Ad hoc Committee on Options for Neutron Sources in Canada

Report to the CINS membership
June 2015

1. Introduction

The *ad hoc* Committee on Options for Neutron Sources in Canada[1] was formed at the 2014 AGM following an extensive discussion on future neutron sources for Canada. The discussion was supported by an overview of options prepared for the membership.[2] The Committee's mandate was to explore the cost and benefits of the identified options, and report back in the new year, with recommendations that may affect the next edition of the long range plan.[3]

This report contains information obtained from publically accessible websites, and from communications with employees of Canadian Nuclear Laboratories (CNL, the organization that now operates Chalk River Labs), McMaster University, TRIUMF, the Canadian Light Source, KAERI (South Korea), and INVAP (Argentina).

The most significant development for CINS since the 2014 AGM is the announcement by the Government of Canada to permanently shut down the NRU Reactor in March 2018.[4] The Committee thus felt it necessary to present their recommendations in the form of an action plan. The plan is subdivided into two periods: now to 2018, and the long range plan beyond 2018.

We hereby invite feedback from the general membership on the action plan. Your views can be communicated to the Committee via the CINS Science Council by email to council@cins.ca.

2. Possible Neutron Sources for Canada

The Committee found all options discussed at the 2014 AGM are feasible, though some are more practical or desirable.

2.1 A multi-purpose research reactor at Chalk River

In response to the announcement of the 2018 NRU shutdown, CNL is conducting an assessment of the business case for a new neutron source. If CNL pursues a new neutron source it would likely be a multi-purpose research reactor because of its interests in in-core irradiation of fuels and materials as services to industry. However, the planning is at a very preliminary stage and

[1] The committee is composed of a chair and the members of the science council: Zin Tun (chair, Canadian Neutron Beam Centre), Chris Wiebe (U. Winnipeg), Jamie Noel (Western U.), Maikel Rheinstadter (McMaster U.), Zahra Yamani (Canadian Neutron Beam Centre), and Harlyn Silverstein (U. Manitoba).
[2] Zin Tun. Possible Neutron Sources for Canada beyond NRU Reactor: A Review prepared for Discussion at CINS AGM 2014. http://cins.ca/meetings/2014/4p1_n_sources_review_ZT_oct30.pdf
[3] See 2014 AGM minutes: http://cins.ca/docs/agm2014/CINS%20AGM%202014%20Minutes.pdf.
[4] See discussion and links to original sources provided at: http://cins.ca/news.html#NRU-closure-2018.

CNL does not view a decision on a new reactor as imminent. Given the long lead times generally required for building a reactor, this Committee estimates that a new neutron source at Chalk River, if built, will not be operational until 2028 or later.

2.2 The Saskatchewan initiative

In 2010, the Government of Saskatchewan and the University of Saskatchewan jointly proposed to the Federal Government to build a research reactor in Saskatchewan for neutron beams and medical isotope production.[5] In the proposal, Saskatchewan will contribute 50% of the project development cost, 25% of the construction cost and another 25% of the operating cost of the facility. At the time, the Federal Government was considering various ways of producing medical isotopes, and responded to the idea of a new research reactor, thus:

> A research reactor serves many missions. The need for a new reactor for these other purposes would need to be based on a thorough assessment of the missions, including neutron scattering and R&D for the nuclear industry, and consideration of the appropriate sharing of costs among the many users and beneficiaries of such a facility. This assessment is outside the scope of this response.[6]

Subsequent communications from Natural Resources Canada (NRCan) indicated that the federal government needed to complete related tasks before it would have the resources to consider a new reactor.[7] Thus, the Saskatchewan initiative is believed to be on hold at least until the restructuring of CNL is complete.

On the provincial side, Saskatchewan has pursued complementary initiatives in the meantime to develop nuclear capabilities through the establishment of the Fedoruk Centre. Thus, we believe that the province is still genuinely interested, though some details of the original proposal may no longer be up to date.

The Saskatchewan proposal is modelled after the Australian OPAL Reactor, supplied by INVAP of Argentina. INVAP confirmed to us that they are keen to supply a turn-key facility to Canada. For the reactor, cold source, two initial guides and the guide hall building, but excluding instruments is estimated to be in the range $300 - 500M (US). These numbers are consistent with those used in the 2010 Saskatchewan proposal.

Another active reactor vendor globally is KAERI, South Korea. KAERI indicated to us that they also are interested in building a research reactor for Canada. However, KAERI is building or upgrading reactors in three different countries and estimates that it will be another 5 years before it could take on a new international project.

---

[5] Government of Saskatchewan. The Canadian Neutron Source: Securing the Future of Medical Isotopes and Neutron Science In Canada. July 31, 2009. http://www.gov.sk.ca/adx/aspx/adxGetMedia.aspx?mediaId=883&PN=Shared

[6] Natural Resources Canada. Government of Canada Response to the Report of the Expert Review Panel on Medical Isotope Production. March 31, 2010. http://www.nrcan.gc.ca/energy/uranium-nuclear/7795.

[7] For example, in NRCan's presentation at the Canadian Association of Physicists Congress in June 2010, it confirmed that the restructuring of AECL (now CNL) would be dealt with first.

2.3 A new core for McMaster Nuclear Reactor

The McMaster Nuclear Reactor (MNR) upgrade discussed at the AGM was based on the 1993 proposal by the University.[8] Since the proposal calls for replacing the current core with a MAPLE-type core, it requires a vendor who is experienced in the MAPLE technology and is willing to retrofit a new core in an existing reactor. The second requirement is not trivial; most vendors would rather build a new reactor than do a one-time retrofitting project.

The original developer of the MAPLE technology was AECL, which has been divided into Candu Energy and CNL. CNL operates the research facilities at Chalk River, and is expecting new management later in 2015. Approaching CNL to inquire about revitalizing the MAPLE technology for a project like upgrading MNR will thus need to wait for another one year or so.

Another reactor vendor experienced in the MAPLE technology is KAERI. KAERI might consider supplying a MAPLE core, but is more likely to be interested in supplying a new reactor to Canada. However, as stated above (Sec 2.2), due to their current work load, they will not be able to start working on the project for next 5 years. KAERI indicated that knowing the preliminary timeline would be useful for their long range planning.

Renewed interest by the CINS Science Council in a McMaster upgrade led us to consider if a higher flux could be obtained by reconfiguring the current core. By scaling the flux/power ratio inversely with the ^{235}U inventory in the core, it is estimated that a core of 9×6 inch^2 footprint and 8 inch height will yield an unperturbed core flux of 2.6×10^{14} neutrons/cm^2/sec at 6 MW thermal power. For such a small core to achieve criticality, the fuel must be surrounded by a beryllium reflector. CNL is interested in this idea, not only for the possibility of the MNR upgrade but also as a basic concept for new small high-brilliance neutron sources. In the 2015/16 fiscal year, CNL plans to do a generic feasibility study on this concept. If proven feasible, this will be an attractive option; however, prior acceptance by the University and approval by the Reactor Operations are required to apply this idea specifically to MNR.

2.4 Spallation sources

Unlike a research reactor, no contractor is able to build a turn-key spallation neutron facility. This is because the expertise required for various components is so diverse and each highly specialized. Consequently, the construction must be managed by a group of in-house scientists and engineers. Many subsystems can, and will be contracted out, but the overall design authority rests with the host organization.

In Canada, two prime locations with required expertise are CLS (Saskatoon) and TRIUMF (Vancouver). In addition, pockets of expertise exist in various Canadian universities and private companies (for example, the BC based company EBCO Industries) that could potentially design and build the required accelerator. Augmenting this are scientists and engineers whom could be attracted to Canada from other countries for specific technologies (e.g. liquid spallation target). Hence, a spallation source in Canada is technically feasible.

[8] A Proposal to Upgrade McMaster Nuclear Reactor. October 8, 1993. http://cins.ca/docs/MNR_1993.pdf.

This Committee has contacted the Directors of CLS and TRIUMF for more information. The direct quotes extracted from the replies effectively summarize the current thinking at these facilities with respect to building a spallation neutron source.

Response from CLS

> The provincial government still remains very favorable to "things nuclear" as evidenced by the establishment of the Fedoruk Centre here at the University. With the recent success of accelerator production of medical isotopes the focus is back on accelerators as well.
>
> However, for neutron scattering, the province is more likely to be supportive of a research reactor instead of a spallation source.

Response from TRIUMF

> If the science case for a DC source is compelling, then Canada should consider building such a facility. But if the science can be addressed only at a pulsed facility, Canada is better off using SNS. It would be very hard to justify building a lesser facility in Vancouver given that Canada has already made contributions to SNS.
>
> TRIUMF's highest priority over the next five years is completion of ARIEL, our new rare isotope ISOL facility. Beta NMR will be among the first science capabilities enabled by ARIEL. Beta NMR is complementary to neutron scattering because it measures magnetic properties locally in position space, as opposed to momentum space. TRIUMF will certainly be working to grow its user community in this important area. Beta NMR does not replace neutron scattering, but it does open up new opportunities for material characterization.
>
> What's beyond ARIEL? TRIUMF will start thinking about that in the next year or so, in close collaboration with the Canadian community. There are lots of ideas on the table, and there is no reason why a DC neutron source could not be among them. At its core, TRIUMF responds to the needs of the Canadian university community. If the community decides that such a source is the next move, we will respond appropriately.

The responses above indicate TRIUMF is open to the idea of considering a spallation neutron source. When the TRIUMF management starts thinking of what they should do beyond ARIEL by 2016, CINS should be ready to make a meaningful input. As such, we need to have settled the "pulsed vs. DC source" question within a year.

3. The Path Forward – a Recommendation

In light of the announcement for NRU shutdown in 2018, CNL is planning for a 'neutron gap'. Further, CNL plans to take full advantage of the remaining three years of NRU operation to maximize benefit from the reactor, and will continue operating the Canadian Neutron Beam Centre (CNBC). It is expected that the CNBC will continue to offer access to neutron beams to the user community, to the maximum extent possible through March 2018.[9]

The Committee has developed an action plan to preserve the Canadian neutron scattering program based in Canada beyond 2018. We believe the plan will lead to retention of neutron scattering expertise while minimizing disruption in the user support currently provided by the CNBC at Chalk River.

The plan outlined below is a recommendation by this Committee. The Committee is seeking feedback, comments and suggestions through an iterative consultative process to arrive at a plan that can be ultimately approved by the CINS board and the membership.

The text below is written in its final form if no modification is needed. As such, the phrase "CINS recommend", for instance, means "the majority of CINS members recommend".

3.1 Immediate Action Plan – Now to 2018

1. After the announcement of new management for CNL, which is expected in mid-2015, CINS will collaborate with CNL or universities interested in neutron scattering to explore how part of the CNBC's operations at Chalk River can be moved to MNR. The goal is to obtain approval in principle from McMaster University to host national research infrastructure with the reactor operating at full power and on a 24-hour basis, subject to funding availability (see point #4) and negotiation of formal agreements between all stakeholders.

2. With its relatively low flux, MNR is unlikely to be able to fulfill all the requirements of CINS users. Hence, CINS will collaborate with CNL or universities interested in neutron scattering to work out a plan, separate from point #1 above, to transfer part of CNBC's operations to a foreign source. Oak Ridge National Laboratory (ORNL) is the most logical location since Canada has already made significant contributions to two instruments at SNS, namely VULCAN and SEQUOIA and these instruments are aligned with two of Canada's areas of expertise in neutron scattering: quantum materials and metallurgical materials engineering.

3. Though CINS members may be interested in access to all types of instruments at both SNS and HFIR, for the period leading up to 2018 CINS should focus on securing access to VULCAN and SEQUOIA as high priority items. To enable a smooth transition, we recommend that those who may support or use these instruments after 2018 seek to gain operational experience by performing experiments on them before the NRU shutdown.

4. Significant funds will be required for capital projects (acquiring, upgrading or relocating and adapting equipment) and for operations beyond 2018. CINS will play a role in identifying potential funding sources, preparing the required applications, and securing the support of our university administrators. We, the members, pledge to take part proactively in these activities. The amounts needed may be on the order $5-10M for capital and $10M annually for operations.

[9] See discussion and links to original sources provided at: http://cins.ca/news.html#NRU-closure-2018.

CINS will seek to play a stronger role in the governance of the resulting facilities for neutron beams, which may include oversight of funds and operations.

5. CINS support CNL's plan to use NRU to its full capacity to the end. We recommend that no spectrometer parts or ancillary equipment needed at NRU be transferred to MNR, or to any off-site location, prior to the final shutdown.

6. The spectrometer structures designed for NRU are not suitable for MNR. Even though most of them will fit physically, they will encroach into the adjacent beam port areas. Also, moving neutron activated spectrometer components is not easy (and expensive). Thus, CINS should support projects to build or upgrade instruments at MNR where moving them from NRU is more difficult or inconsistent with point 5.

7. To ensure a smooth transition, the following three instruments should be given high priority to be in operation at MNR by 2018:

- MacSANS, a new CFI-funded small-angle neutron scattering (SANS) instrument, which is currently in the design stage and is planned to be complete in 2018.
- An upgraded McMaster Alignment Diffractometer (MAD) that can be configured as needed, either as a reflectometer or as a diffractometer.
- A new powder diffractometer with a very large multi-wire detector.

Together with the two ORNL beamlines identified above, this suite of five instruments would be well aligned with the distribution of Canada's areas of expertise in neutron scattering.

8. For the powder diffractometer at MNR, a 1200-wire detector with 0.1°-resolution, if available, is recommended for two reasons: it will help to compensate for the relatively low flux of MNR, and also simplify the instrument design by not requiring the ability to move to cover a sufficiently large range of 2θ.

9. Options to increase core flux at MNR should be actively explored. Of particular interest are ways of increasing the flux without a long shutdown of MNR (for example, by reconfiguring, rather than replacing, the core). In the interest of avoiding another major disruption, the upgrade, if feasible, should be delayed at least for a few years beyond 2018.

3.2 <u>Planning for 2018-2028 and beyond</u>

The resources established at MNR and ORNL should collectively act as the national neutron scattering infrastructure for Canada that continues to welcome both Canadian and international users.

CINS should continue to pursue a sustainable neutron scattering program for the long term. To this end, CINS's activities should include the following:

1. Continue efforts towards building a new neutron source in Canada, whether a research reactor or a spallation source.

2. Be an active partner with other stakeholders in any effort to pursue a new neutron source. It is anticipated that by 2020 CINS will have a demonstrated track record of participating in operations of a user facility on a modest budget (Section 3.1, point #4). This will enable CINS to make a meaningful contribution to this partnership.

3. Determine the source requirements, for example, in the case of a spallation source: pulsed vs. DC source (within the next 2 yrs).

4. If reconfiguring the MNR core to increase neutron flux is shown to be feasible without a long shutdown, partner with other stakeholders to secure funds for the project.

5. Maintain the momentum to upgrade MNR to a much higher flux (complete replacement of the core as proposed in 1993). Explore whether a partnership between CNL and KAERI makes sense, and if the MAPLE technology is still the best solution. Upgrading MNR to a higher flux level and installing a cold-source are highly desirable. However, the upgrades should ideally happen after Canada has built another major neutron source. A strategy based on two neutron sources is required to avoid another neutron drought in Canada.