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The Nuclear Enterprise and NRC Opening Plenary

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Canada

SLIDE 1: The Nuclear Enterprise and NRC

Good morning, ladies and gentlemen. Il me fait grand plaisir de me joindre à vous aujourd’hui pour cette première plénière.

L’occasion de s’adresser à autant de membres d’un secteur de la haute technologie canadienne est plutôt rare et je l’apprécie.

The nuclear industry makes a vital contribution to our nation’s economy, and to our society, and the organization I represent—the National Research Council—is proud of our affiliations with this industry.

Comme beaucoup le savent, le CNRC a joué un rôle déterminant dans l’évolution de l’industrie nucléaire canadienne. À dire vrai, le thème choisi cette année pour ce séminaire – « L’innovation dans le nucléaire au Canada » – décrit parfaitement le travail poursuivi par le Conseil dans ce secteur crucial.

SLIDE 2: Working for Canada since 1917

This might surprise some Canadians. Recent public opinion research suggests that many in this country are unaware of the scope of NRC’s work.

Evidently, some do not realize that NRC is much more than the big wind tunnel at the Ottawa airport, or the long "beep" on the radio that announces one o’clock. The reality is that NRC is Canada's leading federal research agency. This might seem obvious, given that the word “Research” is right there in the middle of our name. For more than 90 years, our scientists have been involved in ground-breaking research in a wide variety of areas. Their work has resulted in great benefits for Canada, and for the rest of the world.

To get a sense of what I mean, consider the following examples:

SLIDE 3: A Proud History

NRC played an important role in the development of **radar** during the Second World War.

In 1950, NRC scientist, Dr. John Hopps, developed the world’s **first pacemaker**, paving the way for biomedical engineering.

A **bomb sniffer** small enough to fit in an attaché case was developed at NRC in 1966. Updated versions of this technology are in use today by police forces, customs, airports, airlines, and embassies.

In 1971, NRC's Dr. Gerhard **Herzberg** won the Nobel Prize for his work identifying molecules in space. He has been heralded as the father of modern spectroscopy.

In the early 1970s, NRC researchers collaborated with the Bank of Canada and Identicard to develop an optical coating technology used to **combat counterfeiting**.

A team of NRC researchers quickly identified a **shellfish toxin** that had caused the closure of the entire East Coast shellfish industry in 1987.

NRC researcher Dr. Harold Jennings developed a synthetic **vaccine against Meningitis C**, which, in 2000, was used in a mass immunization program in the UK and elsewhere.

NRC spin-off IMRIS manufactures an **MRI machine** that reduces repeat surgery to near zero and has been approved for sale in the USA and Europe since 2003.

In 1994, Dr. Bertram **Brockhouse** won the Nobel Prize for his work pioneering the field of neutron spectroscopy.

Coincidently, Dr. Brockhouse's work was one of the many activities that arose out of **NRC's Atomic Energy Project at Chalk River Laboratories.**

SLIDE 4: The Potential of Nuclear

The central role of NRC in the development of nuclear energy in Canada is a reflection of our bold approach to innovation.

In the middle of the 20th century, NRC recognized the huge potential for innovation that could be realized from the discovery of nuclear energy.

To get a sense of the atmosphere of opportunity that existed in the scientific world over 60 years ago, consider the following comparison. Following the recent discovery of fission, scientists had determined that:

Burning one gram of octane will release **48 <u>thousand</u>** Joules of energy.

Fission of one gram of uranium-235 will release **80 <u>billion</u>** Joules of energy.

Clearly, there was an opportunity for science to bring great benefits to society if this energy could be harnessed and converted to some useful form, like electricity.

SLIDE 5: George Laurence

NRC’s involvement with nuclear reactor technology started far earlier than many people realize. Starting in March of 1940, the great Canadian scientist George Laurence began experiments that resulted in a prototype design of nuclear reactor which he built in the basement of NRC’s building at 100 Sussex Drive, a couple of kilometres from here.

If that device had reached its fruition, Laurence would have been the first scientist to demonstrate sustained fission, 18 months before Enrico Fermi in Chicago. It seems he was denied that achievement by the impurities in the materials he was able to obtain.

SLIDE 6: Choosing Chalk River

Recognizing the tremendous potential from this new field of science, in 1944 NRC President C. J. Mackenzie along with leading NRC scientists Ned Steacie, George Laurence and Nobel Laureate John Cockcroft, worked to select a suitable location for Canada’s National Laboratory for the nuclear sciences.

The men visited various places in Ontario and Québec. Finally, they chose a location up the Ottawa River from where we are now: a small stretch of farmland that had been cleared out of the forest near the village of Chalk River.

In August 1944, the Government of Canada bought the farmland and a team of less than 50 engineers and designers began plans for the laboratory.

By October of that year, three buildings to house workers had been constructed and 350 labourers were working on-site.

SLIDE 7: The ZEEP Reactor

Within a year there were 3,000 people at Chalk River designing and building the two nuclear reactors and all the related infrastructure needed to support them.

In September 1945, the ZEEP reactor began operating. It took just 14 months from the time when the farm was purchased. ZEEP was the first nuclear reactor outside of the United States to begin operation. The engineer behind that project was George Klein, a prolific Canadian scientist, and the focus of a fascinating biography written by Dick Bourgeois Doyle of the NRC in 2004.

ZEEP was built on an accelerated schedule to be a simple, low-power reactor that would enable scientists to understand how a nuclear core would work. It produced only **100 Watts of heat**. It was a tool to help build the next reactor, NRX.

SLIDE 8: The NRX Reactor

NRX was always the focus of NRC's Atomic Energy Project. It was designed to be a workhorse of science and innovation. In July 1947, the **NRX** reactor started up. At that time, it was the **most powerful reactor** on earth, producing **30 million Watts of heat.**

So in three years, Canada had built a world-class nuclear laboratory campus and at its centre, the world's most powerful nuclear reactor: an intense source of neutrons. The next time someone tells you something can't be done, remember this example.

The NRX reactor quickly established Chalk River Laboratories and built a visionary program that launched Canada into the forefront of the nuclear age.

SLIDE 9: Hungry for Neutrons

This first reactor is an excellent example of how to maximize the return on investment from a major science facility.

At the time, nuclear science and technology was in its infancy. NRC scientists made sure that NRX was a versatile and a flexible machine.

It had a great many holes around its perimeter to allow neutrons and gamma rays out, and experiments to be inserted into the core. This photograph shows a great many experiments clustered around the NRX reactor, hungry for neutrons.

One early innovation that arose was the production of isotopes. Using the vast numbers of free neutrons in the core of NRX, atoms of an element could capture neutrons and become heavier isotopes of the same element. Initially, small quantities of isotopes were produced—mainly for use in universities as chemical tracers.

But a revolutionary innovation was on the horizon: the field of modern nuclear medicine.

SLIDE 10: Modern Nuclear Medicine

Up to that point, radium had been used in certain medical treatments. However, in theory scientists recognized that cobalt-60 could provide an intense source of gamma radiation that could be used to kill cancer cells.

In a collaboration that involved NRC scientists at Chalk River with doctors in hospitals in Saskatoon and London, Ontario, Canada became the first country in the world to treat cancer patients using cobalt-60.

Growing from that first innovation, Canada is now home to the world's largest medical isotope industry.

This industry has grown considerably over the years. NRU—the reactor that followed NRX—makes more medical isotopes than any other facility in the world. On an annual basis over 21 million people in 80 countries are treated with isotopes from the NRU reactor at Chalk River Laboratories. This initial innovation has grown to make a huge impact on global health.

Those raw isotopes are manufactured into medical products by the world's leading medical isotope business – MDS Nordion.

I'm sure Steve West, who's speaking after me, can attest to the value of the NRU reactor.

SLIDE 11: NRU a Versatile Science Facility

When NRC's leaders and their scientific team began the design of NRU in 1949, they aimed high. NRU is a visionary, multipurpose science facility. At an equivalent of more than $500M, it is Canada's largest investment in any science facility, but one that has repaid that investment many times over.

The isotope revenues from NRU have more than covered its initial capital cost. But they were not a factor when the reactor was designed by NRC in the early 1950s. Molybdenum-99 from NRU, used in over 5 million nuclear medicine scans each year, is a major revenue stream from NRU today. It was not developed until NRU had been operating for well over a decade. This is a testimony to the versatile nature of this facility. When a need arose for neutron-based research in society that required a response from the science community: NRU was able to make this substantial contribution.

And, the future looks even more promising. The demand for medical isotopes world-wide continues to rise. And in a young field of science like this, there is great potential for new innovation with a large impact on society: new isotopes and new applications.

The medical isotope business in Canada today is an excellent example of why governments invest in large-scale national science infrastructure. If the proper tools are in place, bright Canadian minds can achieve great things.

Another example – in a completely different domain of science – arose from Canada's investment in NRX & NRU.

SLIDE 12: Bertram Brockhouse

In 1950, a young scientist from Alberta moved to NRC at Chalk River with his family. His name was Bert Brockhouse.

Don Hurst, who was then head of Physics in the NRC Atomic Energy Project, gave him a task, “Find something useful to do with neutrons.” And that’s exactly what Brockhouse did.

The idea of scattering neutrons from the structure of materials at the atomic scale was already being pursued at Chalk River and elsewhere. However, Bert Brockhouse took neutron scattering to a whole new level.

He is credited with the development of the triple axis neutron spectrometer. As some of you may know, that’s an instrument that can probe atoms’ positions and their movements.

His Nobel Prize in Physics in 1994, which he shared with fellow neutron scatterer Clifford Shull from the USA, recognized that the activity of materials research using neutrons is a powerful and invaluable technique, now in use in countries around the world.

SLIDE 13: NRC Canadian Neutron Beam Centre

À présent, les activités canadiennes de diffusion des neutrons relèvent du CNRC. Grâce à son Centre canadien de faisceaux de neutrons, au réacteur NRU, les chercheurs des universités de chaque province entreprennent des projets novateurs et les scientifiques canadiens ont accès au réseau international de laboratoires qui emploient des faisceaux de neutrons. Le Centre canadien de faisceaux de neutrons du CNRC jouit d’ailleurs d’une renommée mondiale dans les **applications industrielles de la diffusion des neutrons**.

Les neutrons peuvent nous en **apprendre beaucoup sur les matériaux,** ce qui s’est avéré un atout précieux pour les entreprises de maints secteurs, notamment ceux de l’aérospatiale, de l’automobile, de la métallurgie, de l’électronique et de l’énergie.

Some projects from the NRC Canadian Neutron Beam Centre have been of direct benefit to the nuclear industry, measuring material conditions in feeders, pressure tubes and heat exchanger components. One project produced the important knowledge needed to improve the manufacturing process for feeders, an important question affecting their lifespan: a multi-million dollar issue.

Neutrons are often able to obtain unique information about materials not accessible using other techniques. In some circumstances, companies may use a computer model to analyze the strength of their material, but in a highly regulated environment such as the nuclear or aerospace industries, the regulatory body demands actual data to support a computer model.

SLIDE 14: Understand Materials - Improve your Business

A good example of that was a Canadian steel manufacturer that produced steel components from coil for use in the construction industry. The Canadian Standard at the time did not permit these components to be used in certain applications such as bridge building, because of concerns about the strength of the steel.

From a project at NRC Canadian Neutron Beam Centre, the company was able to demonstrate clearly that their steel was strong enough for bridge construction. The factual data was used to upgrade the Canadian Standard, which:

- opened up a new market for the company,
- ensured safety in bridge construction was based on knowledge,
- and lowered the cost of bridge construction.

Obviously, given that advances in materials underpin so many aspects of our modern lives, neutron scattering has remained an important scientific discipline worldwide for the past 50 years.

Today, I am proud to say that NRC's Canadian Neutron Beam Centre in Chalk River, based in the NRU reactor, continues to enjoy a world-class reputation in this field.

NRC's scientists engage in their own cutting-edge research and enable projects from over 200 scientists from across Canada and around the world each year.

SLIDE 15: A Versatile Tool

Over the years, NRC's neutron spectrometers at the NRU reactor have been used to look at a multitude of materials spanning almost every element in the periodic table. These projects illustrate the diversity of research in which neutrons can be applied.

Some projects from the past year have examined:

- **the way in which cholesterol sits in a cell membrane.**
  Cholesterol is important in brain function. Neutrons provided a unique insight into this aspect of membrane structure, and the cholesterol was found in an unexpected position. NRC has a strong biophysics group that use neutrons in their work. They use the gentle nature of the neutron to probe

materials like membranes under realistic conditions. Other projects have focused on Alzheimer’s disease and Simian Immunodeficiency Virus (SIV). When we talk of “materials research”, everything is made of materials: even us.

- **the stress in a railroad track that led to a derailment.**
  Neutrons are non-destructive but can probe deep into metallic components. Measuring stress in something like a railroad track can only be done with neutrons. This project was carried out with the Transportation Safety Board in a forensic examination of a serious derailment with environmental consequences. In this case, we hope that knowledge of materials will help to prevent other accidents with this kind of damage.

- **the behaviour of a mysterious superconducting compound at 10 degrees Kelvin.**
  Neutrons have unique magnetic properties that mean they are the probe of choice for magnetic and superconducting materials. Superconductivity is a phenomenon that has been studied for several decades now. With the promise of revolutionizing electronic devices, it is a challenging field that still contains many mysteries. The ability to research questions at the cutting edge of condensed-matter physics as well as to measure the strength of railroad track shows what a diverse group NRC has at Chalk River.

- **the changes in structure of a polymer in response to laser light.**
  In this experiment, neutrons measured the polymer film *in situ* while a laser beam was applied. This work arose from some imaginative research by a young professor and his graduate students at McGill university. This material that deforms under the action of laser light could find an application as an information storage medium.

SLIDE 16: NRU - the birthplace of CANDU

The third sector of science and industry that has derived enormous benefit from the NRU reactor is the sector represented here today. NRC’s pioneering work has had a tremendous impact on a very successful industry, one that makes a crucial contribution to the quality of life of all Canadians.

The nuclear energy sector is responsible for producing one-sixth of Canada’s electricity. This comes from 18 operating CANDU plants in three provinces—Ontario, Québec and New Brunswick.

In Ontario, nuclear is even more important, producing 50 percent of Ontario’s electricity.

Other benefits include the 30,000 high-skill, high-wage jobs that depend on the industry, the $5 billion in annual activity generated by the country’s nuclear sector, and just as importantly, all done without generating greenhouse gases.

In fact, in Ontario alone, nuclear power generation keeps well over **70 <u>million</u> tonnes** a year of CO2 out of the environment.

As another spin-off, lower activity cobalt-60 from CANDU reactors is used in food and medical equipment irradiators to sterilize products. Today, **more than a third of the world’s** disposable medical supplies are sterilized with Canadian cobalt-60. You can see that this represents an enormous benefit to world health, and those CANDU reactors only exist because of the wealth of fundamental knowledge gained in the NRU reactor.

SLIDE 17: Return on Investment

When we look at all these examples, one thing is clear: as a result of the commitment of NRC science leaders back in the 1940s and 50s, Canada has reaped over 50 years of excellence in:

- nuclear medicine
- materials research
- nuclear power technology

But the NRU is 50 years old and as you all know, it has a limited shelf life. At the same time as we celebrate its achievements and the benefits that it brought to Canadians, we should turn our attention to what is being done in other countries and try and glean some lessons learned.

SLIDE 19: International Perspective

Many other countries around the world have been faced with the issue of whether to renew or not their neutron-based S&T facilities. Many of these facilities are similar in age to NRU.

Some of these are close to their end of life, others have already closed down. It is worth surveying the international scene to discover what the response has been from other nations whose neutron sources have reached the end of their operations.

First, we should note an important difference between neutron R&D facilities and the major science facilities required for astronomy or particle physics. Today, in these latter areas, scientists need access to the highest energies and the greatest viewing distances to make meaningful contributions to progress in their fields.

The costs of truly competitive facilities for particle physics and astronomy have therefore reached the level that demands capital investments as major international partnerships. This is not the case for neutron facilities, where, beyond a certain basic level of flux, a national-scale facility can contribute to the total world capacity of facilities for cutting-edge materials research.

Some countries such as Sweden and Denmark have closed their research reactors without building replacements. Research programs needing neutrons may be able to access other European sources. It will be interesting to learn whether their domestic programs can be maintained through reliance on foreign facilities. Those reactors did not sustain an isotope industry in their respective countries nor a nuclear industry.

On the other hand, many industrialized nations have recently invested in new neutron sources. The size of national investment has varied from one project to the next, but expressed in Canadian dollars new facilities have cost: Australia: $300M, Germany $750M, Japan: $2.4 B, UK: $250M and USA: $2.2 B. The Australian project will supply their domestic isotope market and support a neutron scattering laboratory.

The other countries have all built facilities dedicated only to materials research with neutron beams, recognizing that the knowledge arising from these facilities is linked to economic competitiveness. These are facilities that help to train highly qualified people with advanced knowledge of materials: materials for manufacturing, materials for medical applications, materials for communication, transportation and energy management.

This brings me to the future.

It is difficult to think that the future of neutron research will not be a bright one.

We have only to look at the immense promise for discovery and innovation in nuclear medicine, materials research, and nuclear power technology. And, Canada currently has great strength in all three.

Parce que nous avons investi, parce que nous avons innové, le Canada peut maintenant se targuer d’avoir l’industrie la plus solide au monde dans le domaine des isotopes médicaux et industriels.

Because of past investment and past innovation, we now have the world’s strongest industry in medical and industrial isotopes.

Nous disposons d’un avantage sur le reste de la planète, un avantage dont il faut profiter pour lancer le courant d’innovation qui aidera les malades des générations à venir avec de nouveaux isotopes, de nouveaux traitements, de nouveaux outils diagnostiques.

Canada is extremely well positioned, at the moment, as there is a very serious worldwide shortage of neutron facilities that are suitable for R&D activities in the nuclear power industry. There is only one such facility in Canada, one in the US, two or three in Europe.

Today, nuclear technology for generating electricity stands on the threshold of a revolution of a similar magnitude to the one that occurred at its birth in the 1950s.

At the moment, there is a move toward new reactor technologies that will dramatically increase the energy we can extract from our natural resources, and decrease the volume of waste produced per kilowatt hour.

Through international research initiatives such as “Generation Four”, it may be possible to increase the energy that we can unlock from Canadian uranium reserves from a few decades to over 5,000 years of electricity, with no greenhouse gas production.

SLIDE 21: Science at Work for Canada

Yours is an industry that is currently going through exciting times. The scientific infrastructure and the research activities that have brought you this far are a catalogue of great Canadian achievements.

After all, AECL was and remains NRC’s single largest spin-off and I am proud that NRC played a role in the development that has brought us to where we are today.

I look forward to the next chapter in that story of Science at Work for Canada.

Thank you very much. Merci beaucoup.