

Chemical Institute of Canada | For Our Future

Neutron quest March 2018

March 2018 MATERIALS

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A dual spectrometer high resolution powder diffractometer at the NRU Reactor in Chalk River, Ontario. Photo credit: Canadian Neutron Beam Centre

Canada is quietly marking a scientific and technological milestone this spring with the final shutdown of the National Research Universal (NRU), a nuclear research reactor located on Ottawa River near the small town of Chalk River, about three hours' drive west of the national capital. With that, the country is severing one

of the world's most durable links to the 20th century's enthusiasm for nuclear energy, as well as a scientific tool that will be challenging to replace.

The NRU first achieved a critical fission reaction in 1957, when the pure and applied science surrounding fission was still being explored. The beckoning potential of this frontier easily eclipsed the economic, environmental, social, and political pressures that have subsequently turned the construction of any kind of nuclear installation into a daunting prospect. At the time, however, such facilities were embraced by governments eager to keep pace in a new field that had already demonstrated an awe-inspiring potential in war and promised to deliver many positive impacts in peace-time.

Few of these installations would last as long as the NRU reactor, which quickly distinguished itself as a leading research centre. Investigators were given wide discretion to find out what they could do with the high levels of neutrons produced by the reactor and they eagerly embraced the opportunities for creativity. Among the most prominent innovations was the technique of neutron scattering, a powerful new addition to our scientific tool kit, employing beams of these uncharged particles from the core of the reactor to probe

the molecular structures and dynamics of any kind of material.

Neutrons have the ability to pass through dense materials and scatter from nuclei deep within a target's structure. In this way they generate images of large scale structures, just as X-rays produce radiographs, though they are much more sensitive to light materials, such as plastics, oils, or water. For this reason, neutron radiography has become an important industrial technique to verify the quality of critical metal components, such as turbine blades for jet engines, which might be all but impossible to check in any other way.

Neutron beams can also generate diffraction patterns to reveal crystal structures in a manner similar to X-ray diffraction, as well as non-destructive maps of internal stresses. Neutron stress scanning at the NRU reactor helped to resolve uncertainties in the cause of the 1986 destruction of the space shuttle Challenger, an accident thought to be caused by internal flaws in key parts.



Work with neutron beams at the NRU reactor in the 1950s and 1960s later earned Bertram Brockhouse the Nobel Prize in Physics. Photo credit: Canadian Neutron Beam Centre

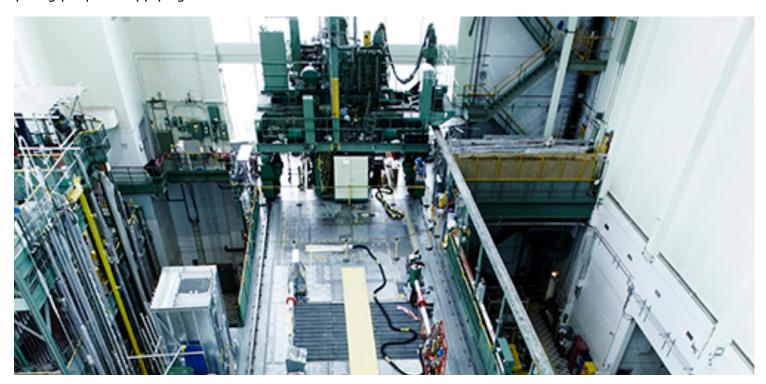
Pioneering work on neutron spectroscopy at Chalk River in the 1950s and 1960s was led by Bertram Brockhouse, who later earneda Nobel Prize in physics for these fundamental contributions. The NRU reactor quickly became the centrepiece of a community that includes some 800 people in dozens of Canadian universities and government departments as well as foreign institutions in 22 other countries. At the heart of this community is the Canadian Neutron Beam Centre (CNBC), the venerable "hub" of local scientific and technical expertise that developed the neutron beam lines — the intricate laboratory equipment that surrounds the reactor — and facilitates the research conducted there.

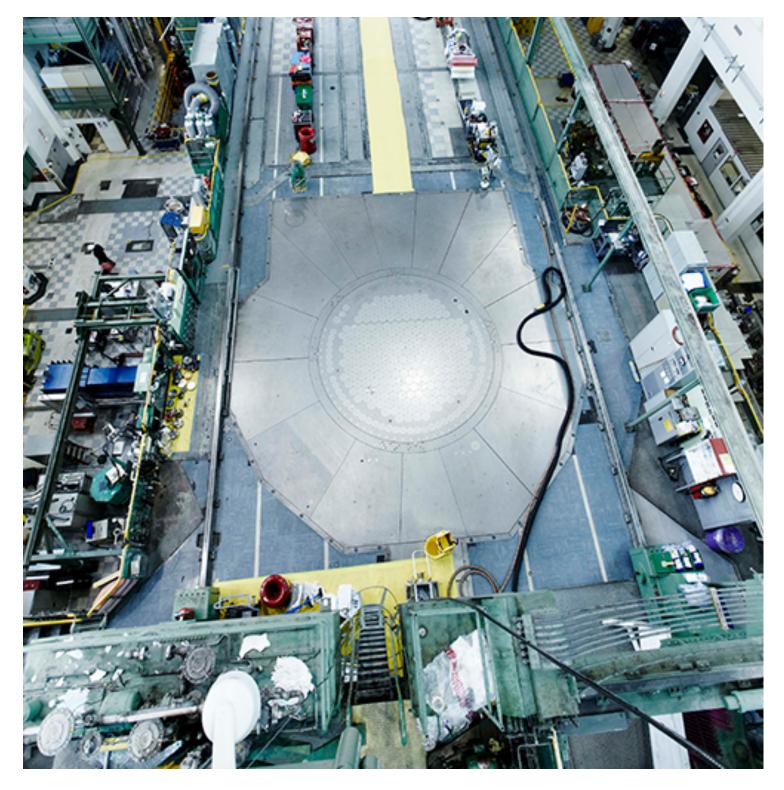
"Neutrons are a scarce resource and I'd like us to exploit them," says Bruce Gaulin, who heads up the Brockhouse Institute for Materials Research at McMaster University. "The irony is that Canada was a heroic player in founding the field and now we're going to be in this situation where we could be on the sidelines completely. We're definitely not going to be in a leadership position, but it could be worse than that. It could be that we don't have anywhere to go."

McMaster is one place to go — home to a research reactor that is almost as old as the NRU reactor. However, the Hamilton reactor is much less powerful — 5MW as opposed to 135MW — and will not be able to provide the necessary neutron flux to meet the needs of many researchers. Much of the research traffic that travelled through Chalk River is therefore expected to migrate to neutron beam sources in other countries, generated not only by reactors but also through a sophisticated particle acceleration method of spallation.

An outflow of Canadian research represents both a risk and an opportunity, according to John Root, who directs the CNBC. Without a functioning reactor to generate neutron beams, he warns, the hub at Chalk River is likely to disappear, taking with it the hard-won knowledge and skills that have served science for decades.

"Our role was to provide a human interface between the machine and visiting researchers, from universities, government labs or industries," he states. "We learn their language and we learn how to design an experiment that would address their research interests. And we help academic leaders educate young people in applying neutron methods to research materials of all kinds."





A view from the gallery of the NRU Reactor facility in Chalk River, Ontario. Photo credit: Canadian Neutron Beam Centre

Some of these activities will continue at McMaster, Root acknowledges, but he expects much of this capability will be lost unless specific efforts are taken to preserve it. The most obvious step would be to build a new Canadian neutron source comparable in scale to the NRU reactor, an option that he and others have been recommending since the early 1990s. Their calls have never mustered the political will and financial backing necessary for this ambitious proposal, and even if they were successful today it would be

at least another decade before such a facility would be up and running.

""A replacement source, a domestic source in Canada, is still a long way off...but the need for neutrons is still here now, and still urgent," says Brock University physicist Thad Harroun, who is the current President of the Canadian Institute for Neutron Scattering (CINS), the organization representing the broad neutron user community.

In that light he and others adopted an entirely different strategy in 2015, when the NRU reactor's operator Atomic Energy of Canada Ltd. officially announced the date of the permanent closure as March 31, 2018. That same year a coalition of interested parties formed the Canadian Neutron Initiative (CNI), to establish a new, university-led framework for stewardship of Canada's capacity for materials research with neutron beams, building on existing national and international resources. With executive leadership from the University of Saskatchewan, McMaster University, CINS, and the Canadian Nuclear Association, the CNI's efforts accelerated in 2017 to include several forays to Ottawa for meetings with different branches of government, culminating with testimony before the finance committee's pre-budget consultation.

A CNI delegation also travelled to Lund, Sweden, where a large pan-European spallation source is in the early stages of development and Canada's participation is being encouraged. Harroun notes that this is not the only foreign lab offering to help the Canadian neutron scattering community find a new home. For the last 10 years Canada Foundation for Innovation funding has secured dedicated beam line access at the leading US facility for such work, the Oak Ridge National Laboratory in Tennessee. Visiting Canadians are also familiar at another major neutron scattering laboratory maintained by the National Institute for Standards and Technology in Washington, DC. No less welcome is the possibility of increasing Canada's presence at the Institut Laue-Langevin in Grenoble, France, which maintains a reactor 10 times more powerful than the NRU reactor. Other facilities in the UK, Germany, Russia, and Australia have likewise expressed interest in hosting a Canadian presence.

"With access to one or two per cent of the facility in Grenoble, we could support a good chunk of a Canadian program," observes Root "It is important to recognize that 'a fulsome Canadian program' would include more than simply beam-time for experienced Canadian users. Canadian leadership in neutron scattering means that Canadians are participating in development of neutron instruments and methods, inventing novel ways to apply neutron beams for materials research and development, and ensuring that new users (such as industry clients) are supported by a professional service to understand each user's knowledge requirements and translate neutron methods to address those needs. Some of this capacity can also be sustained and rejuvenated by connecting Canadians into major science facility projects such as the European Spallation Neutron Source in Lund, or the anticipated Second Target Station project at the Oak Ridge Spallation Neutron Source."

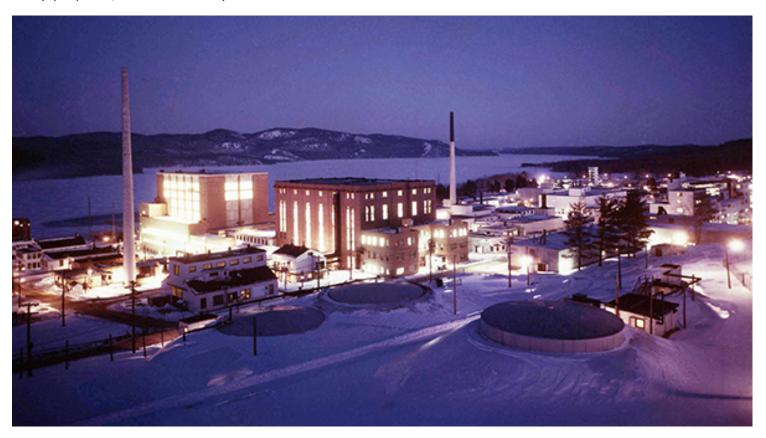
All of these options would come at price, as each foreign institution would expect some sort of contribution in terms of cash, equipment, or human resources in exchange for providing Canadian researchers with access to their facilities. Such funding is one of three priorities CNI has been presenting as part of its rounds to offices on Parliament Hill. The lobbying efforts include support for the expansion of facilities at the McMaster reactor, as well as some sort of central site that would serve as a home base for all Canadian activities around neutron scattering, comparable to the National Research Council's Herzberg Institute, which co-ordinates the country's many astronomical activities around the world.

Root regards such a coordinating organization as essential to sustain and rejuvenate the national program and its capabilities, as well as effectively branding all of Canada's efforts in the field, wherever in the world they might take place.

"We can still run a national program with a team of experts — technicians and scientists — who can be an interface between our user community of about 800 people and whatever facilities are available to us," he says.

In order to realize these three goals, the CNI has suggested a federal funding package of \$24 million over the next three years and \$19 million annually from 2021 to 2029. In contrast, it has been costing around \$100 a year to keep the NRU reactor running, a sizeable amount that was part of the rationale for retiring the reactor. For Gaulin, those numbers make CNI look like a bargain.

"This is on the order of \$20M a year, so it's a fifth of what they're already paying," he insists. "It's not a crazy proposal; it's not a luxury. We need this."



The NRU reactor building in Chalk River, Ontario. Photo credit: Canadian Neutron Beam Centre.

In its formal submission to the government last year, the federal finance committee apparently agreed and recommended funding for the Canadian Neutron Initiative, to maximize the performance of the McMaster Reactor, and to assist with access to foreign facilities. But when the budget came out at the end of February, although it was praised for its strong support of science and technology initiatives, there was no specific mention of the CNI and it remains unclear if available money might be buried in some other federal program. For his part, Harroun remains optimistic.

"The door's not closed," he says. "We just need to continue the work and continue the dialogue. The CNI is a great solution; I hope that will be acknowledged soon."

Nor does he want to consider sweetening CNI's proposition by reducing the size of the request. "So many of the foreign labs are so keen to have us as partners, it really does need to be a substantial outlay," concludes Harroun.

Meanwhile, just before the budget came down McMaster carried out a ribbon-cutting ceremony for its new neutron scattering beam hall, while NRU reactor staff have begun considering how instrumentation installed at Chalk River could be re-deployed in Hamilton or even further afield as part of the envisioned agreement with laboratories outside of Canada. As wistful as it might be for many observers to reflect on the 70-year legacy of a venerable research enterprise, Root is eager to cast this turning point in a more positive light.

"We have the opportunity to move forward into a new framework, a university-led science capability for Canada and have a distinct voice and distinct constituency that can speak up about that capability in the future," he says. "What we're looking for is a signal, a strong signal that the federal government recognizes neutron beams are important for materials research, and that's important for Canada."

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