Neutrons Canada Prospectus

November 2021

1 Executive Summary

Research institutions across Canada are invited to become founding Members of a new organization, "Neutrons Canada," which will govern, manage, and represent Canada's infrastructure program for research and development with neutron beams.

This prospectus provides potential founding Members with (1) the context for the founding of Neutrons Canada, and (2) recommendations for the purpose, roles, potential scale and scope, and governance structure of the prospective organization. The recommendations arise from the consultative processes of the Canadian Neutron Initiative (CNI) working group over the past few years, including the January 2020 Roundtable on Neutrons Canada attended by university Vice-Presidents of Research, at which the CNI working group was appointed as the steering committee for the establishment of Neutrons Canada.

Innovation in materials underpins many technology advances for national priorities, such as a clean environment, a clean growth economy, safety and security, and health. Neutron beams are irreplaceable tools for such application-driven research as well as for fundamental research.

Creation of Neutrons Canada is part of a cohesive, multidisciplinary, national strategy to rebuild Canada's capabilities for research using neutron beams following the closure of Canada's primary neutron source, the NRU Reactor in Chalk River, in 2018. At the scale required to meet the Canadian demand for neutron beams, an infrastructure program is now estimated to cost $20M per year. The rebuilding of Canada's neutron infrastructure is already underway with the McMaster-led national CFI 2020 Innovation Fund (IF) award, "Building a Future for Canadian Neutron Scattering" (Phase 1), which is providing $36M toward the neutron beam laboratory at the McMaster Nuclear Reactor (MNR) and six-year partnerships with two US neutron facilities. The proposal for this award envisioned the creation of Neutrons Canada as the organization that would not only operate the neutron beam laboratory at McMaster, but also coordinate access to the requested infrastructure at foreign partner facilities along with other infrastructure to be proposed in coming years (the University of Windsor is currently leading a "Phase 2" proposal). If the awarded and proposed projects are successful, then Neutrons Canada will manage or oversee at least $70M in infrastructure distributed at 3 to 5 locations, domestic and foreign, by the end of 2030.

On behalf of its Member institutions, Neutrons Canada will play an essential role in facilitating community activities to secure capital and operating funds for the infrastructure program. It will deliver or support major neutron projects and related initiatives as appropriate. Neutrons Canada will represent the program as a credible institutional voice to government, as Canada's agent for contracts with foreign neutron sources, and as a consensus builder among the communities that rely on neutron beams. Coordinating such efforts nationally will be the most effective means to deliver a truly pan-Canadian program that enables the community to speak with one voice.

Applying best practices for the governance and management of Major Research Facilities (MRFs) in Canada, it is recommended that Neutrons Canada be created over the next year as a not-for-profit corporation with an independent Board of Directors elected by Member institutions that conduct research with neutron beams. In doing so, Neutrons Canada can begin building expertise to assist with the major projects and neutron-beam user operations at distributed neutron sources, and also begin to undertake activities to secure funding (for example, long-range planning, government relations, future CFI proposals, project and program support and management, etc.).

2 About Neutrons Canada and Its Context

2.1 A national neutron strategy

Neutron beams are versatile and irreplaceable tools for twenty-first century research, innovation, and education, and Canada has been a global leader in materials research using neutron beams for 70 years. Access to neutron beam infrastructure, including neutron sources, instrumentation, and the necessary expertise, is critical for Canadian researchers to help with challenges related to climate change, a clean growth economy, and the development of innovative materials for safety, security, and health. Problems that can only be solved using neutron beams include *in situ* observation of small atoms such as hydrogen or lithium in battery cathodes for clean energy storage or in biomembranes for understanding health, disease, and treatments. In addition, conducting materials research at major neutron facilities has been shown to profoundly impact the training of Highly Qualified People, inspiring students to pursue higher educational achievement and careers in sectors that need their skills for innovation.[1]

Canadian researchers lost access to neutron beams in 2018, when the NRU Reactor in Chalk River closed and when Canada's only agreement with a foreign neutron source expired. Further, the restructuring of federal agencies has left no government institution responsible for providing neutron beam infrastructure for the user community.

Yet Canada still has (1) a base of excellent researchers who require neutrons, including about 100 principal investigators at Canadian universities in addition to experts within industry and government labs; (2) expertise in neutron sources and instruments; (3) a medium-brightness neutron source, the McMaster Nuclear Reactor (MNR), that has been prepared to operate for decades into the future; (4) the strong reputation needed to attract partnerships, collaborations, and expertise; and (5) most recently, a

Figure 1. Left: Geographic distribution of researchers participating in research relying on access to the former Canadian Neutron Beam Centre (CNBC) at the NRU Reactor, across 30 Canadian universities and 22 countries (represented by flags). Right: Beam time by user type over the last five years of the CNBC's operation (2013–2018).

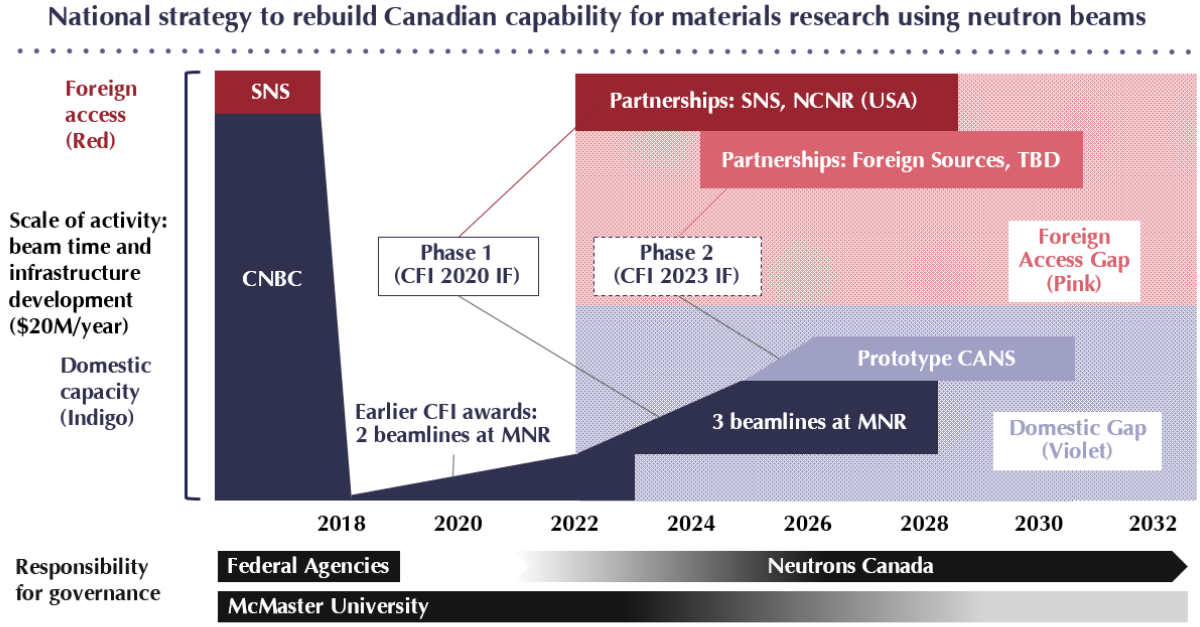
[1] Strategy Policy Economics (2019). Study of CNBC Performance and Impacts. http://cins.ca/docs/Strapolec_2019.pdf

major CFI 2020 Innovation Fund (IF) award to add beamlines to the MNR and create two foreign partnerships.

To continue building on this foundation, the Canadian neutron beam community is aligning around a cohesive, multidisciplinary, **national strategy to rebuild Canada's capabilities for research using neutron beams (the "national neutron strategy")**, which is presented in a paper entitled "A National Strategy for Materials Research with Neutron Beams."[2] This strategy paper describes in more detail the neutron beam user community, the present and historical context for materials research with neutron beams, and the impacts of such research for Canada. It discusses in detail the following four strategic objectives:

1) To create foreign partnerships;
2) To build on Canada's existing domestic capabilities;
3) To explore and develop new neutron sources; and
4) To create a new governance and management framework for these activities.

The major projects and facility operations required for strategic objectives 1, 2, and 3 of the national neutron strategy comprise a program that would be implemented by a dedicated organization, provisionally called "Neutrons Canada," which is the central feature of strategic objective 4. Section 7.4 of



Acronyms: Canadian Neutron Beam Centre (CNBC); Spallation Neutron Source (SNS), NIST Center for Neutron Research (NCNR), Canada Foundation for Innovation (CFI), McMaster Nuclear Reactor (MNR), Compact Accelerator-based Neutron Source (CANS).

Figure 2. Illustration of the infrastructure rebuilding projects within the national neutron strategy and remaining gaps to be filled to meet researchers' demand for neutron beams.

[2] Canadian Neutron Initiative. A National Strategy for Materials Research with Neutron Beams: Discussion on a National Neutron Strategy (Consultation Draft, Feb. 2021). https://fedorukcentre.ca/documents/resources/cni/discussion-on-national-neutron-strategy-consultation-draft---2021-02-18.pdf

the aforementioned strategy paper outlines the concept for Neutrons Canada and its context in more detail. Introductory information is summarized in the current prospectus.

2.2 Scale of the infrastructure program: Short term and long term

2.2.1 Short-term

In the short term, the infrastructure program will consist of the investments already secured. The rebuilding of the infrastructure program (as illustrated in Figure 2) began with the McMaster-led national CFI 2020 IF award, "Building a Future for Canadian Neutron Scattering" (Phase 1). This award, supported by 17 universities with CFI institutional envelope, is contributing to strategic objectives 1 and 2 of the national neutron strategy by providing $25M for developing the neutron beam lab at the MNR and by investing $11M in instrument development at two neutron facilities in the US. The foreign investment will leverage one-fifth of the Canadian need for beam time at world-leading foreign facilities—beam time that will continued to be needed even after the neutron beam lab at the MNR is fully operating.

2.2.2 Long-term

At the scale required to meet the Canadian demand for neutron beams, the infrastructure program is estimated to cost $20M per year. This estimate includes an attributed cost of neutron production at the MNR as well as operations of the neutron beam lab as a national user facility ($9M per year), in which case it will meet up to half of Canadian requirements, enabling high-demand 'workhorse' applications suitable for a medium-brightness, steady-state thermal neutron source. The $20M per year estimate also includes the full cost of acquiring sufficient beam time at world-leading facilities in the US and Europe ($9M per year). It also includes the cost of developing innovative neutron sources, such as a prototype compact accelerator-based neutron source, and of operating such a source ($2M per year). It does *not* include building a brighter neutron source for Canada, which may cost in the range of $200M to $1B, depending on the technology and scale desired.

2.2.3 Gaps to be filled

To meet the Canadian demand for neutron beams and bridge the gap between the short-term and long-term scenarios described above, the infrastructure program needs the following:

- Funds to operate the neutron beam laboratory at the MNR as a national user facility;
- Funds to maximize neutron production at the MNR by boosting the reactor's operating power and by increasing its operations to 24/7;
- Access to additional beam time, especially for high-brightness, cold, and pulsed beams that are not available at the MNR;
- A sub-program for the facilitation of Canadian participation in neutron sources abroad and a means to sustain the foreign partnerships over time;
- A sub-program for the exploration and development of innovative neutron beam instruments and neutron sources; and
- An organization, Neutrons Canada, for the purpose and activities described in section 2.4.

As a step toward filling these gaps, the University of Windsor is leading a national CFI 2023 IF proposal entitled "Building a Future for Canadian Neutron Scattering, Phase 2," which seeks (1) to make another

essential contribution to the infrastructure program by investing further in foreign partnerships to secure more beam time (strategic objective 1); and (2) to build a domestic prototype compact accelerator-based neutron source—a key investment that advances strategic objectives 2 and 3 by adding domestic capacity and exploring the potential of this innovative technology for neutron sources.

If the Phase 1 and Phase 2 projects are successful, and if funds are secured for operating the infrastructure program, then Neutrons Canada will oversee or manage at least $70M in infrastructure distributed at 3 to 5 locations, both domestic and foreign, by the end of 2030.

2.3 Neutrons Canada in the context of the CFI 2020 IF award

The CFI 2020 IF proposal, "Building a Future for Canadian Neutron Scattering" (Phase 1), envisioned the creation of Neutrons Canada as the organization that would operate the neutron beam laboratory at McMaster and coordinate access to the requested infrastructure at foreign partner facilities, along with other infrastructure to be proposed in coming years. While McMaster would retain ownership of the infrastructure and be responsible for managing the award, operations of the infrastructure would be transferred to Neutrons Canada. This transfer "is expected to be no more than five years from award finalization. This timeframe will enable Neutrons Canada to lead strategic planning processes and negotiations concerning potential renewals of the foreign partnerships and to be ready to operate the domestic lab as a user facility before the final neutron beamline is completed."[3]

2.4 Neutrons Canada: Purpose and key activities

The purpose of Neutrons Canada will be to:

> **Govern, manage, and represent Canada's infrastructure program for research and development with neutron beams, including international partnerships that secure access to world-leading neutron laboratories, operation of Canada's domestic neutron beam facilities, and national initiatives for future neutron sources, thereby enabling Canadians to address major social and economic challenges.**

The national neutron strategy envisions several key activities that Neutrons Canada will advance. These are:

- Building consensus among the multidisciplinary and multisectoral (i.e. industry, government, and university) research fields that rely on neutron beams; coordinating the development of user-community roadmaps for Canada's neutron capabilities; and facilitating community activities to secure both capital and operating funding for the infrastructure program;
- Operating domestic neutron beam infrastructure as national user facilities, including managing the allocation of beam time resources through peer-reviewed competitions;
- Fostering Canada's neutron beam capabilities, including through conducting professional outreach, training users, and developing neutron beam technology;

[3] McMaster University. Building a Future for Canadian Neutron Scattering. CFI 39734. January 2020. (Section 5: Sustainability)

- Facilitating Canada's activities at world-leading neutron facilities by developing equipment as in-kind contributions, supporting user access, engaging Canadian industry, and negotiating agreements with these foreign partners; and
- Conducting science communications and public outreach.

Neutrons Canada will be the organizational structure that enables university leaders (e.g. Vice-Presidents of Research) to coordinate their efforts on strategic decisions for this field. Coordinating efforts nationally will be more effective than individual institutions each making their own efforts, and it will enable a truly pan-Canadian program. Additionally, pooling the Members' resources into a single entity with specialized expertise and focus will alleviate university leaders of the burden of allocating the time, attention, and resources required for managing and administering the research infrastructure.

As the manager of the infrastructure program, Neutrons Canada will be naturally placed to act as a credible institutional voice to government. By integrating the bottom-up activities of the broad user community with the top-down interests of science policy and funding bodies, Neutrons Canada will enable the neutron beam community to arrive at consensus and speak with one voice, thereby giving funding bodies confidence in their funding decisions.

2.4.1 Analogues of Neutrons Canada

Precedents for organizations that provide a research field with some or all of the functions listed above exist in Canada and abroad (described further in section 7.4.2 of the strategy paper; footnote 2). Within the field of materials research using neutron beams, the most comparable organization to Neutrons Canada is the Jülich Centre for Neutron Science (JCNS) in Germany. The JCNS offers German researchers access to 18 beamlines in multiple countries (i.e. Germany, France, and the US) and is developing beamlines for a fourth outstation in Sweden at the soon-to-be-opened European Spallation Source. In addition, it is spearheading the development of designs for compact accelerator-based neutron sources. The JCNS supports users at its outstations and provides scientific IT services, in addition to conducting its own in-house research and development programs in neutron beamlines and methods that enhance the capabilities that the JCNS offers to users. Notably, these are many of the same functions that will be needed for the Canadian infrastructure program, which will rely on a mixture of foreign neutron sources as well as the MNR and which could include a new source at the University of Windsor.

Within Canada, all of the research fields that rely on Major Research Facilities (e.g. major synchrotrons, astronomical observatories, accelerators, ocean and polar environmental monitoring networks, high-performance computing, and micro-device design and fabrication facilities) have their own national coordinating organizations that foster their corresponding scientific communities, providing much more than just bare access to equipment. In addition to operating domestic infrastructure, the coordinating organizations may also facilitate participation in international facilities. For instance, TRIUMF acts as Canada's gateway for involvement in CERN, the world's largest particle physics project. The Canadian Light Source locates some Canadian staff at foreign light sources to facilitate Canadian research. The NRC Herzberg Astronomy and Astrophysics Research Centre facilitates Canadian participation in international astronomy facilities as "Canada's gateway to the stars."

To meet the Canadian demand for neutron beams sustainably, **Canada needs an organization that facilitates participation in international neutron sources and fosters the Canadian neutron beam user community,** as well as one that operates domestic neutron sources as user facilities.

2.5 Immediate priorities, timelines, and funding

In the next few years, it will be critical to launch the neutron beam laboratory at the MNR as a user facility with two beamlines; to begin implementation of the CFI 2020 IF award (i.e. establishing two foreign partnerships and adding three beamlines at the MNR); and to secure funding for operations and further capital projects through CFI Major Science Initiatives Fund (MSI) and CFI Innovation Fund (IF) applications or through other means (e.g. government relations).

Creation of Neutrons Canada will need to take place over the next year or two for it to assist with major projects, operations, and activities to secure funding, as illustrated in Figure 3. Additionally, to meet commitments to the CFI (see section 2.3), Neutrons Canada should be ready to negotiate renewals of the foreign partnerships established via the CFI 2020 IF award. Renewal without a gap between the partnerships will require funding via the CFI 2026 IF competition cycle, which will likely begin formally in 2024. (In turn, the process to develop a Neutron Long-Range Plan should be completed before that competition.) Neutrons Canada should also be ready to operate the neutron beam lab at the MNR within five years of finalization of the CFI 2020 IF award. Thus, Neutrons Canada and McMaster will need to work together to secure the expertise required to operate the lab as a national user facility. This expertise could also be critical to the development of the additional beamlines funded by the CFI 2020 IF award. Further, if the CFI 2023 IF proposal is successful, having such expertise already in place will enable Neutrons Canada to manage the development of the innovative neutron source and instruments that will be located at the University of Windsor.

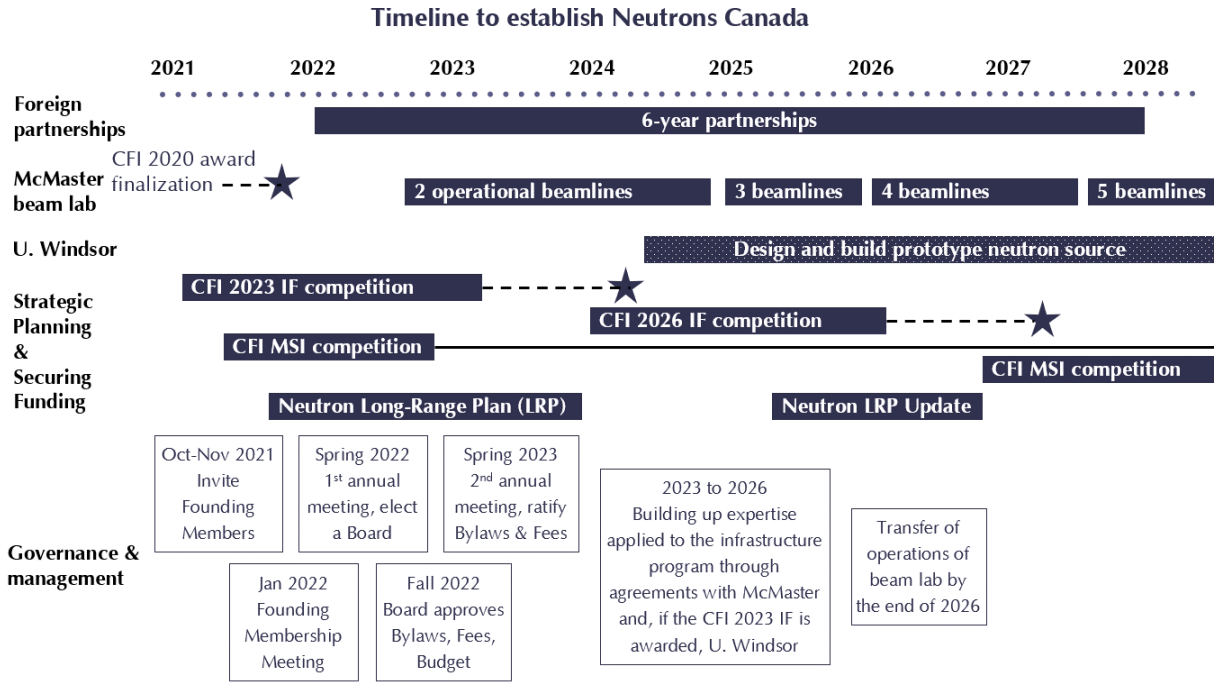


Figure 3. Illustration of major activities of the infrastructure program and steps in establishing Neutrons Canada.

Over the long term, Neutrons Canada should be sustained primarily through government funding sources, as is the case for all other Major Research Facilities in Canada (e.g. those listed in section 2.4.1). However, initial funding for the start-up of Neutrons Canada must come from institutional contributions. An initial membership fee (e.g. $10,000–$15,000 per year, to be established by Neutrons Canada's Board) will be essential to pool resources to meet common objectives. McMaster, as the host of the MNR, will provide significant additional support in-kind, which may be offset via the 5% award for the management and governance of multi-institutional projects associated with the CFI 2020 IF award. In the early years of its establishment, Neutrons Canada will be focused on building its base of scientific and technical expertise that can be applied to the operations and capital projects of the national infrastructure program through cost-recovery agreements with holders of grants, such as the CFI 2020 IF award, or, if successful, a CFI 2023 MSI or a CFI 2023 IF award.

3 Proposed Governance Model

The final governance structure is to be determined by the founding Members and the initial Board of Directors that they elect. This section describes the governance model recommended by the CNI working group.

3.1 Development of the recommended governance model

The recommended governance model has been developed through examination of best practices for Major Research Facilities (MRFs) in Canada and through stakeholder consultation. In 2009, Janet Halliwell was commissioned by federal funding agencies to produce a handbook on the governance and management of MRFs. The resulting publication provides guidance on the various stages in an MRF's lifecycle.[4] The CNI working group has monitored more recent developments at MRFs such as TRIUMF, the New Digital Research Infrastructure Organization (NDRIO), and the facilities funded by the CFI Major Science Initiatives (MSI) Fund (e.g. SNOLAB, the Canadian Light Source, and Canada's National Design Network). The CNI working group's analysis of best practices has also included online research, attendance at CFI MSI workshops on governance and management, attendance at the International Conference on Research Infrastructures, and direct conversations with TRIUMF, SNOLAB, and the National Research Council (which is responsible for TRIUMF and Canada's involvement in astronomy facilities).

The stakeholder consultations have included consultative presentations to university VPs of Research during the CFI 2020 IF competition and at the January 2020 Roundtable on Neutrons Canada;[5] to Canadian neutron beam users (e.g. at the December 2020 Roundtable on a National Neutron Strategy[6] and at the annual meetings of the Canadian Institute for Neutron Scattering since 2016); and to government agencies, notably the Canada Foundation for Innovation, as well as Innovation, Science and Economic Development Canada.

An outcome of the January 2020 Roundtable on Neutrons Canada was that the CNI working group would act as a steering committee for the establishment of Neutrons Canada. It would report back to Canadian university VPs of Research with recommendations on Neutrons Canada's roles, its structure, and the timeline for its establishment.

3.2 Guiding principles

From this examination of best practices for MRFs, coupled with the purpose and context of Neutrons Canada (described in section 2), the following guiding principles for the new organization can be derived:

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[4] Janet Halliwell. 2009. Handbook of Governance and Management of Major Investments in Science and Technology.
[5] Canadian Neutron Initiative. Canadian Leadership in Materials Research with Neutron Beams. (Jan. 2020) https://fedorukcentre.ca/documents/resources/cni/neutrons-canada-roundtable-2020-jan-29---full-report.pdf
[6] Canadian Neutron Initiative. Report on Outcomes of the CNI-CIFAR Roundtable on a National Neutron Strategy. (Dec. 2020) https://fedorukcentre.ca/documents/resources/cni/rountable-report-on-national-neutron-strategy---2021-01-28.pdf

- **National scope and mandate:** The infrastructure program must enable a broad base of Canadian scientists and engineers to conduct their research. Credibility as a national program requires the active participation of many universities and other institutions across Canada.
- **Inclusion of stakeholders:** The neutron beam user community is multidisciplinary, multisectoral, and varied in degrees of expertise in neutron techniques. Input from the full spectrum of voices will be needed.
- **Independence:** A best practice for MRFs is to be independent from host institutions.
- **Scalability:** The governance structure should be scalable and should consider both the short-term and long-term scales described in section 2. The experience of MRFs that have sought to change their governance structure suggests that it is much more difficult to change the structure after the organization is established than it is to set it up for long-term scalability from the beginning. For example, it took several years for TRIUMF to secure approval from its joint venture partners to incorporate. Also, changing Compute Canada into the New Digital Research Infrastructure Organization (NDRIO)—that is, from a federation of local facilities into a unified program with a truly national outlook—has been a major restructuring effort.

3.3 Governance diagram

Figure 4 illustrates the recommended governance model for Neutrons Canada as a not-for-profit corporation. The institutional Members determine the composition of the Board of Directors. The Board oversees the strategic direction of the organization and the acquisition, operations, and allocation of resources. The Board appoints a Director to lead the organization. The Director and highly qualified staff operate the national program, including implementing development projects and facilitating user access to neutron sources in Canada and abroad. Contracts between Neutrons Canada and various neutron sources determine the relationship with each source. Neutrons Canada seeks input from various advisory bodies, including advisory committees and the Canadian Institute for Neutron Scattering (CINS), which represents a significant portion of neutron users in Canada. The roles of each are explored further in the following sections.

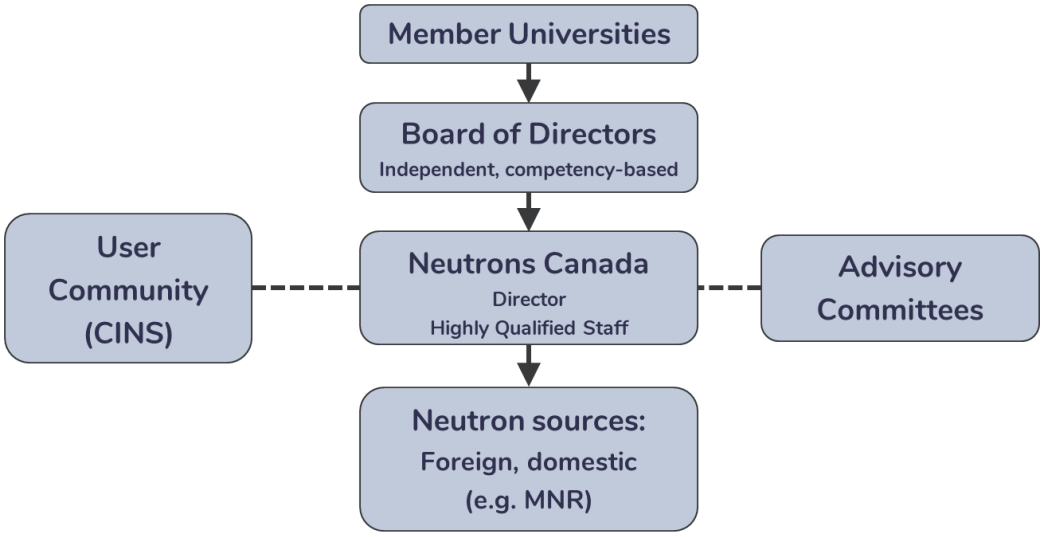

Figure 4. Illustration of the recommended governance model for Neutrons Canada. Line accountabilities are illustrated as solid lines, and advisory or supporting relationships as dashed lines.

3.4 Legal structure

Incorporation as a not-for-profit corporation is recommended as the observed best practice for MRFs in Canada to achieve independence. Identified by Halliwell in 2009, the trend to formalize the separation legally through incorporation has continued to the present, with TRIUMF and NDRIO being recent and notable examples. Most MRFs in Canada have adopted the not-for-profit corporation model. The only notable exception to the trend is SNOLAB, which has been seeking to achieve this status.[7] Incorporation comes with legal requirements for annual membership meetings, a board of directors, record keeping, and audits of financial records—activities that are consistent with the purpose and scope of Neutrons Canada.

3.5 Membership

The Members are intended to be the universities and other research organizations across Canada that conduct research using neutron beams. Presently, 17 universities have demonstrated their interests in such research through their contribution of portions of their CFI institutional envelopes to the CFI 2020 IF award; 6 additional universities have either participated in the CNI working group or its activities, or are considering a contribution of their CFI institutional envelopes to the CFI 2023 IF proposal.

3.6 An independent Board of Directors

In the recommended governance model, the Board of Directors is the principal governing body for Neutrons Canada. The Board will have the authority to appoint, dismiss, define key accountabilities, and evaluate the performance of the Director. In consultation with the Director, the Board will develop and approve the organization's strategy and policies, and will oversee allocation of resources, performance reporting, and risk management.

Board members will be charged with the responsibility to act in the best interests of Neutrons Canada. Board members must **act independently**, not as representatives of Member institutions, host institutions, neutron sources, or any other organization with which they may be affiliated.

As envisioned in the CFI 2020 IF application and as recommended by Halliwell's governance handbook (footnote 4), to further ensure the Board's independence, the Chair of the Board is expected to be independent of institutions that host neutron beam infrastructure managed by Neutrons Canada.

The Board will recruit nominees to reflect a balance of governance competencies, technical knowledge, pan-Canadian and international perspectives, gender, and diversity.

3.7 Director

The Director leads Neutrons Canada and is responsible to develop Neutrons Canada's vision with the Board and then implement it. The Director will be accountable to the Board for the general supervision of the staff and the management of the affairs of the corporation.

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[7] SNOLAB. Implementation plan for 2017-2022. https://www.snolab.ca/wp-content/uploads/2020/10/SNOLAB-Implementation-Plan-.pdf.

3.8 Advisory bodies, including the CINS

The Canadian Institute for Neutron Scattering, or CINS, is a not-for-profit, voluntary organization that represents a significant portion of Canada's neutron users—namely, researchers from universities who frequently use neutron beams for scattering purposes. (Section 3 of the strategy paper, "A National Strategy for Materials Research with Neutron Beams," describes the multidisciplinary, multisectoral community of neutron users, as well as some differences between expert and non-expert users in more detail.) The Director of Neutrons Canada will consult with the leadership of CINS on Neutrons Canada's strategic plans, on policies that directly affect user access to Neutrons Canada programs, and on its user-facing activities.

Neutrons Canada will also require input from other perspectives, and as such will establish one or more advisory committees in the future. For instance, Neutrons Canada may establish user advisory committees comprised of users of the various infrastructure included in its infrastructure program. Members of advisory committees will also function as points of contact with a wider network of experts across Canada and internationally.

3.9 Neutron sources

Neutrons Canada will, in time, operate a neutron beam lab at the McMaster Nuclear Reactor (MNR) as well as other possible domestic facilities that may be created as part of Neutrons Canada's infrastructure program. The MNR itself, and all its other associated infrastructure and programs, will remain the purview of McMaster University. Additionally, Neutrons Canada will forge agreements with foreign neutron labs for access by Canadian researchers and will facilitate Canadian participation at those labs, which could include the deployment of equipment and staff to those facilities to support Canadian user access. Neutrons Canada will negotiate terms of engagement with each neutron source, including the MNR and foreign sources. Neutrons Canada will act as a paying customer, partner, or member of the neutron source, as appropriate.