CANADIAN NEUTRON INITIATIVE

Canadian Leadership

in Materials Research with Neutron Beams

Report on a Roundtable Meeting towards the establishment of "Neutrons Canada"

BrightnESS² is funded by the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 823867
FILL2030 is funded by the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 731096

Table of Contents

1. Executive Summary

On 2020 January 29, VPs of Research or their designates from 16 universities met in Ottawa to discuss a proposed new pan-Canadian, university-led framework to manage Canada's infrastructure, international partnerships, projects, and programs for materials research with neutron beams.

Canada's long-term competitiveness relies on a complete twenty-first century scientific toolkit to develop materials for innovation in priority areas, such as producing and storing clean energy, growing the economy through advanced manufacturing and clean technologies, and promoting health through biomedical and life sciences. Neutron beams are versatile and irreplaceable tools for materials research, and Canadians have been applying them to make major socio-economic impacts in these priority areas for several decades. The impacts range from bolstering Canada's scientific reputation in Nobel Prize-winning science to saving hundreds of millions of dollars by reducing downtimes of Canada's fleet of nuclear power stations. Canada lost access to neutron beams in 2018, when the country's only major neutron source, the NRU reactor in Chalk River, was closed permanently with no plan for replacement.

A university-led working group, the "Canadian Neutron Initiative" (CNI), laid a foundation for strategic planning for the future of materials research with neutron beams in Canada and has gathered support from 23 institutions across Canada.

Its strategy consists of four key elements:

1. Building on existing domestic capabilities, including full exploitation of the McMaster Nuclear Reactor (MNR), a medium-brightness neutron source;
2. Forging partnerships with high-brightness neutron sources in other countries;
3. Exploring investment in new domestic neutron sources for the long term; and
4. Creating a new, national governance and management framework for these activities.

Activities underway in Canada include a $47M project proposal to the CFI-IF program (a start toward elements 1 and 2 of the strategy) and a study of new technology for a possible future neutron source (element 3). Element 4 can be addressed by establishing a pan-Canadian, university-led entity, which could be named "Neutrons Canada", to manage a coherent national program. The program is envisioned to be of the scale of a Major Research Facility (MRF) in operations and impact.

Therefore, “Neutrons Canada” should apply best practices for governance of MRFs in Canada, and incorporate lessons from international experience in managing national and multi-national research infrastructures. Roundtable participants heard from leaders of major European facilities on these matters, as well as from Canada’s Chief Science Advisor, while sharing their own experiences with Canadian MRFs.

The university executive participants formed a consensus around three propositions:

1. Canada should maintain its leadership role in materials research with neutron beams;
2. Canadian universities need to establish a pan-Canadian, university-led framework to govern, manage, and represent Canada’s program for materials research with neutron beams; and
3. Canadian university Vice-Presidents of Research (VPR) should devote their own time and attention to help shape this new framework and to ensure ongoing engagement of their universities as Institutional Members.

The CNI working group will invite additional university executives to join the current group and act as a steering committee for the establishment of Neutrons Canada. The steering committee will engage with other key stakeholders to further develop the national neutron strategy and key messaging. The steering committee will report back periodically to Canadian university VPRs with recommendations on Neutrons Canada’s roles, its structure, the timeline for its establishment, and how it will be resourced.

2. Introduction

Canada's long-term competitiveness relies on a complete twenty-first century scientific toolkit to develop materials for innovation in priority areas. Neutron beams are powerful and versatile tools for materials research, as illustrated in the next section. Canada has been a leader in this field for over 70 years, but Canada lost access to neutron beams in 2018 when the country's only major domestic neutron source, the NRU reactor in Chalk River, was shut down permanently. About 800 researchers were relying on access to neutron beams there, at the time. Canada's only agreement for access to a foreign neutron facility, the Spallation Neutron Source (SNS) in the U.S., also expired that same year.

"The roundtable meeting of university executives from 16 institutions across Canada was an historic moment, topping off five years of work to establish a new, pan-Canadian, university-led framework to govern, manage, and represent Canada's programme and capacity for materials research with neutron beams."

– Dr. Karen Chad, Vice-President of Research, University of Saskatchewan and Chair of the CNI working group

Now, Canadian universities have an opportunity to take over the stewardship of this national capability, which was managed historically by federal agencies. Collective university leadership has already begun through the Canadian Neutron Initiative (CNI) working group. University-led activities are underway to build domestic capacity at the McMaster Nuclear Reactor (MNR), to secure access to leading neutron sources in other countries, and to explore reinvestment options for the long term. The CNI working group serves in a coordinating role, integrating such activities into a cohesive vision. Ultimately, the CNI working group aims to establish a new, pan-Canadian, university-led framework for the stewardship of Canada's capability to conduct research with neutron beams.

On January 29, 2020, the CNI working group convened a Roundtable Meeting with Vice-Presidents of Research and Associate Vice-Presidents from 16 universities across Canada. The group met in Ottawa to discuss action on an essential feature of the new framework: whether and how to establish a new, pan-Canadian, university-led organization, "Neutrons Canada." The executive participants heard input from Canada's Chief Science Advisor, from leaders of European neutron facilities, and from CNI working group members. The meeting was facilitated by Janet Halliwell, a former executive of science funding agencies responsible for large-scale science projects.

The Roundtable Meeting was organized by the CNI working group and supported through a partnership with the European Spallation Source (ESS) via its project BrightnESS[2]. BrightnESS[2] is funded by the European Union Framework Programme for Research and Innovation, Horizon 2020, to support the long-term sustainability of the ESS, its community, and the network of neutron sources in Europe. One of its objectives is to explore collaboration opportunities between the ESS and countries both within and outside Europe.

3. Materials Research
Underpins Canada's Priorities

3.1 A CLEAN ENVIRONMENT

About 85% of greenhouse gas emissions in Canada result from energy production and related activities.[1] Materials research using neutron beams enables more reliable emissions-free base-load electricity generation.

A few examples:

- **With 15% of Canada's electricity generated by nuclear power, innovations to maintain the safety and reliability of this emissions-free base-load source are essential. Neutron stress-scanning was applied to examine cracking in key components that caused the 1997 and 2001 Point Lepreau Nuclear Generating Station shutdowns, which together cost over $50M.** The results provided assurance to the regulator that the station could be restarted, thus avoiding further losses. Subsequent neutron beam research aided Canada's fleet of reactors to reduce downtime associated with the cracking issue over the next 20 years. The value of the avoided losses in electricity production from this research was in the hundreds of millions of dollars—a figure exceeding all of Canada's direct investments in neutron beam capabilities since the 1940s.

  http://bit.ly/34su3Gx

- **Hydro-Québec has used neutron stress-scanning data in research to improve the reliability of turbine runners, which are key components in hydroelectric dams. Turbine runners can cost up to $10M each, and losses in electricity production if one fails can be very costly.** Hydro-Québec has used the stress-scanning results to show that optimization of manufacturing processes like welding and heat treatment can improve the lifetime of turbines, often without any increase in the manufacturing cost.

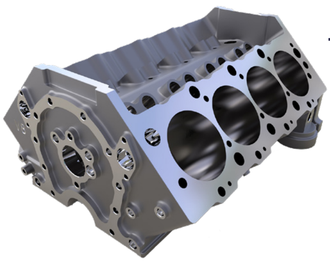
  http://cins.ca/2015/07/01/hydro

Neutron beams were critical to explain, and prevent downtime from, cracking issues at Canada's fleet of nuclear power reactors.

[1] CAIT Climate Data Explorer. 2015. Washington, DC: World Resources Institute. Accessed from Environment Canada. The Science of Climate Change. Annex 2. Nov. 23, 2015. https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/science.html.

3.2 ECONOMIC COMPETITIVENESS AND CLEAN GROWTH

Materials research with neutron beams enables innovation in the advanced manufacturing of energy-efficient, lightweight planes, ships, and cars.



Neutron beams were critical to ensuring reliability of car engine parts manufactured using innovative methods.

A few examples:

- **Nemak Canada evaluated the effectiveness of less resource-intensive heat treatment processes on aluminum alloy engine blocks to ensure that these processes would not compromise reliability.** The results are saving the Nemak plant in Windsor, Ontario, $2M–$3M every year.

- **Canadian aerospace leaders Bombardier and Standard Aero gained knowledge needed to reduce scrap waste and advance methods to make and repair engines (1), while Rolls-Royce recently patented a new alloy that it aims to use in higher-efficiency jet engines (2).**

  (1) http://cins.ca/tag/aero+impact
  (2) http://cins.ca/2017/01/10/aero-3

- **In 2013, Ivaco Rolling Mills invested $80M to expand its plant in Eastern Ontario.** The company attributed part of its recent success to neutron stress-scanning research that enabled the company to add value to its steel rod products.

  http://cins.ca/2013/09/01/metal

3.3 SAFETY AND SECURITY

Materials research with neutron beams enhances the safety of pipelines and rails, and helps to determine the fitness-for-service of naval ships.

A few examples:

- **The Canadian pipeline industry has improved its practices to ensure acceptable stress levels, avoid cracking, and predict pipeline lifetimes, based on neutron-beam analyses of stress.**

  http://cins.ca/2017/09/27/pipeline

- **Examination of railroad tracks associated with the 2005 train derailment, which spilled over 800,000 L of oil into Lake Wabamun in Alberta, produced data that informed the 2011 updates to Transport Canada's "Track Safety Rules" regarding the minimum frequency of ultrasonic rail testing.**

  http://cins.ca/2014/07/01/rail

- **Defence Research and Development Canada (DRDC) has qualified a new method for joining metals to repair Canadian naval vessels.** Canada's allies are now advancing this method further to join aluminum components in the construction of high-speed, lightweight ships (1). DRDC has also gained knowledge to safely extend the lifetimes of Canadian ships, thereby saving resources for other security needs. It has also leveraged these findings to gain close working relationships with Canada's allies on projects to manage corrosion and other aging concerns common to many Western navies (2).

  (1) http://cins.ca/2013/03/01/defence-5
  (2) http://cins.ca/2014/11/01/defence
  http://cins.ca/2014/05/01/defence-2

Neutron beams were critical to explain cracking issues in Canada's aging pipelines and develop industry standard practices to ensure reliability.

Neutron beams have been applied by researchers at the University of Saskatchewan to advance global food security.

3.4 HEALTH AND FOOD SECURITY

Materials research with neutron beams assists with designing better medical devices and disease treatments, as well as in developing resilient crops for global food security.

A few examples:

- Econous Systems Inc. is using new coating technology for medical devices to develop medical tests for the early detection of ovarian cancer, which is essential for surviving this disease.

  http://cins.ca/2016/10/26/bio-4

- Life scientists are applying knowledge from neutron-beam tests to pre-clinical trials of cancer treatments based on cancer-killing nanoparticles.

  http://cins.ca/2017/10/26/cancer

- The Global Institute for Food Security at the University of Saskatchewan has recently developed neutron imaging as a method to accelerate the development of crops, such as by matching genetic variation to observable traits that enhance drought resistance.

  http://cins.ca/2017/05/04/agriculture

4. Canadian Context and Vision for Neutrons Canada

4.1 STATUS OF NEUTRON BEAMS IN CANADA

Canada pioneered the development of neutron beams as a tool for materials research at the Chalk River Laboratories in the 1950s and 1960s. Beginning in the 1980s, it also led the world in developing applications of neutron diffraction for industry. Since then, many neutron beam techniques have matured, and the Canadian Neutron Beam Centre (CNBC) supported a user community that grew to about 800 research participants distributed across Canada and around the world. Canada also made a valued contribution to developing leading-edge neutron instruments at the Spallation Neutron Source in the U.S., which has enabled Canadian researchers to remain at the forefront of neutron spectroscopy. Canada's international stature as a global leader in conducting materials research with neutron beams has remained strong, such that several leading international neutron facilities have reached out to Canada to offer partnership opportunities since the 2015 announcement of the closure of the NRU reactor, the neutron source for the CNBC.

In the years leading up to the closure of the CNBC, the governance and management framework fell apart due to mission and program changes at the three following federal agencies responsible for various aspects of Canada's neutron beam capability: (1) The National Research Council, which owned and operated the CNBC; (2) Atomic Energy of Canada Ltd., which owned and operated the NRU reactor; and (3) the Natural Sciences and Engineering Research Council (NSERC), which supported university access to the CNBC. After the decision to permanently shut down the NRU reactor, none of these agencies retained any mandate or mechanism to provide neutron beam infrastructure for the future. Canada's neutron beam users, organized via the Canadian Institute for Neutron Scattering (CINS), appealed to university executives for help.

Seizing the opportunity for leadership in materials research with neutron beams, executives from the University of Saskatchewan, McMaster University, the Canadian Nuclear Association, and CINS formed the CNI working group in 2016, and were joined by the University of Windsor in 2019. The working group has been a forum for strategy development and action on activities toward rebuilding Canada's future for materials research with neutron beams. It has gathered support from 23 Canadian institutions, and its funding request for a new national framework for this research area was endorsed by the House of Commons Finance Committee in 2017 and 2018.[2]

[2] See House of Commons Finance Committee reports on its consultations for the 2018 and 2019 budgets available at: http://cins.ca/docs/HC_FINA_report_2017_12.pdf and http://cins.ca/docs/FINA_2018.pdf

4.2 A NATIONAL NEUTRON STRATEGY

Consultation with stakeholders to date has identified the following four elements as being essential for a national neutron strategy:

1. Build on existing domestic capabilities, including full exploitation of the McMaster Nuclear Reactor, a medium-brightness neutron source;
2. Forge partnerships with high-brightness neutron sources in other countries;
3. Explore and invest in developing new neutron sources for the long term; and
4. Create a new, national governance and management framework for these activities.

A critical priority is to restore some access to neutron beams for Canadian researchers as soon as possible through elements 1 and 2 of a national strategy. For this purpose, McMaster University led a proposal to the Canada Foundation for Innovation (CFI) 2020 Innovation Fund competition for a $47M infrastructure project with domestic and foreign components and 17 universities have contributed portions of their CFI grant request quotas to this proposal. The project would be a major step forward, but a full-scale national program (excluding reinvestment in neutron sources) is expected to cost $20M per year to operate, which is more than can be sustained through existing science funding programs.

Countries around the world are reinvesting in neutron sources because the supply of neutron beams is shrinking as older sources retire. Canada will have to reinvest as well in order to continue as a participant in this field over the long term (element 3 of a national strategy). Options include major contributions to new multi-national sources (e.g. to the ESS or to the second target station at the SNS) or to a new domestic facility, which could range from a $500M dedicated neutron beam reactor to $1–$2B for a multipurpose research reactor or a spallation source. A further option might be a Compact Accelerator-based Neutron Source (CANS), a concept technology that is proposed for lower-cost medium-brightness neutron sources, potentially making a new source for much of Canada's needs achievable for $100M. The University of Windsor is leading a feasibility study for a prototype CANS.

Achieving a cohesive national strategy requires a dedicated organization (element 4 of a national strategy). Neutrons Canada is thus envisioned as a new entity that can manage the above activities as a coherent program, play a unifying role for the neutron beam community, and be a credible and trusted institutional voice. The scale of the investments required and the complexity of the needed infrastructure would qualify the program as a Major Research Facility (MRF), as defined in Canada's Fundamental Science Review.[3] Canada's MRFs include TRIUMF, Compute Canada, Ocean Networks Canada, the Canadian Light Source, and others.

[2] Naylor et al. "Investing in Canada's Future: Strengthening the Foundations of Canadian Research." April 10, 2017. http://www.sciencereview.ca/eic/site/059.nsf/eng/home

> **"We were very grateful to be joined by experts from ESS and the ILL to help our university leaders envision a future where a new organization, such as the proposed Neutrons Canada, could partner with world-class neutron beam facilities and enable Canadians to continue contributing to the leading edge of materials research with neutron beams."**
>
> **– Dr. John Root, Executive Director of the Fedoruk Centre**

4.3 PROPOSED GOVERNANCE STRUCTURE FOR NEUTRONS CANADA

Neutrons Canada should be positioned as managing an MRF-scale program within the funding jurisdiction of Innovation, Science and Economic Development Canada (ISED) and its portfolio of agencies (e.g. the CFI). As such, it should adopt emerging best practices for governance and management for MRFs. The CNI working group envisions Neutrons Canada to be a university-led entity whose Members are organizations (primarily universities) with an interest in neutron beams. Members will elect an independent Board of Directors on the basis of governance competencies, technical knowledge, and principles of equity, diversity and inclusion. Members of the Board of Directors will not represent interests of neutron sources or host institutions. The Board will appoint an Executive Director ("Director"), who will lead the organization.

The Director's highly qualified staff will manage the national program, including implementing development projects and facilitating user access to neutron sources in Canada and abroad. This program may include the direct operation of domestic facilities (e.g. a neutron beam lab at the McMaster Nuclear Reactor). Neutrons Canada will act as a paying customer of the neutron sources and will negotiate terms of engagement with each source, which could include deployment of employees to support user access to the facilities. CINS will represent the user community, providing advice to the Director, and will coordinate with Neutrons Canada on strategic planning and funding applications. Other advisory committees may extend the expertise of Neutrons Canada as needed, and may contain, for example, experts from industry, other MRFs, or the international neutron community.

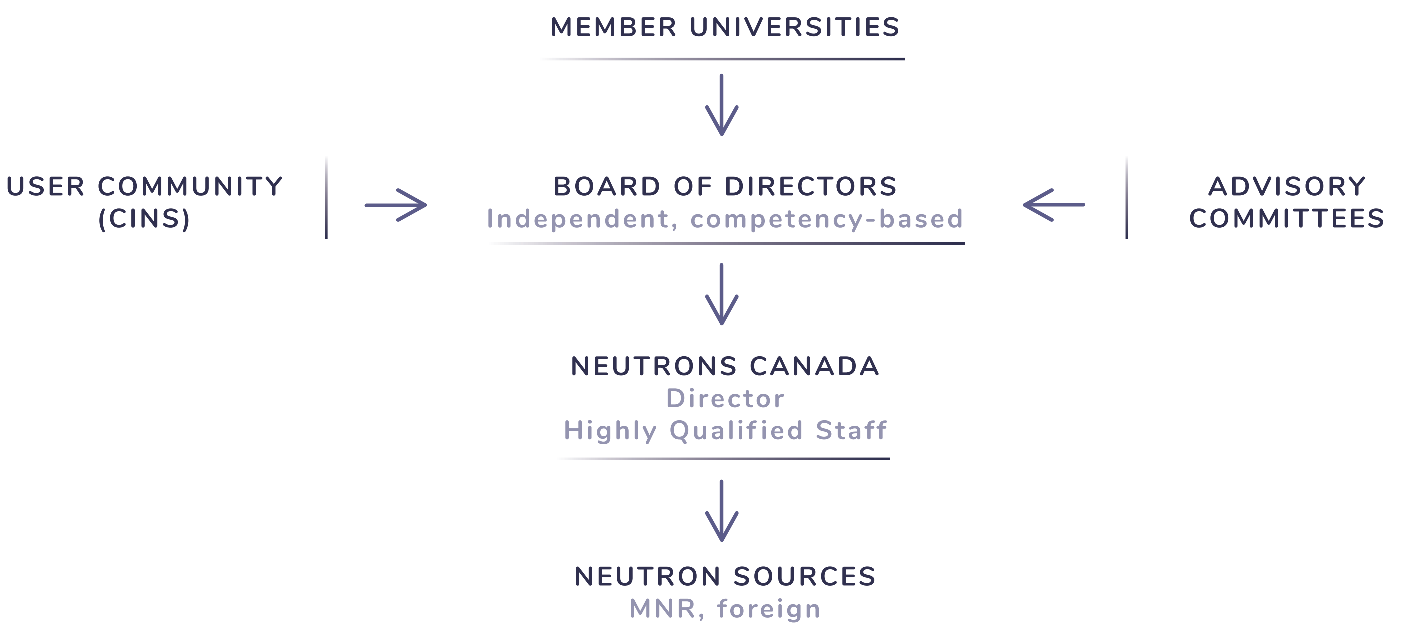
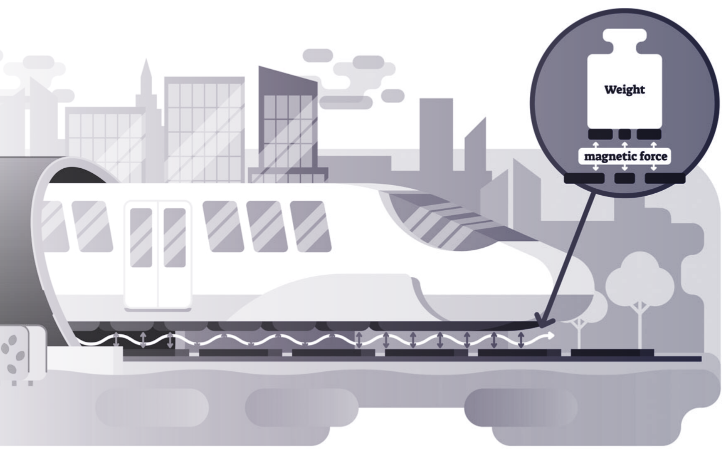


Figure 1. The proposed governance structure for Neutrons Canada.

5. Input and Discussion

5.1 MANAGEMENT OF NEUTRON SOURCES AS RESEARCH INFRASTRUCTURES IN EUROPE

Participants considered European experiences in managing national and multi-national research infrastructures and in roadmapping exercises for such infrastructures, as presented by leaders of the two largest neutron beam facilities in Europe: John Womersley and Andreas Schreyer of the ESS, and Helmut Schober of the Institut Laue-Langevin (ILL). John Womersley is a former Chair of the European Strategy Forum on Research Infrastructures (ESFRI), and Helmut Schober is the current Chair of the League of advanced European Neutron Sources (LENS).



These presentations also served to indicate ways in which Canada could participate in multi-national science facilities. For instance, an organization such as Neutrons Canada could be an agent that secures for Canadians a portion of a multi-national facility's neutron beam time by acting as the Canadian partner in that facility's operations.

European neutron sources are making impacts in health, transportation and clean technology through scientific excellence.

Neutron sources in Europe are accessed by a community of 6,000 users for a variety of research and innovation programs. Recent examples of areas where excellent science and impacts have been enabled by European neutron sources include: observing water motion in fuel cells for electric vehicles; understanding superconductivity for levitation of high-speed trains; identifying active sites in proteins for use as pharmaceuticals; improving medication for fighting HIV; understanding molecular mechanisms of neurodegenerative diseases; improving battery lifetimes for storage of renewable energy; improving thermoelectric generators for energy conservation; and laying foundations for quantum computing.

5.1.1 INSTITUT LAUE-LANGEVIN (ILL)

The ILL in France is an example of a world-leading multi-national neutron source, in which Canada could participate immediately to gain access to neutron beams and know-how in neutron science and technology. The ILL's strategy to attract and enable excellence in science includes: performing rigorous peer review of users' proposals; operating a neutron source with maximum neutron brightness and reliability; continually renewing the neutron beam instruments to be best-in-class (with 5% of its annual budget reserved for this purpose); and providing holistic support for user experiments, including expertise, sample environments, labs, and data analysis.

The ILL is accessed by about 1,400 users each year and must continually adapt to user needs. A client-service orientation is essential to its business model. The ILL is mainly dedicated to neutron beams (it enables some irradiation for medical isotope production). It employs about 500 highly qualified staff to operate the reactor (approximately €2B in replacement value), along with over 40 instruments, 2 cold sources, and 1 hot source. A science campus of complementary capabilities has grown up around the neutron source; this campus includes the European Synchrotron Radiation Facility, which has been recently upgraded to become the world's first fourth-generation synchrotron.

The ILL operates with 14 member countries funding its annual budget of about €95M. Currently, two-thirds of the users who propose a project must be from member countries for the proposal to be considered in the competitions for beam time. Membership provides the opportunity for guidance from the ILL's scientists on developing a proposal. It also provides access to support labs (e.g. for sample preparation), and allows participation in the scientific activities and governance of the facility, in its PhD program, and in the design and construction of instruments. Membership also enables a country's companies to bid on tenders and share in the technology developed. For Canada, an appropriate membership share might be 1–3%, at a cost of about €1M–€3M per year.

5.1.2 EUROPEAN SPALLATION SOURCE (ESS)

The ESS is a major neutron facility under construction in Sweden. Ahead of scientific operations which are scheduled to begin in 2023, Canadian participation would allow an exchange of scientific knowledge in the development of neutron beam instrumentation and accelerator technology. Further, Canadian companies could gain opportunities to supply the construction project. The construction cost is C$2.7B and is funded by 13 member countries. The ESS will achieve an order of magnitude improvement over existing facilities by the more efficient generation and use of neutrons and be the brightest neutron source in the world. The ESS will have 15 instruments to begin with, with plans to add 7 more. There is opportunity for Canada to join as a member and help select the instruments, as well as help develop the instruments and the neutron source itself (e.g. the accelerator and target). When operational, the ESS will be a user facility like the ILL, providing users with tools and support, while users will bring the projects and conduct the experiments. Membership would provide access to all the instruments for experiments.

5.1.3 EUROPEAN ROAD-MAPPING FOR NEUTRON FACILITIES

Canada is not the only country to have lost a neutron source recently, and it can learn from the strategic planning processes of European neutron sources. The European neutron beam community is facing increased neutron scarcity, even as demand for neutrons remains strong. In 2019, three national research reactors shut down: the BER-II at the Helmholtz-Zentrum Berlin (Germany); the Orphée reactor at the Laboratoire Léon Brillouin (France); and the JEEP II reactor (Norway). The Orphée reactor's operator, the CEA, aims to preserve its core of expertise by evolving its mission to become a "virtual lab" that relies on accessing neutrons elsewhere (similar to the existing Jülich Centre for Neutron Scattering in Germany). Several of the nine remaining neutron sources in Europe are also approaching the end of their lifecycles, and even the ESS will not replace all the capacity that is likely to be lost by 2030. Roadmapping for neutron facilities in Europe is thus a major ongoing activity, and European nations will need to reinvest in further new neutron sources just to sustain the supply of neutrons in balance with demands. In such a climate of increasing pressure on neutron facilities, Canada cannot expect to participate for long in European facilities without making a financial contribution.

Europe spends about €500M annually on building and operating neutron facilities. The formation of LENS in 2018 was intended to strengthen cooperation between the remaining facilities and avoid duplication of efforts. LENS's objectives include developing common strategies and coordinated interactions with common stakeholders; optimizing use of resources across Europe's portfolio of neutron facilities; and providing a joint platform for representing the facilities and promoting the impact of research using neutron beams. LENS has also formed working groups to address specific topics regarding facility operations, as well as one to address planning for future neutron sources.

One strategy that Europe is considering for future neutron sources is the development of Compact Accelerator-based Neutron Sources (CANS) as an alternative to building new medium-brightness reactor sources for the purpose of addressing the growing scarcity of neutron beams. The feasibility of CANS technology for this purpose is currently being explored, and LENS is developing a position paper on how such technology could fit into a European roadmap for neutron sources.

5.1.4 EUROPEAN ROAD-MAPPING FOR ALL RESEARCH INFRASTRUCTURES

European experience with a variety of research infrastructures can serve as a model for a Canadian approach to road-mapping that includes prioritization of investments from all disciplines. The establishment of the European Strategy Forum on Research Infrastructures (ESFRI) in 2002 has enabled progress toward European-wide management of large-scale pan-European research infrastructures. One goal of ESFRI is to achieve a coherent and strategy-led approach to policy-making for research infrastructures of pan-European relevance. To do this, it supports prioritization of pan-European research infrastructures, assists in developing new initiatives and coordinates the integration of national institutes into European infrastructure (e.g. infrastructures for data). ESFRI does not fund any facilities. The EU may fund the development phase of a proposed infrastructure project for two to three years, but then funding has to come from national governments. The EU does not fund ESFRI, nor its road-mapping activities. Rather, ESFRI's member countries pay for its activities to ensure there is no duplication in their investments. Thus, road-mapping and funding are separated.

ESFRI divides its roadmap into six research areas: Energy, Environment, Health & Food, Digital, Physical Sciences & Engineering (which includes neutron beam facilities), and Social & Cultural Innovation. This allows for division of planning processes along lines of scientific communities. Research-area plans are then rolled into the full ESFRI roadmap. All roadmap projects are monitored for progress toward implementation and are measured against minimum requirements, which provides evidence for decisions about whether they should remain in the roadmap. Existing facilities are reviewed periodically against generic performance indicators.

"Roadmapping of Major Research Facilities is needed more now than ever, because the way science is done has changed; many more scientists from a wide variety of disciplines now rely on these facilities."

– Mona Nemer, Chief Science Advisor for Canada

5.2 MAJOR RESEARCH FACILITIES IN CANADA

The executive participants heard both Dr. Mona Nemer, Chief Science Advisor for Canada, and Janet Halliwell speak of their experiences regarding stewardship of Canadian investments in MRFs. Many participants shared their own experiences with MRFs as well. Early in Dr. Nemer's mandate, she was charged with providing advice to the federal government to address the challenges related to the stewardship of MRFs. The advice has been provided, and the matter is in the hands of ISED at this time.

Canada's model for the stewardship of large research infrastructures, or MRFs, has been evolving. It is often ad hoc and has been increasingly operated by entities outside government. The National Research Council and the Canadian Space Agency have long-standing federal mandates for managing Canada's involvement in international ground-based telescopes (e.g. the Canada–France–Hawaii Telescope) and space-based telescopes (e.g. the James Webb Space Telescope), respectively. Beginning in the 1960s, some new MRFs in other fields have been owned and operated by consortia of universities and funded by governments (e.g. TRIUMF). Since the CFI was created in 1997, more facilities have been created that are funded by multiple sources and owned by a single university on behalf of a larger research community (e.g. the Canadian Light Source, Ocean Networks Canada, SNOLAB). Over the last decade, the CFI's Major Science Initiatives Fund has driven continuous improvement in MRF governance, and as a result, new MRFs are typically not-for-profit corporations owned by multiple member institutions (e.g. the New Digital Research Infrastructure Organization [NDRIO]), and some older MRFs are transitioning, or have transitioned, to this model as well (e.g. SNOLAB).

Today, there remain serious challenges in the stewardship of MRFs in Canada—notably, the need for road-mapping Canada's needs for MRFs so as to inform orderly decision making about lifecycles as well as choices between options for new MRFs.

Road-mapping and orderly business-case development can assist government decision making on policy questions such as:

- Which MRFs does Canada need to build itself, and to which foreign MRFs does Canada need access? What capacity issues or strategic issues will inform these decisions? In what areas should Canada lead, as opposed to participate?
- What are the lifecycle costs of Canada's existing facilities? What costs are fixed, and what costs are more variable? What is the appropriate contribution of federal and provincial sources?
- How can the federal government decide between investments in facilities requested by one research community over another?
- How can Canada coherently manage its portfolio of investments in MRFs, including ensuring best practices for governance and management?

The executive participants at the Roundtable recognized that Canada needs a way to bring the various research communities together for road-mapping exercises. They further recognized that Canada needs an overarching body for prioritizing the major investments in these roadmaps to create a national roadmap (Canada's Fundamental Science Review recommended such a body). The completed roadmap will then help everyone to know what areas are the highest-priority investments in MRFs, so that the science community will provide consistent advice, regardless of whom the government consults.

The executive participants identified the following positive developments regarding MRFs in Canada in recent years:

- Canada's Fundamental Science Review identified the challenges and suggested some solutions.
- The CFI has signalled a willingness to accept a broader mandate for MRFs, and has increased its funding through its MSI Fund for several MRFs from 40% to 60%.
- The CFI will receive predictable annual funding beginning in 2023, which could make it more feasible for the CFI to fund memberships in foreign facilities as well as the operating costs of Canadian MRFs.
- The Canada Research Coordinating Committee, which was recently created by the federal government, takes a whole-of-science view and therefore could play a role in national road-mapping exercises, perhaps by providing small investments towards coordinating the various research communities that rely on MRFs.
- Canada can benefit from other countries that have road-mapped similar MRFs; they can assist Canada in identifying user groups to ensure that all potential MRF users are at the table.

Participants agreed to separate the discussion between (1) the bigger picture of MRFs in Canada, and (2) what can be done now to make progress towards Neutrons Canada specifically.

5.3 TOWARDS NEUTRONS CANADA

Substantial discussion was framed around confirming the rationale for a pan-Canadian entity, "Neutrons Canada," that would govern, facilitate, and coordinate Canada's research infrastructure, international partnerships, and major programs for materials research with neutron beams. This discussion explored the necessary characteristics of a new, university-led, pan-Canadian organization and what its responsibilities may include.

The executive participants reflected on comparable examples of such national bodies where institutions are the Members:

- The Association of Canadian Universities for Research in Astronomy (ACURA) acts as an umbrella organization for the academic community and provides an institutional voice. It assists in coordinating long-term planning and plays a role as an international intermediary by signing agreements on behalf of the Canadian astronomy community.
- The Institute for Particle Physics (IPP) determines how NSERC funding is distributed to its Members. Although the funding flows through universities, funding for the indirect costs of research goes back to the IPP to support its governance and management activities.
- TRIUMF, Canada's particle accelerator centre, is a joint venture of institutions that was created for the purpose of operating this infrastructure on behalf of its Members.
- The New Digital Research Infrastructure Organization is designed to implement Canada's $500M digital research infrastructure strategy. It is currently being set up with institutional membership and a fee structure.

Participants identified key advantages of a national, institution-level membership structure in an MRF:

- A national organization helps the community coordinate planning activities and maintain coherent messaging.
- A national organization provides the institutional credibility required to sign international agreements (e.g. for memberships in foreign facilities).
- An institutional structure enables university leaders (i.e. at the VPR-level) to coordinate their efforts on strategic decisions.
- An institutional entity can provide authoritative input to government decision-making.
- An institutional entity can receive funding to conduct MRF governance activities and alleviate resource demands on individual universities to perform such functions.

The executive participants also identified some challenges with an institution-level membership structure in an MRF—namely, the fact that retaining the attention of university executives on overseeing the MRF can be difficult. Participants suggested that delegation of institutional representation must not be allowed to descend as far as individual users, because then it becomes hard to separate institutional and researcher viewpoints. Participants were further concerned that such delegation could create a communication gap that results in executives not being as well informed about the issues as they could be and are therefore unable to communicate consistent messaging when discussing the MRF with government.

"Canada has an excellent neutron beam user community. Despite the loss of the Canadian Neutron Beam Centre, Canada can continue its excellence in this field, if there is a focused effort and an organization that can do the strategic work needed to regain access to neutron beam infrastructure."

– Helmut Schober, Director, Institut Laue-Langevin

Participants contributed ideas to retain the engagement of institutional executives through policy (e.g. requirements for the qualification of institutional representatives in the bylaws) or through the set of issues on which they are requested to advise (e.g. long-range planning, international agreements, management of assets).

Executive participants also identified the following roles and responsibilities for Neutrons Canada:

- To serve as a body that coordinates the neutron beam community in planning, communicating, and shepherding major neutron initiatives through the decision-making process.

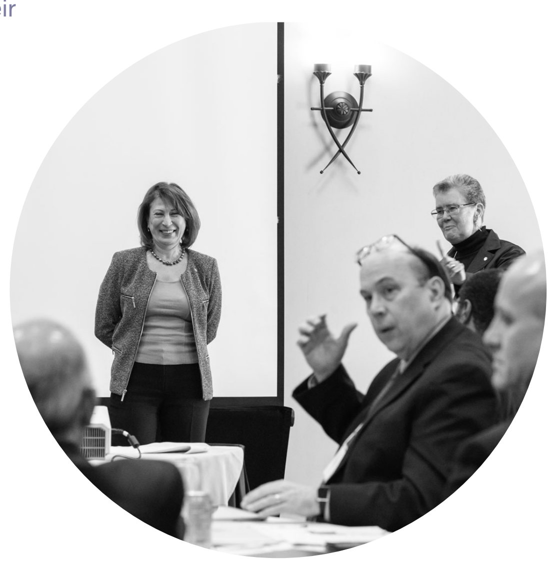
- To serve as a body that delivers the major neutron initiatives of member institutions.
- To provide stewardship, including governance and management of resources, for a national program for user access to neutron beam facilities, both domestic and foreign.
- To act as an umbrella organization for the highly qualified staff required to deliver a concerted national neutron program, channeling Canadian talents and leadership in national and international activities.
- To operate neutron beam facilities, particularly domestic ones.
- To negotiate and provide oversight for international partnerships.
- To serve as a credible institutional voice regarding neutron beam infrastructure (i.e. a voice that is distinct from advocacy groups).
- To network with other MRFs towards a coherent national governance framework for all Canadian MRFs.

6. Consensus and Path Forward

The university executive participants formed a consensus around three propositions:

1. Canada should maintain its leadership role in materials research with neutron beams;
2. Canadian universities need to establish a pan-Canadian, university-led framework to govern, manage, and represent Canada's program for materials research with neutron beams; and
3. Canadian university Vice-Presidents of Research should devote their own time and attention to help shape this new framework and to ensure ongoing engagement of their universities as Institutional Members.

The CNI working group will invite additional university executives to join the current group and act as a steering committee for the establishment of Neutrons Canada. The steering committee will engage with other key stakeholders to further develop the national neutron strategy and key messaging. The steering committee will report back periodically to Canadian university VPRs with recommendations on Neutrons Canada's roles, its structure, the timeline for its establishment, and how it will be resourced.



7. Appendices

7.1 MORE INFORMATION

For more information about the materials research using neutron beams and the Canadian context of this research area, see the following links:

- Scientific, Social and Economic Impacts of Canadian Materials Research with Neutron Beams
- Canadian Neutron Initiative
- Canadian Finance Committee endorses Canadian Neutron Initiative for second time – 2018
- Canadian Governor General meets King of Sweden at European Spallation Source – 2017
- Canadian scientific delegation visits the European Spallation Source – 2017
- Chief Science Advisor to Canada visits Institut Laue-Langevin in Grenoble – 2018

For more information about Canada's stewardship of Major Research Facilities, see the following links:

- Canada's Fundamental Science Review – 2017
- CFI Discussion Paper on the Future of Research Infrastructure in Canada

For more information about the global context of neutron beams, see the following links:

- Neutron Sources around the World (Listing by NIST)
- American Physical Society Report 'Neutrons for the Nation'
- Neutron scattering facilities in Europe: Present status and future perspectives
- League of European Neutron Sources in the context of Horizon Europe

7.2 CNI WORKING GROUP AS OF JANUARY 2020

Working group executive leaders:

- Karen Chad (Chair), University of Saskatchewan, Vice-President of Research
- Karen Mossman, McMaster University, Acting Vice-President of Research
- Michael Siu, University of Windsor, Vice-President of Research
- Thad Harroun, Canadian Institute for Neutron Scattering, President

Supporting institutions:

1. Brock University
2. Canadian Institute for Neutron Scattering
3. Canadian Light Source
4. Canadian Nuclear Association
5. Dalhousie University
6. McGill University
7. McMaster University
8. Memorial University of Newfoundland
9. Nemak Canada Corp.
10. Queen's University
11. Simon Fraser University
12. Sylvia Fedoruk Canadian Centre for Nuclear Innovation
13. University of Alberta
14. University of British Columbia
15. University of Calgary
16. University of Guelph
17. Université de Montréal
18. Université du Québec à Trois-Rivières
19. University of Toronto
20. University of Saskatchewan
21. University of Windsor
22. University of Winnipeg
23. Western University

7.3 NEUTRONS CANADA ROUNDTABLE ATTENDEE LIST

Tim Kenyon	VP Research	Brock University
Thad Harroun	President	Canadian Institute for Neutron Scattering (CINS)
Graham Gagnon	Associate VP Research	Dalhousie University
John Womersley	Director General	European Spallation Source (ESS)
Andreas Schreyer	Director for Science	European Spallation Source (ESS)
Sharon Cosgrove	Associate Director for Strategy	European Spallation Source (ESS)
Mona Nemer	Chief Science Advisor, Canada	Innovation, Science and Economic Development Canada (ISED)
Joshua Bowie	Senior Policy Advisor	Innovation, Science and Economic Development Canada (ISED)
Helmut Schober	Director	Institut Laue-Langevin (ILL)
Martin Walter	Senior Advisor	Institut Laue-Langevin (ILL)
Janet Halliwell	Principal, JE Halliwell Associates	JE Halliwell Associates Inc.
Jean Saint-Vil	Special Advisor to the Vice-Principal (Govt and International Relations)	McGill University
Karen Mossman	Acting VP Research	McMaster University
Chris Heysel	Director for Nuclear Operations	McMaster University
Neil Bose	VP Research	Memorial University of Newfoundland (MUN)
Dugan O’Neil	Associate VP Research	Simon Fraser University
John Root	Executive Director	Sylvia Fedoruk Canadian Centre for Nuclear Innovation
Niki Schrie	HR & Operations Manager	Sylvia Fedoruk Canadian Centre for Nuclear Innovation
Daniel Banks	Consultant	TVB Associates Inc.
Matthias Ruth	VP Research	University of Alberta
Helen Burt	Associate VP Research	University of British Columbia
Robert Thompson	Associate VP Research	University of Calgary
Malcolm Campbell	VP Research	University of Guelph
Richard Leonelli	Chair, Physics Department	University of Montreal
Nick Jones	Associate VP Research	University of Regina
Karen Chad	VP Research	University of Saskatchewan
Vivek Goel	VP Research	University of Toronto
Kevin Shoemaker	Associate VP Research (Acting)	Western University
Drew Marquardt	Assistant Professor	University of Windsor
Michael Siu	VP Research	University of Windsor
Jino Distasio	VP Research	University of Winnipeg