc.). These platforms support an emerging research ecosystem that is forming a hub and spoke model and that mobilizes a wide range of physical, social and cultural research, skills, knowledge and equipment. While at best loosely coordinated, this ecosystem represents a major science investment and can collectively be considered as one of the federal government's major research infrastructure commitments (see CSA Report on PCSP).

Why is this so important? Northern and Arctic research, both land- and ocean-based, is increasingly of critical economic, environmental and geopolitical importance. It is at the heart of local, national and international efforts to understand the rapidly changing Arctic, as well as the implications of those changes on Canada's Northern populations and the wider planet. It is also one way for Canada to peacefully assert its sovereignty over its vast northern reaches. Increasingly, northern Indigenous peoples are active research participants and leaders.

[5] "Northern" in this document refers to the Arctic (the area above the Arctic circle), the Subarctic (the region below the Arctic circle that extends south to the line of discontinuous permafrost) and the socio-economic North, extending below the 60th parallel to include designated regions in the northernmost reaches of some provinces.

Appendix 1 identifies a number of national platforms for Northern research:

- Canadian Research Icebreaker Amundsen
- Canadian High Arctic Research Station (CHARS)
- Polar Environment Atmospheric Research Laboratory (PEARL).
- The Churchill Marine Observatory (CMO)
- The Centre d'etudes nordiques (CEN)

Among other significant Northern /Arctic research facilities that are more regional in focus, but together constitute Key elements of national platform are:

- Kluane Lake Research Station (Arctic Institute of North America, AINA)
- Western Arctic Research Centre (WARC) (Aurora Research Institute), Inuvik. WARC
- Churchill Northern Studies Centre. Churchill Science (Independent NFP)
- Territorial research centres: Yukon Research Centre, Aurora Research Institute, Nunavut Research Institute (short description....)
- Arctic Research Foundation. ARF – private non-profit. Arctic ships and mobile remote labs
- Western Arctic Research Centre (Aurora),
- McGill Arctic Research Station,
- Labrador Institute Research Station (Memorial U)
- There are increasingly Indigenous communities who offer space for researchers to live, store equipment, gather and meet with knowledge keepers

The Polar Continental Shelf Project (PCSP), housed in Natural Resources Canada, is a major Arctic logistics hub that provides logistics coordination and planning, helping to coordinate research support and to defray the very high cost of northern research. While not a major research facility *per se* it is an essential component of the northern research ecosystem. A recent report on PCSP, and northern research more broadly, by Canada's National Science Advisor, provides in further insights to both this facility and broader aspects of Northern research. CSA Report on PCSP

All components of the northern / Arctic research infrastructure ecosystem are actively engaged in co-development and shared governance with indigenous peoples together with a commitment to helping to build research leadership and capacity based '*in the North for the North'* –aligned with northern expectations and needs (e.g. Inuit Tapiriit Kanatami (ITK) National Inuit Research Strategy ITK NISR/) and potentially offering models for research governance elsewhere in Canada ~~and~~. In fact, newer models for northern facilities are increasingly focused on indigenous ownership and control. The Indigenous Guardian system is an increasingly research-capable system of regional support.

Northern research infrastructure faces all of the systemic challenges identified in the main part of this paper, while also experiencing critical additional issues. Costs for research, infrastructure and skills in the North are exceptionally high (often referred to as the 'northern premium'), a significant pressure that is typically not recognized in standard funding mechanisms. Northern digital infrastructure is woefully inadequate to meet the needs of modern science. Aso, northern and indigenous governments are greatly challenged in accessing the highly leveraged CFI funding partnership model due to their limited budget capacity. For example, the January 2024 CFI Northern Fund requires 50:50 partnered funding CFI Northern Fund.

Effective coordination and networking among northern research facilities are crucial for maximizing the impact of investments in northern research. While component entities work to build and leverage complex suites of partnerships, linkages, shared knowledge, etc., the lack of a cohesive national research strategy, or at least a northern research strategy, or at least a coherent approach to coordinating and investing in northern research facilities, poses a challenge in aligning facilities with strategic research agendas and ensuring effective access to resources. Addressing this gap is imperative, as a well-connected network of research facilities, and their skills and capacity, would significantly enhance Canada's ability to conduct effective northern/Arctic research, ultimately benefiting local communities, the broader scientific community and society at large.

Canada's northern/Arctic research infrastructures cannot really be considered in isolation from related circumpolar activities and partnerships. Many Canadian northern research stations are part of INTERACT (international Network for terrestrial Research and Monitoring in the Arctic' https://eu-interact.org/), an organization that seeks to strengthen capacity for research, monitoring, data management and other activities across the Arctic (northern Europe, US, Canada, Greenland, Faroe Islands, Scotland), and offers access to numerous research stations (Russian participation is on hold). Canada's north has been an area of high international research cooperation through the Arctic Council and its working groups Arctic Council and the International Arctic Science Committee (IASC) IASC.