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• Meet the New CNS President
• Extended Book Review “The Spinning Magnet” • Canada’s First Nuclear Training Simulator

Problems and Solutions: Which Comes First?

Ontario Premier Doug Ford will end Ontario's Cap-and-Trade program and has already eliminated Ontario's Carbon Tax, while at the same time supporting the extended operation of the Pickering Nuclear Generating Station. This will stop the annoying drain on the pockets of tax-payers for false expectations of environmental good and will do real good for the environment instead. But what happens next?

The Federal Liberals are intent on imposing their "solution" to global warming with a new carbon tax, and it is not clear if the Ontario Conservatives can stop them. Perhaps Ford has a strategy to stop the Federal nonsense, or if not, is surely working one out: a climate change strategy that is actually pertinent to the problem. That is, clearly defining the problem first and working out a solution that fixes it; not the other way about! The Liberal plan is a solution in search of a problem. If the problem is desire to extract more of our hard-earned paycheque, then a carbon tax makes sense. But even the Liberals know that a new tax will go over like a lead balloon, which is another problem that can be solved with deception. The Liberal solution is to tell us that a carbon tax fights climate change by reducing GHG emissions. The nose grows longer.

Ontario has already made great strides to combat climate change and improve human health by phasing out coal for electricity generation. This was made possible by investing in nuclear refurbishment to bring idled nuclear plants back into service. It should also go a long way to supporting the Federal climate change targets (supposedly the Liberal Governments objective) and should be acknowledged by the Feds as a "credit" that meets the stated intent of a national carbon pricing system. But Ontario can and must do more to reduce GHG emissions.

Ontario is the second largest GHG emitter in Canada, second to Alberta. This is primarily due to Ontario's large population which requires the movement of people and goods from place-to-place. Transportation is now the largest source of GHG emissions in Ontario. For moving people, it's cars, buses and rail, whereas for goods, it's trucks and rail that dominate the transportation sector. In short, gasoline and diesel are the predominant fuels of transportation. It is time to replace carbon-based transportation fuels with clean electricity.

Our reliance on cars, buses, trucks and rails is non-negotiable, but alternative fuels for transportation are not only possible, but economic as well.

Cars: EV charging stations for cars are widely available across Southern Ontario, and along popular northern routes including Timmins. They are located within range of most electric vehicles, and the range of EV cars is steadily increasing. Many EV stations are free! (The CAA and other organizations supply maps to locate the nearest EV station.)

Trucks: Most trucking in Ontario are same-day return trips. Many businesses with same-day deliveries are building up their fleets with new electric trucks, such as the Tesla "18-Wheeler". They are much cheaper to fuel and maintain than diesels.

Buses: Not every city can afford a subway, and streetcars do pose a nuisance at times, but trolley buses do make sense. They were very popular for a century and cheaper to operate than diesel, but most cities phased them out. Why? Are overhead wires ugly? Buses take a repeated route, and those routes can be "strung" once more.

Rail: A no-brainer. Plans to electrify the GO transit rail corridors are approved, so why not go the next step and electrify all popular routes?

True, it will take time and money to replace gasoline and diesel, but the money will come from savings in lower operating costs. No need for a carbon tax, and such a plan to electrify transportation could mean that the 2030 GHG targets might actually be met, unlike the current government plan that won't even come close to meeting the UN targets!

In This Issue

CNS Member Bruce Heinmiller (Deep River) is like many who enjoy reading about science and readily picked up a copy of *The Spinning Magnet: The Force that Created the Modern World and Could Destroy It*, by Alanna Mitchell. It was a good read for Bruce, except for the science stuff, and he has prepared an extended book review for this edition of *The Bulletin*.

John Luxat is our new President (the second time for John) and you will find some interesting tidbits of his life history in the CNS News section, describing how his expert skills evolved from Record Players to iPods, not to mention a multitude of professional accomplishments. The full slate of the new CNS Council is updated on p.47.

As usual there are technical papers and news items that are sure to interest most readers. If not, tell your editor what you would like to see! Also, if you have or know a student returning to school, let them know that their CNS Membership is free.

From The Publisher

Power reactors are built for electricity production. For more than thirty years, nuclear generation has been the principal source of electricity in Ontario. Today, about two-thirds of all the electricity used in Ontario comes from nuclear power and its trio of nuclear power stations at Bruce, Darlington and Pickering.

The old historical questions about the reliability of nuclear power to provide electricity are simply no longer relevant. As seen in the *2018 Nuclear Canada Yearbook* on nuclear reactor performance tables, nine power reactors in Canada operated during 2017 at nearly 90 per cent capacity factor or higher during the year. A similar picture of reliability emerges when considering all CANDU reactors around the world.

Nuclear power is important not just for electricity production however. It can also produce useful isotopes as well. This past summer has seen two extremely important developments in this area. First was the announcement by Bruce Power that it would be producing Cobalt-60. Co-60 is used around the world for gamma irradiation. The new production of cobalt started when Bruce Power started a maintenance outage for Bruce 8 in September. During the outage, the steel adjuster rods are replaced with new cobalt targets for conversion to Co-60.

This is highly important for Canada's nuclear industry. Canada has been one of the world's most important sources of medical radioisotopes, particularly with respect to Co-60. Production of new cobalt from Canada's power reactor sector will allow it to remain so. Up until 2016, much of Canada's cobalt production came from the NRU reactor in Chalk River. New production from power reactors will allow Canada to retain its dominant role in isotope production of cobalt.

Just as exciting has been the announcement by Ontario Power Generation (OPG) of its innovative work in production of Molybdenum-99. In collaboration with BWXT, reactors at Darlington will now be producing Mo-99, the parent material for the important radioisotope Tc-99m. This substance is important for medical imaging.

The targets will be inserted into the reactor in the fuel channels. Mo-99 can thus be produced while the reactor remains online making electricity. Subject to regulatory approval, Darlington will be the only source in North America producing Mo-99.

Up until 2016, the principal source of Mo-99 was the NRU reactor in Chalk River, one of about four such sources around the world. Prolonged outages of any of these research reactors endangered global supply of Mo-99, as was seen with the lengthy outage of NRU in 2008. New production from Darlington will go a long way towards eliminating this threat.

The sources of this new production will not be disappearing anytime soon. Darlington is undergoing refurbishment of all its reactors, starting with Unit 2. These refurbishments, when complete, will allow the Darlington station to remain in operation past the mid-point of this century. It will make possible the provision of both electricity and essential medical substances for most of the next thirty years.

To a considerable extent, the Canadian nuclear industry can be considered the inventor of medical irradiation technology. Starting in the 1950s, Canada was the home of the invention and development of cobalt gamma irradiation. And the Canadian industry has continued to innovate in this area. Nordion has developed new technologies, particularly the gamma knife, to allow irradiation to be targeted on tumours without damaging health tissue nearby. So new isotope production from Ontario's power reactors will allow Canada to retain its dominance in this field.

Until now, Canada has depended heavily on production of these materials from the NRU in Chalk River. Now the power sector is receiving the relay baton and picking up the mission. And it has the potential to remain a dominant supplier for many decades to come.

It's possible only in Canada with CANDU reactors. It's only its online refueling technology which allows such innovative molybdenum irradiation. So the summer of 2018 has been very important for nuclear innovation in Canada, brought to you by your friendly, neighborhood nuclear power sector.

CGH

Contents

Editorial 1

Canada's First Nuclear Plant Operator Training Simulator and The Guys That Made it Happen 4

Book Review: The Spinning Magnet 6

Context, Calibration and Causation, The Three Cs that Demystify Science and Enable Better Decision Making 9

Determining Appropriate Licensing Strategies for Novel Nuclear Technologies in Canada 15

The COG Strategic Research and Development Low Dose Radiation Research Program 18

A Case Study on Introducing Small Modular Reactors into a New Non-Nuclear Jurisdiction 22

Customized Irradiation Sites for Medical Isotope Production 27

CNS News

Meet the President

General News

More Than 5,100 People Toured the Bruce Power Site This Past Summer . . . 36

OPG Investing in Pickering Unit 1 36

Tumour Treatment Isotope to be Made at Bruce-8 37

Nuclear Key to Ontario Prosperity 38

Completion of Fuel Loading at Tianwan 4 39

Cameco Shutdown Extended Indefinitely 40

Fuel Removal Work Starts at Japan's Monju Reactor 41

Publications 44

Calendar 45

When Am I Going to See a Commerial SMR Operating in Canada 48

~ Cover Photo ~

Life-saving cobalt-60 rods are lowered into a shielding flask at Pickering GS, to be shipped to Nordion for processing and distribution to facilities around the world. Over half of the world's supply of Co-60 is produced in Ontario.

Photo courtesy of Ontario Power Generation.

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Canada's First Nuclear Plant Operator Training Simulator and The Guys that Made it Happen

by MICHAEL CHATLANI, VP Marketing and Sales, L3 MAPPS

As L3 MAPPS celebrates 45 years of success in the nuclear power plant simulation field, they recall their first project–an important project that set the stage for who L3 MAPPS would become in the world of power plant simulation. In 1973, Ontario Hydro (now Ontario Power Generation) selected L3 MAPPS' predecessor (CAE) to develop the first nuclear power training simulator for its Pickering A nuclear generating station. The first-of-a-kind project was a huge feat and the simulator was put into service in November 1976. L3 MAPPS wanted to hear firsthand from some of the key project team members who were involved in that first project and held an internal event on 25 April 2018–Meet the Pioneers.

Building the First-ever Canadian Nuclear Power Plant Simulator

The Pickering A simulator project was a model of good customer/vendor cooperation. Ontario Hydro provided a shift supervisor (equivalent of a senior reactor operator) to provide plant operational knowledge and testing. In addition, a very competent plant engineer from Ontario Hydro was stationed at L3 MAPPS' Montreal facility for the duration of the contract to facilitate data acquisition and to understand what was being built.

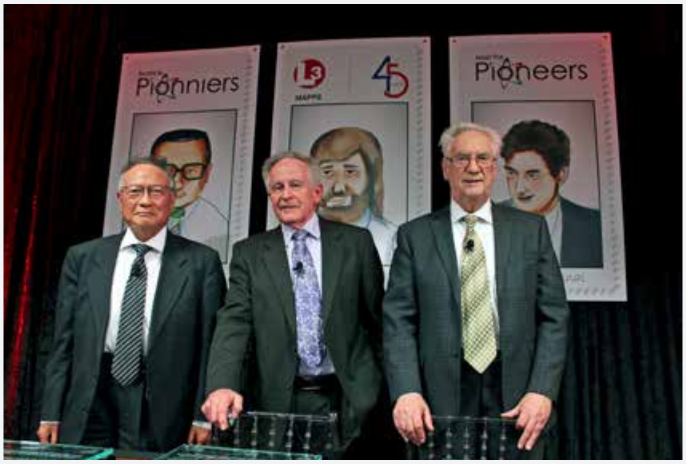
The Pickering A simulator was an overwhelming challenge in terms of modeling. Unlike other nuclear power plants in the U.S. that used basically analog or manual controls at the time, all CANDU* plants are computer controlled. Therefore, in addition to modeling all of the plant systems (with which L3 MAPPS had limited experience at the time), the Pickering A simulator also had to replicate the full computer control system.

There were far more systems and controls than in a flight simulator, and the team had difficulty sizing the simulator since the L3 MAPPS project team didn't fully understand the complexity of the processes taking place within a nuclear power plant. From the company's previous experience, a flight simulator typically used only one or two CPUs. The Pickering A simulator was configured with three CPUs. The challenge was that all these programs that ran in different computers had to talk to one another. The electrical engineering department had to design and build the data link to connect the three computers, an interface controller to talk between the computer and the interface, and a new input/output (I/O) system to provide the required resolution. All of the data link and I/O software also had to be written.

At the same time, a new computer was needed and the Texas Instruments TI-980A was selected. But this computer had no software. The operating system and the editors, compilers, linkers, executive, real time dispatcher, debuggers all had to be written from scratch… all the system software! It was phenomenally good software. It had to be–there was no Plan B. Once the software was available, it would be used for all other simulators that followed for the next decade.

Back then, simulation was really an art. Now people take for granted how much processing power is behind the computers they use and don't really need to care, because they have computers that are one twentieth the price, 10,000 times more powerful and thousands of times more accurate than the ones that were employed on the Pickering A simulator project.

In the early 1970s, the reactor core model was based on Avery's (1958) method for solving the diffusion equations. The resulting core model used a small number of nodes to represent the 14 reactivity control zones for flux tilt spatial control core and a single energy group. The Pickering A simulator used seven radial zones and two axial zones for a total of 14 zones. These 14 zones corresponded one-to-one to the 14 actual zones controlled by the light water Liquid Level Zone (LLZ) controllers in the real reactor. Each one of these 14 zones was modeled based on the full imple-



mentation of the Avery model. The zones were coupled using coupling coefficients which reflect the probability that a free neutron "born" in the first zone would migrate to the other zone. The inputs to the model were not macroscopic cross-sections but reactivities. In addition, there was an overall single point reactor model that normalized and encompassed the values of all of the 14 individual models. Certain parameters such as Xenon buildup and decay were only modeled in the point model. The values from the single point model were used to interact with the instruments on the panels and the plant computer control models such as the Unit Power Regulator (UPR), whereas the Reactor Regulating System (RRS) interacted with both the 14 zonal models and the single point model. The Avery model was very computationally effective, since none of the current core models could ever run in real-time on the computers available in 1973. In addition, the Avery model was used by Atomic Energy of Canada Ltd. (AECL) in the plant design.

Even though there was so much work performed for this first-of-a-kind project, the Pickering A full scope simulator was successfully put into service in November 1976. As can be imagined, it was a huge team effort involving many engineering disciplines from both Ontario Hydro and CAE. Nevertheless, L3 MAPPS specifically acknowledged three key players that spearheaded the development and validation of the Pickering A simulator back then at an event coined "Meet the Pioneers."

Meet the Pioneers

The Meet the Pioneers event, which took place at L3 MAPPS' Montreal facility, was aimed at recognizing the achievements of fantastic people who did some amazing things and engaging the current generation of L3 MAPPS personnel to recall how it all started and how the pioneers overcame new and grand challenges to develop the first-ever Canadian nuclear power plant simulator. L3 MAPPS had the great opportunity to hear from Q.B. (Jordan) Chou, Les White and George Bereznai–brilliant and articulate gentlemen who knocked it out of the park.

Q.B. (Jordan) Chou: Jordan was Ontario Hydro's supervising design engineer, Simulation, Reliability and Special Studies section. Jordan was instrumental in guiding CAE, especially when they were dealing with developing and validating their first thermal-hydraulic models. Jordan was a tireless proponent towards the success of this first nuclear power plant simulator project. Jordan is now president & CEO of Canadian Power Utility Services.

Les White: Les was the CAE project engineer and lead simulator system architect who needed to make sure they devised a solution that was credible and would satisfy a very knowledgeable customer, Ontario Hydro. Les now enjoys his well-deserved retirement.

George Bereznai: George was the training department representative from Ontario Hydro, leader of the Ontario Hydro model developers who were resident at CAE for the project and the one who ensured the simulator did what it was supposed to do. George is now a professor and dean at University of Ontario Institute of Technology.

The event was held in one of L3 MAPPS' larger conference rooms with Jordan, Les and George seated at the front of the room. Dr. Ron Oberth (president of the Organization of Canadian Nuclear Industries) made a few opening remarks and the event moderator, Michael Chatlani (vice president of marketing & sales, L3 MAPPS), asked the pioneers many questions. Through their answers, more than 80 of L3 MAPPS' personnel that attended learned about the pioneers' involvement in the construction of the Pickering A simulator, the technical and organizational challenges and how they were overcome, how closely the project teams worked together, and much more.

Following the Q&A session, the pioneers were each presented with a framed version of an article that appeared in L3 MAPPS' newsletter earlier this year, "Pickering A Simulator–First-of-a-Kind Initiative Opens Doors for L3 MAPPS Global Success" and Rangesh Kasturi (L3 MAPPS president) celebrated the pioneers' accomplishments with a commemorative plaque. To cap it off, the pioneers were invited to cut the official Meet the Pioneers cake.

L3 MAPPS will release a video of the event on its YouTube channel later this year.

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The Spinning Magnet: the force that created the modern world and could destroy it

by ALANNA MITCHELL; 2018; 320 pages (hardcover); $34.00 (CAD); Penguin Canada; ISBN 978-0-670-07019-0.

[Ed. Note: This book review submitted by CNS Member Bruce Heinmiller contains important commentary needed to debunk the junk science in an otherwise excellent narrative on the earth's magnetic field, and its probable "reversal" in the future. Whether or not life as we know it is doomed to oblivion is a subject of opinion of the book's author who is an authority on Latin.]

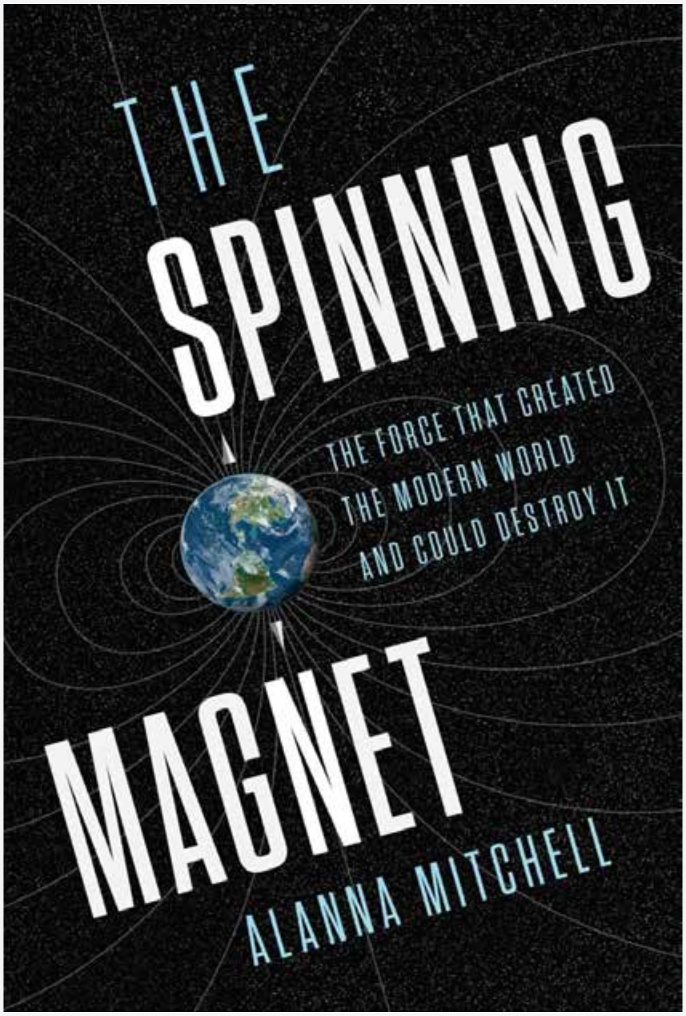
This book is a narrative about electromagnetism, the character and significance of the Earth's magnetic field, and, as the book's destination, a warning. The text is an engaging collage of the author's interviews with scientists in various fields, her resulting account of the science and history of the discovery and properties of electromagnetism, and some speculation on effects from the expected magnetic field collapse during the next pole reversal. The scope of material is remarkably broad which contributes to an entertaining read. The following outlines some of the book's principal contents.

The author outlines the science of magnetism at the atomic and molecular level, along with the history of mankind's observations about the Earth's changing magnetic field, its use in early navigation, and more recently, appreciation of its relationship to auroras and the trapped-radiation Van Allen belts. She relates in some detail how magnetic materials in the rock record established both when pole reversals had occurred and, relatively recently, how they contributed to the acceptance of continental drift and plate tectonics.

The contributions of the scientists and mathematicians responsible for the development of electromagnetic theory are also well chronicled, and she relates electromagnetism (Maxwell's equations, in effect) to the origin and behaviour of the Earth's magnetic field, and also to the threat of induced currents in our electronics infrastructure from severe solar-particle-event magnetic storms.

The author discusses at some length her assessment of the potential consequences of a diminished (and shifting) geomagnetic field during pole reversal. One direct potential effect is the impact on the many species that rely on the Earth's magnetic field for navigation. The ability of various species to adapt to a changing field is uncertain and is appropriately left by the author as an open question.

The other outcomes of a field collapse documented or posited by the author result from the loss of geomagnetic shielding against solar and galactic cosmic rays,



and include: enhanced ionizing radiation exposure to astronauts in Earth orbit; more frequent assaults on electronics-based infrastructure on or near the Earth's surface and in satellites; higher UVB exposure (from presumed cosmic-ray-induced ozone depletion); erosion of the atmosphere (from presumed stripping by enhanced solar particle flux in the upper atmosphere); and, exposure of the Earth's population (and non-human biota) to higher levels of ionizing radiation.

With regard to erosion of the atmosphere, the author discusses Mars as an example of a planet whose atmosphere has been severely depleted after permanent disappearance of its magnetic field early in its history. Although she stresses the uncertainty and open questions with respect to potential erosion of Earth's atmosphere, she acknowledges that atmospheric erosion is widely regarded as being too slow a process to result in significant loss of Earth's atmosphere during the expected period of magnetic field collapse during a pole reversal.

Notwithstanding some awkward moments on some technical items throughout the book, the text related to topics other than health physics (well over 90 percent of the book) is scientifically defensible. Regrettably, the health-physics-related content is not, and appears to be unvetted. Here's a cue to the problem: The 25 pages of notes and bibliography contain not a single reference to any publication of national and international committees mandated to research and report on the sources, effects, and risks of ionizing radiation. For example, the book makes no reference to any of: the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR); the National Academy of Sciences Committee on the Biological Effects of Ionizing Radiation (BEIR); the National Council on Radiation Protection and Measurements (NCRP); the International Commission on Radiological Protection (ICRP) – this, in spite of some extraordinary claims the author makes about radiation sources, effects, and risks.

There are too many errors, profound misunderstandings, and non-sequiturs to cover in a book review, but the following addresses several. Here's a sampling of the minor things.

> The 60-year percent decline in the South Atlantic Anomaly field is miscalculated. All A-bomb deaths in Hiroshima and Nagasaki are attributed to ionizing radiation exposure – none to thermal and blast damage. Units of linear energy transfer (LET) are incorrect (missing the concept of ionization density completely); and a unit of energy is confused with that of potential difference.

But there are more serious problems. Again, a sampling.

> The author's descriptions of both radionuclide decay and the nuclear fission chain reaction are confused and incorrect, respectively, although they aren't especially relevant to cosmic-ray dosimetry. They appear to have been introduced expressly to counsel the reader, through accounts of historical gross over-exposures, on how malevolent ionizing radiation is. However, the discussion serves instead to suggest that the author is confused about a few things, including the difference between radiation and a radionuclide or radioactive material. This confusion is affirmed (and has some relevance) in another section where the author confuses radiation transport with radionuclide transport (of the atmospheric cosmogenic spallation product, ^{10}Be).
>
> In discussing health effects, the author states that "chronic health problems" (by which she may mean misrepaired chromosome damage) "leading potentially to cancer, are linked to the long slow exposure" (as with cosmic-ray exposure), as opposed to "short intense exposure". In so stating, she effectively implies that the dose-dose-rate-effectiveness factor (DDREF) is less than unity, contradicting the work of the committees listed above.
>
> A discussion of the use of tissue-equivalent plastic used in characterizing radiation quality and intensity in deep space, gets conflated with assuming the same material as appropriate cosmic-ray shielding at ground level on Earth. The referenced paper makes no mention of application of the material (which is A-150 plastic) as auxiliary shielding material. Furthermore, although it may be effective in shielding against solar hadrons in a space environment (if that were its purpose), it is largely ineffective in shielding against cosmic-ray secondaries at ground level on Earth, the dominant ones being relativistic muons.

Catastrophe (or some lesser putative detriment if catastrophe is not available) is a recurring theme of the book, to the exclusion of presumed benefits. For example, potentially detrimental effects of transient increases in ground-level doses from solar-particle events are highlighted (and ground-level health effects fabricated), with no reference to Forbush decreases – decreases in cosmic-ray intensity as a result of enhanced solar charged-particle plasma and complementary magnetic fields deflecting some of the incoming galactic cosmic rays away from the solar system. These decreases follow solar particle events and also occur more broadly over the 11-year solar cycle, whereby cosmic-ray dose rates on Earth are anti-correlated with solar activity.

To maintain the catastrophe narrative with respect to ionizing radiation exposure as a threat to life on Earth, it is necessary to discount the atmosphere as an effective shield. Because the degree of attenuation afforded by the atmosphere is central to the issue of threats to life on Earth, it warrants examining the author's notions about it.

The most direct reference to the atmosphere as an effective shield is this: "The long-standing belief was that the Earth's thick atmosphere provides a physical barrier against a full blast of solar and cosmic radiation whether the magnetic shield holds or not. Exposure to radiation while you are in an airplane, for example, increases along with altitude and latitude, suggesting that the atmosphere is a filter except near the poles, where field lines converge". The so-called long-standing belief is well founded, but the author's conclusion is not. A measure of the ability of the magnetic field to deflect in-coming charged particles is the geomagnetic cut-off rigidity, a value below which incoming particles are deflected away. (A particle's rigidity is the ratio of its momentum to charge or, in a system of units used in relativistic mechanics, this times the speed of light, giving rigidity units of volts; in the case of an extreme-relativistic proton, its rigidity in GV is numerically about the same as its energy in GeV). At low geomagnetic latitudes, cut-off rigidities are typically up to a couple tens of GV, depending on (relevant) direction of arrival of the primaries, and are essentially zero at high geomagnetic latitudes. However, ground-level cosmic-ray effective dose rates are only about 10 to 20 percent higher at high geomagnetic latitudes compared to equatorial latitudes, and even at long-haul-flight altitudes, average effective dose rates are only nominally 2 to 4 times higher in polar regions compared to equatorial regions. This should be compared to an increase of a factor of nominally 100 in going from ground-level to flight altitudes, and a factor of nominally 1000 in going from ground level to the top of the atmosphere. Given these data, a more coherent conclusion about cosmic-ray dosimetry on Earth would be this: The atmosphere is the chief cosmic-ray shield (at any geomagnetic latitude); the Earth's magnetic field is largely redundant for low-energy primaries, and ineffective for high-energy primaries.

Elsewhere the author states: "The atmosphere will deflect [sic] only the slower less dangerous particles". Again, the atmosphere attenuates the dose rate by a factor of nominally 1000, integrated over the spectrum of primaries; it is the Earth's magnetic field that deflects only the less energetic primaries (and not even those in the polar regions). The author also refers to the atmosphere as a "double-edged sword" because of the production of secondaries. In fact, the double-edged-sword metaphor, if justified at all, is relevant only above the Regener-Pfotzer maximum at nominally 20 km altitude. From the top of the atmosphere to the Regener-Pfotzer maximum, absorbed-dose rates (but not necessarily effective dose rates) do indeed increase, as the effect of high-energy particle multiplication on absorbed-dose build-up exceeds the effect of atmospheric attenuation on dose reduction; however, below the Regener-Pfotzer maximum, the atmosphere is strictly protective, where the production of many generations of secondaries actually assists in sharing the attenuation load, as the secondaries are progressively less energetic, with the vast majority being absorbed before reaching ground level.

In discussing the strong August 1972 solar storm and the serious consequences it would have had for any astronauts on the moon, the author quotes an interview colleague at the University of Colorado at Boulder thus: "It points out that without the protection of a magnetic field, we are very susceptible". Of course, it does no such thing, as there are two attributes of Earth not transferable to the moon – its magnetic field and about 1000 g cm^{-2} of atmosphere.

This is followed by the assertion (attributed to the same colleague) that such events and galactic cosmic radiation will result (at ground level) in widespread acute radiation poisoning! The text continues with "cancer rates to increase by 20 percent across the board", a claim attributed by the author to (unidentified) geophysicists.

But the alert reader would realize that deliverance had appeared merely paragraphs earlier, where leading into the final chapter, the author had suggested that the increase in cosmic radiation (which, by its nature, we can take to mean effective dose) at the Earth's surface during a pole reversal could be 5 to 10 percent (based perhaps on a previously estimated decrease in magnetic field strength down to 10 percent of its current value). This dose increase estimate is very credible (and, not to say, by many orders of magnitude, incompatible with the health effects just described) and is broadly consistent with the currently observed 10 to 20 percent increase in going from maximum (equatorial) to essentially zero (polar) magnetic shielding. Readers familiar with NCRP Report No. 160 will recognize that the anticipated increase represents nominally only 1 percent of the per capita (U.S. resident's) effective dose from natural background radiation from all sources. To prophesy calamity from this should be quite the challenge.

Alas, near the end of the last chapter of the book, as the magnetic field is weakening and shifting during a pole reversal, she raises the spectre of nomadic populations, migrating to survive the ravages of cosmic rays, and perhaps wearing suits of (largely ineffective) tissue-equivalent plastic shielding, or perhaps having to live underground! It's difficult to view this in any serious light. Moreover, it begs this rhetorical question: Why wait for a magnetic field collapse? The author's colleague in Boulder, Colorado is a prime cosmic-ray refugee candidate today; his cosmic-ray dose is not 5 to 10 percent greater than, say, the author's in Toronto, but instead, is about 100 percent greater.

It's regrettable that an otherwise serious well-narrated book about the history and nature of Earth's magnetic field is reduced to this.

Reviewed by;
Bruce E. Heinmiller
Deep River, Canada.

Context, Calibration and Causation, The Three Cs That Demystify Science and Enable Better Descision Making

by R.N.ALEXANDER[1]

[Ed. Note: the following paper was presented at the 38th Annual Conference of the Canadian Nuclear Society and 42nd Annual CNS/CNA Student Conference, Sheraton Cavalier Hotel, Saskatoon, SK, Canada, 2018 June 3-6.]

Abstract

Social science is increasingly demonstrating that throwing more facts into an argument where the parties already have a developed viewpoint is a redundant exercise. New "Facts" that support an individual's argument will be adopted but where the facts don't support the existing viewpoint they are discarded, discounted or otherwise manipulated until they may be seen to support that viewpoint.

This behaviour explains many of the challenges that the nuclear industry and other technology industries have had in trying to be understood.

Equipping people to analyze information and to critically think about the issues may be a more constructive approach. The 3Cs approach of, Context, Calibration and Causation provides some simple tools to enable that critical thinking and could become a useful tool in the nuclear communicator's toolbox.

1. Introduction

Nuclear power can produce emissions free electricity, when it is needed, in the places that it is needed and in the quantities that are needed. Its plentiful availability assures its ability to carry a significant part of the existing power generation load and, very importantly, allow unrestricted decarbonization of our other energy demands, such as heating and transportation, for which no other adequate replacements are on the horizon. As such nuclear power should be a major consideration for any jurisdiction developing its energy strategy.

Notwithstanding the tremendous opportunity that nuclear power affords, most jurisdictions, especially those in democratic nations, are eschewing this opportunity and pursuing a 100% renewable approach that will likely never actually achieve their objectives. New conventional nuclear power has been reduced to a niche option for countries, largely developing ones, that have Governments that are confident in their incumbency and who have sovereign funds large enough to easily accommodate nuclear projects.

There is no one reason for this unfortunate position. The accidents such as those of Chernobyl and Fukushima have undoubtedly led to public concern but economic failure of some new builds [1] and technical problems at others [2] have also been problematic. It is possible that in a changing energy market the conventional nuclear industry was caught without an appropriate product to fit into the smaller grids of the developing nations or which were at a capital cost that fit comfortably into expenditure portfolios of modern jurisdictions. The perception of an apparent lack of closure on the disposal of arising nuclear "wastes" is an ever-present challenge.

But there can be no doubt that one issue is always present and that is the fear of nuclear technology and the radiation that goes with it and the way that this fear is be reinforced by media that often sensationalizes nuclear issues. This media perpetuates and possibly even amplifies this fear.

If nuclear is to make an appropriate contribution to the well-being of our planet, it must break through this barrier of misunderstanding so that decisions may be made rationally and not on the basis of fears that are not justified.

2. The challenge of communication

As society changes so does the need for communication and the ways that that communication can be undertaken effectively.

Nuclear power was born at a time of great scientific discovery and considerable confidence in the power of science to improve human well-being. There were, of course, local pockets of resistance to change, likely based on the type of NIMBYism that would have been against any development, but "environmental issues" and safety concerns were not at the forefront of thinking for populations focused on recovering from the privations of the second world war and cold war threats. The nuclear industry was largely trusted to get on with its "atoms for peace" mission.

Information was at this time largely promulgated to the public through controlled media channels with commentators that were familiar with their subject

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matter and with the time to appropriately convey that information. Journalists were, to some extent, trusted on their commentary.

Overtime the confluence of an increasing appreciation of the horrors of cancer, the association between radiation and cancer, some conspicuous nuclear disasters and the fact that in fiction portraying the end of the world nuclear is normally in some way the culprit, have led to a general fear of the nuclear industry. These nuclear specific concerns are then added to the underlying challenge of NIMBYism and a pervasive dislike by many of "large corporations".

Recently the internet has given rise to the rapid availability of vast quantities of unfiltered information. Ironically, while science did indeed improve people's well-being, it also gave people the time and tools to complain about the things that science does.

These changes appear to have caught science and engineering communicators on their backfoot. Vaccines and Genetically Modified Organism (GMO), pipelines, dams and windmills have all suffered along with nuclear in this regard.

Historically these industries have tried to counter "misinformation" with facts but it is becoming increasingly well recognised that people who have already made up their mind will not change their position on the basis of new fact but will rather either discount those facts or manipulate them to support their original point of view [3]. Typically, the new information will be called into question, especially if it is being provided by an industry that would benefit from having people believe that information. In the case where the information comes from an independent source, for example the World Health Organizations reports on the Fukushima consequences, the default is to invoke a conspiracy theory. Disputing conspiracy theories is very difficult because the dispute just becomes part of the conspiracy.

3. Critical Thinking

Critical thinking is a disciplined process of conceptualizing, applying, analysing, synthesizing, and/or evaluating information. It enables the review information for what it actually reveals rather than what it may be implied to reveal.

The encouragement of critical thinking could be a key to negating and progressively removing anti-science myths, not by presenting new facts, but by enabling the audience to respond appropriately to the information that is being provided to them wherever that information might come from. It thus allows appropriate interpretation of data whether it is presented by a "pro" or an "anti" commentator.

4. Enabling Critical Thinking About Scientific Issues

Some reports and/or articles are just plainly erroneous and there may be no alternative in these circumstances other than to correct the errors. Proper reference and ideally having people discover the information themselves can help.

The greater challenge, however, is when correct information is delivered with spin, bias or inappropriate implication. Application of critical thinking can quickly inoculate against this form of information. Unfortunately, simply telling people to think critically is not likely to be very successful partly because most people think they already think critically but mainly because for much of our life we are trained not to think critically and so are poorly equipped to do so. (In school and in much of further education we are "taught" things and this does not change much as we enter the work force where we are taught how things are done "around here" and punished for failure to follow this group think).

Critical thinking, might however be enabled with a toolkit that makes it easy.

The nuclear industry has three very prevalent areas where a lack of critical thinking is giving rise to ongoing challenges they are;

1. The toxicity of radioactive materials particularly Plutonium [4]
2. The emissions arising from Fukushima [5] and other accidents
3. The consequences of long half-life materials in repositories [6]

In each case factual information is provided that implies a lack of safety (Plutonium is toxic, radiation is being emitted from Fukushima and materials in repositories have long half-lives) but in each case key information is missing.

The thesis of this paper, based on the authors experience in responding to these issues, is that the missing key information can in most cases be categorized as a lack of context, calibration or causation and that by getting audiences to seek out this information they can quickly form a more appropriate view than that perhaps implied by the naked information.

The issues of toxicity, emissions and consequence are used in the following sections to look at how context, calibration and causation might be used to enable demystification of issues and to dispel myths.

5. Context

By far the most significant challenge is information being presented out of context.

Context places information into an appropriate environment and raises issues such as

- What are the consequences of not doing what is proposed
- What are the consequences of the alternatives
- What positive things occur that might counter the negative.
- How does what is proposed compare with other things that we routinely do.

For example, there is no doubt that producing nuclear power has an adverse effect on the environment and has consequences for human safety. Mining uranium creates spoil heaps, processing fuel produces CO_2, plant operations produce active effluents and contaminated/activated components and then of course there is the used fuel. Any one of these issues can be and is used as the basis of arguments to stop the production of nuclear power. Sadly, accidents are possible at nuclear plants and those accidents are universally and extensively reported so that nuclear safety issues appear more of a threat because of our awareness of them.

But arguably, everything that mankind does, and certainly most things we do, have adverse impacts both for health and safety and for the environment.

Clearly context is required for everything we do. Without context we would not drive cars but experience tells us that while they are possibly the most dangerous thing we do we find it hard to lead our modern lives without them.

Similar context needs to be applied to nuclear issues to reveal that without it we have a choice between being unable to sustain our current lifestyles or the use of alternative methods of producing power that may include the CO_2 from fossil fuel use, the changes in land use from hydro, wind and solar and the environmental emissions from magnet, battery and semi-conductor production. The consequences of nuclear power can look bad in isolation but in context they may well be our best option.

With context an industry is not stopped because there is a risk until that risk is compared with the risk of the alternatives. When that comparison is made, nuclear power, which can sometimes lead to a loss of life, would appear to give rise to less loss of life than other ways of producing power as shown in figure 1.

With regard to the toxicity of plutonium it is clear that it is both radiotoxic and chemically toxic and is indisputably "nasty" stuff. Out of context it is very easy to conclude that Plutonium is a very dangerous substance. Context however tells us that we handle toxic materials all the time. The bleach in our kitchen cupboards is toxic. The mercury in our oceans is toxic and the neodymium in a windmill's magnets and an electric vehicles motors is toxic. The challenge is not how toxic something is but whether the environment or human health may be harmed by that toxicity. On this Plutonium has an interesting record as discussed in the section on calibration.

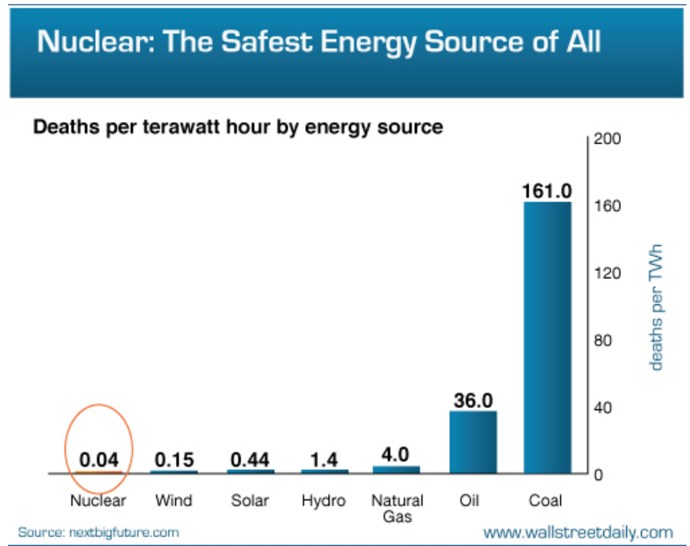

Figure 1: An image readily available on the internet that compares death rates between generation types. This data is variously attributed to a variety of organisations including the World Health Organization (WHO) but the provenance of which the author has never been able to establish.

Outside of the nuclear industry, a consideration of context might well have helped avoid the big international public health disaster that arose from concerns about fats in our diet and which led to fats being replaced with sugars and a consequent increase in loss of life from diabetes. Context may be the missing component of the pipeline debate that is presently raging throughout Canada and should definitely be considered in the debate about GMOs.

6. Calibration

Calibration is likely the easiest to explain and it relates to the quotation of numbers that appear significant but where there is no real significance or where the significance is far less than the number implies. This is a problem for all of science but it is particularly an issue for the nuclear industry that is dealing with;

- atomic scale issues which convert to incomprehensibly large numbers when scaled up to the quantities of material people are familiar with
- units of radiation that people are not at all familiar with (and which even people in the industry struggle to understand).
- timescale issues that are out of all proportion to the length of our own lives

Stories about Fukushima have been rife with a lack of appropriate calibration as may be seen in the many reports that focus on the "tonnes" of radioactive water that is being stored or released into the sea. This number scares people because they understand that a tonne is a lot of material and is frequently quoted as evidence of the ecological disasters created by the incident. Calibrating this number quickly shows that tonnes of water provides absolutely no information whatsoever about the potential ecological damage. It is completely meaningless. What if that water were diluted with sea water so that it became twice as many tonnes of water. Does that double the damage? What if water was extracted so that we had half as many tonnes, does that reduce the hazard? Calibration of the number being provided will not change the consequences of the contaminated water but consideration of the issue would reveal that the numbers provided give no actual indication of the consequence even though they might sound scary. The calibrated may not be so scary.

Plutonium is routinely portrayed as the world's most toxic substance, but as we have seen from putting toxicity into context, toxicity itself is not the end of the story. As well as putting plutonium in the context of how mankind routinely handles toxic materials it is also appropriate to calibrate that toxicity. An attempt to calibrate plutonium's toxicity reveals that the portrayal of plutonium as the world's most toxic substance is in fact far from the truth. Plutonium is considered by some (it is extraordinarily difficult to calibrate toxicity) as 10,000 times less toxic than the clostridium botulinum bacteria, which is, ironically, injected into the faces of half a million people each year for purely cosmetic purposes!

Calibration of the hazard of plutonium itself would need to take into account the contextual issues of how much there is and how it is handled to consider its apparent hazard when compared to other materials. It is an interesting calibration because so far no one is considered to have lost their life as a result of the chemical or radiotoxicity of plutonium.

Another area where calibration is essential is in the field of risk. Some parts of the media love sensation and the internet is rife with it. Stories of a risk doubling (or some other multiple) are common [7]. Sometimes the concern this raises is appropriate, doubling could indeed be serious, but on other occasions, where the original risk was vanishingly small and doubling it makes no real difference, the real risk needs to be understood before behaviours are changed or policy decisions made.

7. Causation

The full title of this C is really causation not correlation. People not familiar with scientific principles, and sadly many that are, often fall into the trap of believing that where there is a correlation there is necessarily a causation. Much has been written to ridicule this behaviour with the classic being the entirely spurious portrayal of the number of pirates in the world correlating with climate change [8].

But the real danger lies in correlations where a causation might be credible or indeed even expected. This can lead to;

- Accidental or deliberate selection of data to create the correlation.
- Reversals of the causation/correlation relationship or lack of clarity over the cause and effect of the correlation
- Jumping to a conclusion about a causation because there is a correlation but where in fact that correlation is caused by a third common factor.

Accidental or deliberate selection of data has been a substantial and challenging problem for the nuclear industry as information such as cancer rates around nuclear facilities require boundary conditions to be set for both time periods and geographical area. More subtle corruptions may also select the type of cancer or the ages of the cancer victims. The principle used is that if the data doesn't tell the story that is desired the first time the boundary conditions are changed until it does. Sooner or later statistical variation will provide the answer that is desired even where absolutely no correlation exists. This is a technique typically used by all sides of the argument including those in the nuclear industry and sadly has led to distrust of any statistics quoted by anyone, anywhere. The data on deaths arising from a range of power production techniques that is presented in figure 1 and referred to earlier could even suffer from such manipulation.

One of the biggest challenges for the nuclear industry are correlations that arise through a third linking event.

Following Fukushima considerable effort was put into monitoring for thyroid cancer. The entire affected population was monitored and new more advanced thyroid detecting techniques were brought in to ensure the maximum effectiveness of the process. Early results clearly indicated that cancers were being established at a higher rate than that which had been discovered previously in the general population. Given that the prophets of doom had forecast this increase in cancer rates they were quick to seize on this data to affirm that the nuclear incident was the cause. More considered studies then looked at what level of thyroid cancer would be discovered if screened the whole population was screened in the way that the affected people were screened. The result was, surprisingly, that the Fukushima population was actually suffering lower rates of thyroid cancer than the general population, information that was not widely in the media.

The correlation was, in fact, not with the Fukushima incident but with the process of screening with more sensitive equipment and techniques.

In a massive and unfortunate irony, it is possible that discovering thyroid cancer earlier may actually increase mortality rates because there is little evidence that earlier intervention will save lives but it is a fact that some lives will be lost through the medical interventions themselves.

The finding of higher cancer rates around the Sellafield nuclear reprocessing facility in Cumbria, England, provides another example of likely false causations. Here, notwithstanding all of the potential for corrupted data, it did appear that a true correlation existed. However, the levels could never be explained by the radiation being emitted. Later studies showed that cancer spikes whenever large numbers of people, that had previously not been in proximity with each other, come together. It is likely that the spike was caused by the exposure of workers to new viruses, a theory that is credible given that viruses are a much more powerful cause of cancer than radiation.

Consideration of whether a correlation actually has the causal relationship that is implied will not change the relationship that exists but it does allow people to determine for themselves whether or not it is something that should concern them.

8. Context and Calibration in the Repository Discussion

One of the greatest challenges that the nuclear industry has today is the effective articulation of the issues surrounding repositories. It is a dialogue that has historically taken place in the absence of any real context or calibration.

A major aspect of the debate appears to be anchored in the fact that radioactive materials have a half- life and the apparently reasonable, but in fact wholly inappropriate, leap of logic that says something must be isolated from the environment until the radioactive decay is complete.

The industry's response to concerns about repositories has typically been to explain the numerous barriers that will prevent materials escaping until complete decay has occurred. There are challenges with this approach because it reinforces the original concerns about radioactivity while simultaneously demonstrating the impossibility of proving you can keep something out of the environment for that length of time.

It is possible that the creation of context and calibration may assist in reducing concerns and/or gaining understanding of repository projects. They are discussed together in this section because where repositories are concerned context and calibration are conflated.

The half-life of one of the isotopes of plutonium is 24,000 years and so it will remain radioactive for 240,000 years. The leap of logic typically means that radioactivity must, in their minds, be different to anything else that we do. At the same time 240,000 years is a period of time that is hard to appreciate.

All of these issues could be contextualized. For example, potassium 40, an isotope that is plentiful and natural, has a half-life of 1.3 billion years and will not have completely decayed for 13 billion years. In terms of calibration that means that potassium 40 was radioactive when the earth was created and will still be radioactive when the sun collapses into a fire ball and then ceases to exist. Calibrating the half-life of plutonium against other materials doesn't make plutonium any less hazardous, but it does demonstrate that determining hazard simply on the basis of half-life is meaningless. This may help move people away from the feeling that used fuel is somehow a fundamentally different hazard to anything else we handle.

Another way to enable contextualisation/calibration and to negate the influence of the apparent special nature of something that is radioactive might be to point out that most things in a repository

aspire to become lead and are on an inevitable mission to achieve this aspiration. Lead is correctly known by people to be a perniciously toxic material and so pointing out that, even after everything has decayed, the repository is still a hazard, may seem counterintuitive. However, while people find it hard to contextualize and calibrate the consequences of radioactivity they can contextualize and calibrate lead. Even though it is toxic we mine lead, we make things with it and we throw it away. It exists in different concentrations in the biosphere and yet the world has not ended, nor (so far as they are aware) have their lives been affected. There is now a basis for comparison and a repository ceases to be as alien as originally thought.

Another useful contextualisation/calibration could be with existing radioactive ore deposits, demonstrating that even if radioactivity is still considered special, it still exists in the environment without causing undue harm. In providing this context the feeling that a repository is somehow special might be removed.

The frame of reference modern humans have for timescale are human lifetimes and in the biosphere a human lifetime is a long-time. Anything outside of this frame of reference is particularly hard to conceptualise and 240,000 years is a fundamentally frightening concept for people that begin to panic at the prospect of a mortgage. The purpose of a repository is though to move those materials from the fast-moving biosphere into the much slower moving geosphere where glacial movement is the equivalent of a space rocket. This re-calibration may help in creating a more helpful vision of a repository's behaviour that may help in gaining acceptance.

Repositories probably suffer most from a lack of context and calibration and may benefit most from being looked at through the proposed lense.

9. Application of the Three Cs and its Effect on the Debate

Application of the three Cs can be achieved through asking questions that are focused on the deficiency within the communication, many examples of which have been included in the discussion. Carefully phrased leading questions should encourage those that are interested to go and find the answer while more casual observers that are not sufficiently interested will at least know not to immediately trust what they have seen.

The author created the concept of the three Cs recently, after decades of amateur communication on nuclear issues and occasional short stints where nuclear communication was a key part of a professional role. The concept is in its infancy and the results all anecdotal, are of no statistical significance. Arguably this paper is exactly the sort of communication that the 3Cs are designed to interrogate.

The results do however suggest that the ideas have some merits. In extensive discussions on the linkedin internet platform it has been observed that presentation of facts that discredit a story regularly lead to an escalation of rhetoric that creates a platform for both sides of the discussion. Since both sides think they are telling the truth followers of the dialogue will likely pick the truth that they want and at the very least critical thinking is suppressed rather than encouraged. Such exchanges likely do as much harm as they do good, no matter how well intentioned they might be.

On the other hand, questions designed to get to the bottom of the story by forcing consideration of context, establishing calibration or questioning the causation, rarely seem to attract adverse responses. Indeed, adverse responses are difficult because nothing has actually been said and would likely reveal further faults in the information.

10. Summary

If nuclear is to make an appropriate contribution to mankind's sustainable use of energy it must overcome the challenges of communication that have led to it becoming largely excluded from the discussion.

Given that people rarely change their minds on the basis of new facts being provided encouraging critical thinking may be a better approach, allowing people to arrive at an informed conclusion in the first place and possibly allowing people to change their own mind if they had already taken a position.

The concept of the three Cs, Context, Calibration and Causation (not correlation), may provide a toolkit that may be used by nuclear communicators.

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Determining Appropriate Licensing Strategies for Novel Nuclear Technologies in Canada

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Abstract

The Canadian Nuclear Safety Commission (CNSC) regulates all nuclear facilities and activities in Canada. Regulatory decisions are founded on science and use rigorous risk-informed decision-making processes. The CNSC uses a combination of prescriptive and performance-based approaches to ensure regulatory activities (licensing and compliance) are conducted in an effective, flexible and pragmatic manner.

Pre-licensing activities ensure regulatory expectations are clear. The CNSC has established a new pre-licensing process, *Determining Appropriate Licensing Strategies for Novel Nuclear Technologies* [1], for developing risk-informed strategies that takes into account the degree of novelty, complexity and potential harm. This process can be applied across all types of activities or facilities, such as those that involve small modular reactors, and across all technology readiness levels. It solicits proposal information and provides the proponent with an overview of the regulatory approach and related expectations. This provides enhanced regulatory certainty regarding the licensing of novel nuclear activities in Canada.

1. Introduction

This paper describes an approach used by the CNSC when regulating activities that span the continuum of technology development over the facility lifespan from design to decommissioning. Pre-licensing activities are an opportunity for a proponent to seek information or clarity prior to engaging in licensing. Within this phase, the CNSC offers two avenues for formal pre-licensing engagement that can be undertaken by a proponent prior to submission of a licence application. These are:

- Vendor Design Review (documented in GD-385, *Pre-licensing Review of a Vendor's Reactor Design* [2]); and
- newly documented internal process for *Determining Appropriate Licensing Strategies for Novel Nuclear Technologies* [1] (colloquially known as 'the 4-Step Process'), which is a method to establish a risk-informed licensing strategy for a proposed activity.

This paper discusses the CNSC's regulatory basis and approach, the inter-relationship of risk-informed, grading and proportionality, pre-licensing engagement, guidance for developing a preliminary description to engage in the 4-step process, and the benefits of establishing a strategy for risk-informed licensing.

2. Regulatory Basis and Approach

Section 26 of the *Nuclear Safety and Control Act* [3] (NSCA) describes the activities that are licenced by the CNSC. Activities that are subject to the NSCA and its regulations are to be carried out in a manner that protects health, safety, security and the environment, while respecting Canada's international obligations. In regulating activities subject to the NSCA, the CNSC uses a combination of prescriptive and performance-based approaches, recognizing that different combinations of these approaches can be used to regulate nuclear activities and facilities in an effective, flexible and pragmatic manner.

Note that not all technology development activities are licensed by the CNSC – only those which would be trigged by Section 26 of the NSCA are subject to licensing. It is important to note that even if a specific activity is not licensed, it should be conducted under an established and competent management system when the activity is intended to support a licence application. This ensures that supporting evidence will be documented and that appropriate quality assurance measures are taken. Proponents are encouraged to discuss these measures with the CNSC in advance as part of the proponent's processes to decide that they will be appropriately addressed in the licensing process.

For new regulated activities or facilities[2], e.g., those for which there is little or no licensing experience in Canada, proponents are encouraged to engage in formal pre-licensing to allow for the definition of an appropriate

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2 Examples include (but are not limited to): fusion reactors, fusion or accelerator driven sub-critical assemblies, large sub- critical assemblies (k_{eff} close to 1), large experimental loops using significant quantities of uranium, prototype facilities, new types of accelerators for therapeutic applications and replacement of de-tritiation facilities.

and efficient regulatory approach. This is done to ensure that the regulatory approach addresses the degree of novelty, complexity and potential harm posed by the activity or facility and ensures there will be no unreasonable risk to the public. This is achieved through the formal pre-licensing activities mentioned above.

3. Risk-Informed, Grading and Proportionality

The CNSC uses a risk-informed approach to grade requirements so that they are proportional to the activity or facility's risk profile. Requirements are developed and applied in accordance with their risk; this is not a relaxation of requirements – this may involve implementing more stringent measures. An example of this would be increased safety margins and instrumentation for demonstration facilities to compensate for uncertainties.

The risks and mitigation approaches need to be clearly described by the applicant/proponent and well understood in order to make an informed decision. Supporting evidence and the quality of that evidence is critical, and plays a major role when making decisions or recommendations for licensing.

This is applicable across all technology readiness levels and is applied for all Safety and Control Areas[3] (SCAs). For example, safety and control measures for environmental protection, physical design, radiation protection and emergency response are all expected to be commensurate with the level of risk associated with the activity or facility.

Increased protective measures should not be viewed solely as increased regulatory burden; many of these measures are put in place to carry out research and design safely in the face of the unknown. Additional protective measures when facing unknown unknowns can come in a number of different forms. Some of these include additional or more robust design measures, restricted operating procedures, and more frequent testing and maintenance activities with broader scopes.

As outlined in the examples above, use of a risk-informed or proportional approach is not limited to regulators – proponents or licensees are expected to use this when exercising prudent engineering judgement.

Existing requirements provide a starting point for regulatory review, but each case will be reviewed on its own merits and alternatives to meeting requirements are allowed. This is not new to the CNSC – historically, requirements were applied in proportion with the risks posed. Key considerations from a reactor's perspective would include the reactor power, type of fuel and its source term, activities and structures surrounding the reactor's core and site characteristics.

Ultimately, all requirements in the NSCA and applicable regulations must be addressed with any deviations explained and justified – the Commission is the final authority for this determination.

4. Pre-Licensing Engagement

Stakeholders are encouraged to engage with CNSC early and often to understand the requirements that need to be addressed for their specific project. Early engagement, particularly around novel proposals, gives all stakeholders time to think about what a proposal may mean from a regulatory perspective.

Pre-licensing activities are generic and can inform a licensing process, but do not result in issuance of a licence or certificate under the NSCA. The pre-licensing results are not binding on the Commission and in no way fetter its review or decision making authority.

Pre-licensing activities can vary in complexity and formality from informal process related questions to technical assessments that provide feedback to a proponent. The objective of pre-licensing activities is to increase regulatory clarity, either through early identification of potential regulatory / technical issues or through improved understanding of the CNSC's regulatory process and requirements, while ensuring public safety.

In addition to informal pre-licensing discussions, there are two types of formal pre-licensing engagement with the CNSC. The first is a Vendor Design Review (VDR), whereby the CNSC reviews a vendor's design to provide early identification and resolution of potential regulatory or technical issues early in the design process. The VDR focuses on design, design process and safety analysis. As mentioned, further information can be found in *Pre-licensing Review of a Vendor's Reactor Design* [2].

The second type of formal pre-licensing engagement with the CNSC is through establishing a risk- informed licensing strategy for the proposed activities. This is a more holistic activity that can be applied across all types of nuclear activities or facilities and across the readiness of the technology. It incorporates both operational and deployment considerations across the lifecycle of the activity/facility.

Establishing a risk-informed licensing strategy is a process through which:

- a written preliminary description of the proposed activity or facility is developed and submitted by a proponent (Step 1) using the guidance provided below in Section 5,
- the submission is assessed by CNSC staff, with conclusions and recommendations documented in a draft report (Step 2),

3 A safety and control area is a technical topic used by the CNSC to assess, review, verify and report on regulatory

- the draft report is reviewed and the strategy is decided on by management and technical experts (Step 3). The review considers all SCAs to determine proportional licensing and compliance activities across the lifecycle of the activity or facility; and
- the CNSC lead licensing director formally responds (Step 4) to the preliminary description with an overview of applicable regulations, licence application guides, information to be submitted in support of licensing, and identifying the CNSC's single point of contact.

The response may also provide information on applicability of an environmental assessment, public and Aboriginal consultation, nuclear liability, security / safeguards considerations, potential timelines, areas of potential delay, useful REGDOCS and standards, and key points that, if changed, may invalidate the strategy. The result provides supplementary guidance to a proponent on the use of the regulatory framework for their proposal.

5. Developing a Preliminary Description

Information submitted in a preliminary description should be of sufficient detail to understand the nature and hazards of the activities being proposed over the life of the potential project. The information, while understandably preliminary in nature, needs to be sufficiently complete so as to allow for impact to be projected for workers, the public and the environment. Sufficient detail to obtain a preliminary understanding of the proposed activity(ies) and hazards is required.

The CNSC has documented the criteria for a preliminary description in *Prepare for and Establish a Preliminary Description of Activities and Hazards* [4], which is available upon request.

These criteria include the purpose of the project, key activities, the facility description, estimates of quantity and form for nuclear and hazardous substance(s), details of the project hazards and waste estimates.

Criteria should be addressed on an 'as applicable' basis. It is not mandatory to submit information to address all of the preliminary description criteria; however the CNSC's review can only be as good as the information that is submitted. It is important to note that the risk-informed licensing strategy will change if the licence application substantially differs from what was proposed in the preliminary description.

In certain instances, a preliminary description of the proposed activities may result in straightforward feedback from CNSC staff if the activities already fall into an existing licensing regime. In other instances where a proposed set of activities are complex and/or precedent may not already exist in Canada, CNSC staff follow the four step process to identify a licensing approach and to provide feedback to the proponent.

6. Conclusion – Benefits of Establishing A Strategy for Risk-Informed Licensing

Both the CNSC and the proponent benefit from the establishment of a strategy for risk-informed licensing. In particular,

The proponent:

- gains a better understanding of the regulatory process;
- understands which aspects of their proposal may trigger additional regulatory scrutiny and can consider whether scaling their proposal is desirable; and
- understands what would need to be provided as part of a licence submission.

The CNSC:

- is made aware of the potential project for planning purposes;
- comes to agreement as to how the potential project would be handled internally; and
- is made aware of potential problem areas and identifies resolution paths.

It is in the proponent's best interest to be upfront about all intended activities and use cases within the preliminary description. This allows the CNSC to provide key information in response, allowing the proponent to address emerging issues early on.

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The COG Strategic Research and Development Low Dose Radiation Research Program

by N.D PRIEST[1]

[Ed. Note: the following paper was presented at the 38th Annual Conference of the Canadian Nuclear Society and 42nd Annual CNS/CNA Student Conference, Sheraton Cavalier Hotel, Saskatoon, SK, Canada, 2018 June 3-6.]

Abstract

The COG Strategic Research and Development (SRD) Low Dose Radiation (LDR) research program (Addressing Public Concerns about Their Exposure to Low Doses of Anthropogenic Radiation) will undertake independent and evidence-based research in response to concerns and worries about the effects of exposure to anthropogenic radiation expressed by the public in Canada. It will investigate low-dose radiation (LDR) and advise the public of findings. It is intended that the work will reduce concerns by providing accurate and unbiased information on the consequences of exposures to LDR. Projects undertaken within the program address the following questions: What are the public concerns regarding exposures to low dose anthropogenic radiation; To what extent are the public concerns justified by evidence of adverse effects; Why are effects seen / not seen following LDR; How best are the results of studies communicated to the public; How effective have the communications been in reducing concerns? The LDR program is forecast to cost > 1 M$/year over several years. The program started January 2018 with 2 funded kick-off projects and another 6 commenced in April 2018. Two further projects are planned to start in 2019.

1. Introduction

1.1 Aim of program

The LDR research program will undertake independent and evidence-based research in response to concerns and worries about the effects of exposure to anthropogenic radiation expressed by the public in Canada. It will investigate LDR effects and advise the public of findings. It is intended that the work will reduce concerns by providing accurate and unbiased information on the consequences of exposures to LDR. Projects undertaken within the program address the following questions: What are the public concerns regarding exposures to low dose anthropogenic radiation? To what extent are the public concerns justified by evidence of adverse effects? Why are effects seen / not seen following LDR? How best are the results of studies communicated to the public? How effective have the communications been in reducing concerns?

1.2 Participants

Members of staff and students from the following organizations are participating in the program: Canadian Nuclear Laboratories, University of Saskatchewan, University of Regina, University of Ottawa and Ottawa Hospital Research Institute, University of Ontario Institute of Technology, Health Canada and the Canadian Nuclear Safety Commission.

1.3 Drivers

The main driver for the program is the need for the nuclear industry in Canada to widen trust within the Canadian population. This need was identified as one of eight strategic priorities that were deemed critical for the continued development, refurbishment and operation of nuclear power plants in Canada. It was recognized that the public should feel confident that it has the appropriate low dose risk information to balance against the benefits derived from the use of nuclear power when making its decisions about power generation. The priorities were identified following consideration of presentations made at a Canadian industry-wide COG workshop in 2015.

If trust were established this could facilitate reduced opposition to the operation of existing nuclear facilities, including power reactors, and the onward development of new nuclear capacity in Canada. Of importance is the public attitude to the possible deployment of small modular reactors (SMRs) in northern Canada. In addition, an understanding of the health effects of LDR, which are currently uncertain, would inform radiological protection practices and regulation. For example, understanding the health effects would allow better informed risk estimates for worker compensation and provide regulators evidence needed for the optimal application of radiological protection practices, including ALARA.

1.4 Background

There is a paucity of information concerning the

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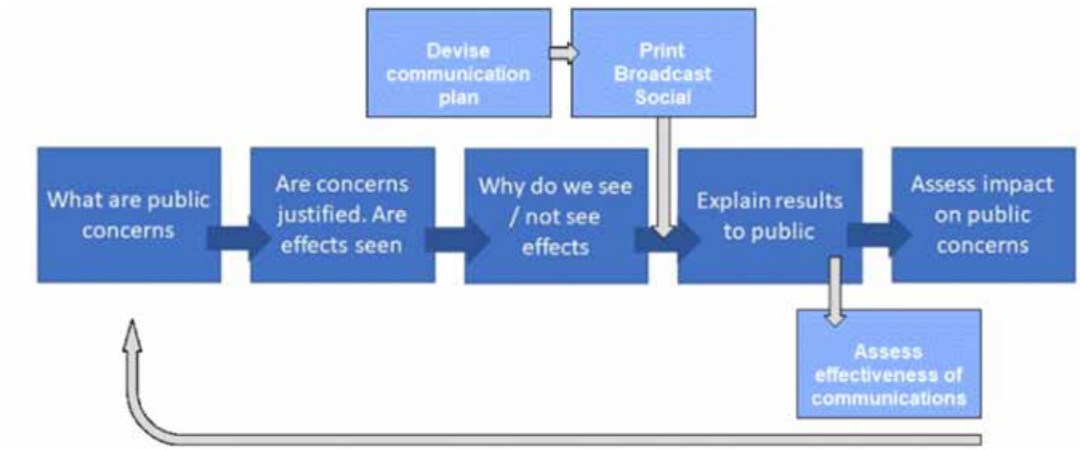

Figure 1: Diagram showing the logic underlying the "Addressing public concerns about their exposure to low doses of anthropogenic radiation" program.

effects of exposures to doses and dose rates of radiation that are relevant to the public situation. Consequently, national and international radiological protection recommendations and regulations are based on the results of epidemiological and radiobiological studies where the doses and dose rates considered / employed are much higher than those that the public may either be expected to receive from the normal operations of nuclear power plants or have received following nuclear accidents. It follows that despite considerable uncertainty, for regulation (and inappropriately for risk estimation), it is assumed that exposures to radiation result only in detriment and the health risks resulting from exposures are linearly proportional to dose without threshold. Given the uncertainty and some recent evidence to suggest that the current low dose, toxicity paradigm may be in error it is widely recognized that research is required to address the consequences of exposures to LDR and to reduce uncertainties [1]. This is critical, since studies have indicated that the root cause of the public reluctance to accept the benefits provided by nuclear technologies stems from its belief that the effects of exposure are uncertain and are a likely cause of cancer and genetic damage [2].

While it is clear to experts that public exposures to radiations released to the environment by nuclear facilities are so small that, even if they exist, they are too small to be measured and should be of little concern, the information provided by and communications of the industry have largely failed to assuage worries and concerns. Social science studies have suggested that drivers of this concern include an embedded public distrust of industry, distrust of the results of its research and its messages, the perception that there is no consensus among experts, and media reporting - when it gives an unbalanced emphasis to incidents involving radiation [3, 4]. The studies suggest that, to change opinions research and effective communications need to be driven directly by the concerns and worries of the public and not by experts who believe that the public should be given the information that it needs to know. Moreover, the communications should be by trusted communicators. It follows that the approach that should be taken to have the best chance of changing public perceptions should be a bottom-up approach where the research undertaken is independent and directly addresses the concerns of the target populations [5]. This is the approach that will be taken by the present strategic program. The logic underlying the research program is given in Figure 1. The program includes the communication of results with constant monitoring of the effectiveness of the communications.

2. Program Plan and Implementation

The LDR Program, which includes both research and communication activities and both social science and physical/radiobiological components, will be driven by the worries and concerns of the public and will be managed by a sub-committee of the COG Health Safety & Environment (HSE) Technical Committee. The membership of the LDR Sub-Committee will be independent of the nuclear power industry and will include academics and trusted members of the community. The leader of the HS&E Technical Committee will attend as an observer to maintain linkages with this committee. The Sub- Committee will receive quarterly reports on project progress and will report any concerns to the COG Technical Committee.

It is intended that the research undertaken should address Canadian public concerns and worries that are revealed by a social science project undertaken by the Centre for the Study of Science and Innovation Policy, Johnson Shoyama Graduate School of Public Policy, University of Saskatchewan and University of Regina

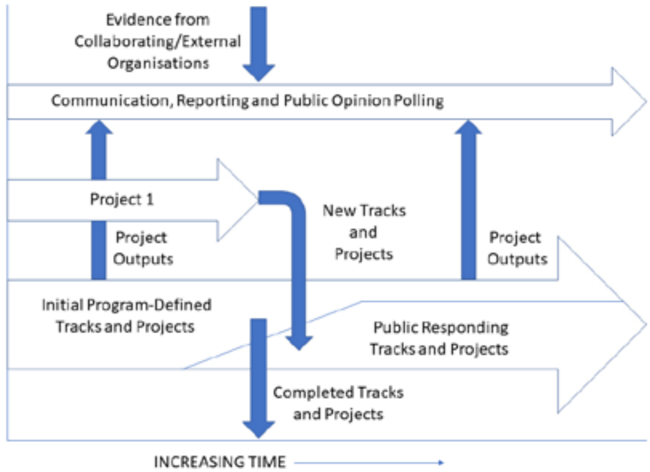

Figure 2: Flow diagram showing project development and information flow as a function of time. This shows how initial start-up projects may be replaced following inputs from social science investigations.

(Track 1, Project1). However, to start the program some assumptions about these concerns have had to be made. The projects, at start up, have been arranged into the social science Track 1 and four research tracks that are based on previously published risk perception information. These are:

- Research Track 2. What are the incremental doses to the public living near NPPs?
- Research Track 3. What is the evidence that shows that health effects are produced by exposures to LDRs and what are these effects?
- Research Track 4. How does LDR influence the development and progression of cancer?
- Research Track 5. How does low dose influence non-cancer health outcomes?

Within these four tracks, nine projects have been identified. Seven of these are radiobiology projects that will examine either cancer or non-cancer outcomes and will build upon expertise and projects that have been funded by the Federal Government as part of its research program at the CNL Chalk River Laboratory. All will study the effects of external gamma-radiation doses below 100mGy – most within the range 1 to 10mGy. These projects will be undertaken by staff at CNL in collaboration with the University of Ottawa, which will provide access to equipment and expertise not available at Chalk River. Work will be undertaken by masters and doctoral students, and by post-doctoral research fellows from the university. Of the other research projects, one will be undertaken by the University of Ontario Institute of Technology. This will look to see if living close to nuclear power plants results in a detectable increase in accumulated radiation dose by measuring stable free radicals produced by past exposures. The project will use extracted teeth donated by senior citizens living either close to or farther from southern Ontario nuclear power plants. The other project will plan for an epidemiological study of a cohort of Canadian power station nuclear energy workers and medical workers exposed to LDR. This will examine all causes of death and longevity because an increasing body of evidence suggests that radiation can influence the prevalence of a wide range of diseases including cardio- vascular disease, which like cancer is also a common cause of death. This study would be conducted by industrial epidemiologists at the School of Public Health, University of Saskatchewan in collaboration with the Radiation Protection Bureau, Health Canada and the Canadian Nuclear Safety Commission. Dosimetry data held by Health Canada would be matched with mortality data held by Statistics Canada.

The non-biological and program-driving project is the social science project (Project 1) which will provide public input and measure public responses to the research program's output with continuous feedback to the LDR Sub-Committee to provide the basis for adjustments to the program. As information on public perceptions is generated by the social science project in Track 1 it will be fed back to the LDR Sub-Committee. This committee will then adjust the ongoing program to directly address the concerns expressed by the Canadian public – including those that might be expressed by northern communities that could potentially benefit from the deployment of SMRs. No concerns expressed will be considered unworthy of follow-up. This process is shown diagrammatically in Figure 2.

The research program will be communicated to the public using a communication plan developed with the help of social scientists at the University of Saskatchewan. It is axiomatic that this dissemination is required if public opinions are going to be impacted by the program of research. The impact of communications will be assessed using both qualitative and quantitative research methodologies including polling, focus groups and citizen juries. Impacts will be fed back to communicators to optimize their presentations and the communication plan will be adjusted as appropriate.

3. Collaboration and coordination

The COG strategic program will not unnecessarily duplicate work being undertaken elsewhere. It will however, use relevant data generated by other groups in its communications. In addition, it will, wherever possible, collaborate/ coordinate activities with other global strategic low dose programs. One possibility being explored is that such research coordination should be through a new OECD Nuclear Energy Agency Advisory Group to its Committee on Radiation Protection and Public Health. Meetings have been undertaken to investigate this possibility. Also, it is possible that monies from a NEA NEST project won by Canada could be used to help fund travel for collaboration and cooperation – particularly between the participating universities.

4. Benefits and risks

The following benefits are expected. Because of it communication outputs, the public will have a better understanding of the potential impacts on the health of those exposed to radiation - at dosages that are appropriate for determining individual risks. A better understanding should reduce fears and worries about the continued operation and future development of nuclear power in Canada. The demonstrated commitment of the Canadian nuclear industry to understand, take seriously and address the concerns and worries of its potential customers should improve relationships with the Canadian public. Feedback received from the social science studies will provide information required to improve the program and industry communication strategies, programs and skills. The execution of the program will enhance the international profile of COG and the Canadian nuclear industry.

The program will also generate information required by radiation protection professionals and increase the number of Canadian experts available to meet industry needs. Outputs of the radiobiology projects will provide information of interest to several Canadian Government departments and agencies – including those that are responsible for the funding and development of the AECL-CNL Federal Science and Technology program of research. Outputs, with those produced by other research groups, will help fill gaps in our knowledge of the effects of LDR - facilitating future improvements in the advice given by radiological protection organizations such as the ICRP and the NCRP and improved risk estimates. The use of COG funds to support the training and development of new masters' students, doctoral students and post-doctoral research fellows at the participating research providers will expand the number of trained specialists in Canada. The program will increase the standing of Canadian scientists and research laboratories in the international arena and help build their communication and collaboration networks.

Three main risks have been identified. Firstly, there is risk that insufficient data will have accumulated to define the risk of changes in health status following exposure to radiation doses of around 1 to 10mGy – the most relevant with respect to public doses. However, there is a reasonable expectation that the radiobiology studies will show effects. Secondly, there is a risk that the public will refuse to accept that the research undertaken is independent and unbiased. To minimize this risk: industry input to the program and its management has been minimized and most of the work undertaken will be by university students, post-doctoral research fellows and faculty staff; staff from government departments are expected to participate in the oversight of the project management; COG will not unreasonably refuse to allow the results of projects to be published. Finally, there is a risk that until radiological protection practice and the regulation of exposures to LDR are changed the public will refuse to accept revised estimates of risk following LDR. Although the focus of the program is meeting the needs of the public, it is reasonable to expect that radiation protection professionals and those responsible for recommending regulations (e.g. in the ICRP and NCRP) will take note of project outputs. However, given that recommendations are only modified occasionally changes to dose limits and constraints are not to be expected soon – if at all. However, changes in the implementation of ALARA by national regulators is a possibility.

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A Case Study on Introducing Small Modular Reactors into a New Non-Nuclear Jurisdiction

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Abstract

A multidisciplinary study is undergoing to develop technical capacity and understand the geographical, geological, environmental, regulatory, and legal aspects of siting a small modular reactor in the Province of Saskatchewan; a non-nuclear-power jurisdiction. The ultimate goal is to produce a series of maps for the best locations for each of the considered factors, and in the process train a number of highly-qualified personnel and develop expertise that could be used to assess nuclear and other technologically complex industrial projects in any jurisdiction. This paper presents the scope of the study and identifies some of the opportunities and challenges, with focus on meeting Canadian and international regulations for siting a nuclear reactor.

1. Introduction

In 2015, electricity generation in Saskatchewan resulted in a total of 15.3 Mt of CO_2 equivalent greenhouse gas emission [1, Table A13-9], of a total emission of 75 Mt [1, Table S-4], with convential coal-fired electrical generation contributing to 30% of base-load generation [2]. Nuclear power, being low-emission technology, can contribute greatly to reducing these emissions by replacing some of the coal-fired units. In addition, being a uranium-producing Province, nuclear- power will add value to the mining process. Nuclear power provides a baseload, unlike solar power and wind energy which are intermittent. It will also facilitate the use of electric vehicles, reducing transportation emission; the transportation sector contributed 16.5 Mt of CO_2 equivalent greenhouse gas emission in 2015 [1, Table A11-16]. Given Sask Power's current generation capacity of about 4.5 GW, and it anticipated need of 7 GW by 2030, small nuclear reactors are suited for the Province's needs, particularly in remote and isolated northern communities not connected to the Province's electric grid. Even in densely populated areas, a small reactor can be used for meeting localized demands without losses in long and vulnerable transmission lines. A small nuclear reactor (from 50 to 300 MW) can also be used for district heating, process industries (e.g. heavy oil desulfurization and petroleum refining), steel making, coal gasification, hydrogen and methanol production, etc.; further reducing the greenhouse gas emissions associated with these industries.

Emerging small modular reactor (SMR) technology offers the advantage of modular manufacturing offsite, and module assembly at site; reducing the manufacturing and construction costs. SMRs can also be incrementally added as need arises and can be designed to be inherently safe. Therefore, SMRs are a viable option for a jurisdiction such as Saskatchewan which has a relatively small power demand and is geographically spread over a large area. Moreover, the Province can position itself among global leaders in nuclear research, development and training for SMRs.

The SMR technology will have to overcome the hurdles of the licensing process [3]. It is challenged by the fact that no SMR has been licensed so far and no demonstration pilot plan has been built, although the Canadian Nuclear Safety Commission is conducting pre-licensing vendor design review and the US Nuclear Regulatory Commission is considering an application for design certification [5]. Once the design licenses are issued, the acquisition of an SMR will have to gain societal acceptability. A separate study is being undertaken in Saskatchewan in this regard, supported by The Sylvia Fedoruk Canadian Centre for Nuclear Innovation [6], to investigate among other things "the societal and public policy dimensions of various energy-production technologies, including international best practices for public consultation, strategic assessment and decision support. Nuclear energy will be a focus area, both as an example of a controversial technology and because it is a source of low-carbon electricity that many experts and governments are considering in plans to fight climate change". In addition, the Fedoruk Centre is supporting the current study to examine the other challenge that will face the placement of an SMR, selecting an economically and environmentally viable site and examining the associated regulatory and technical

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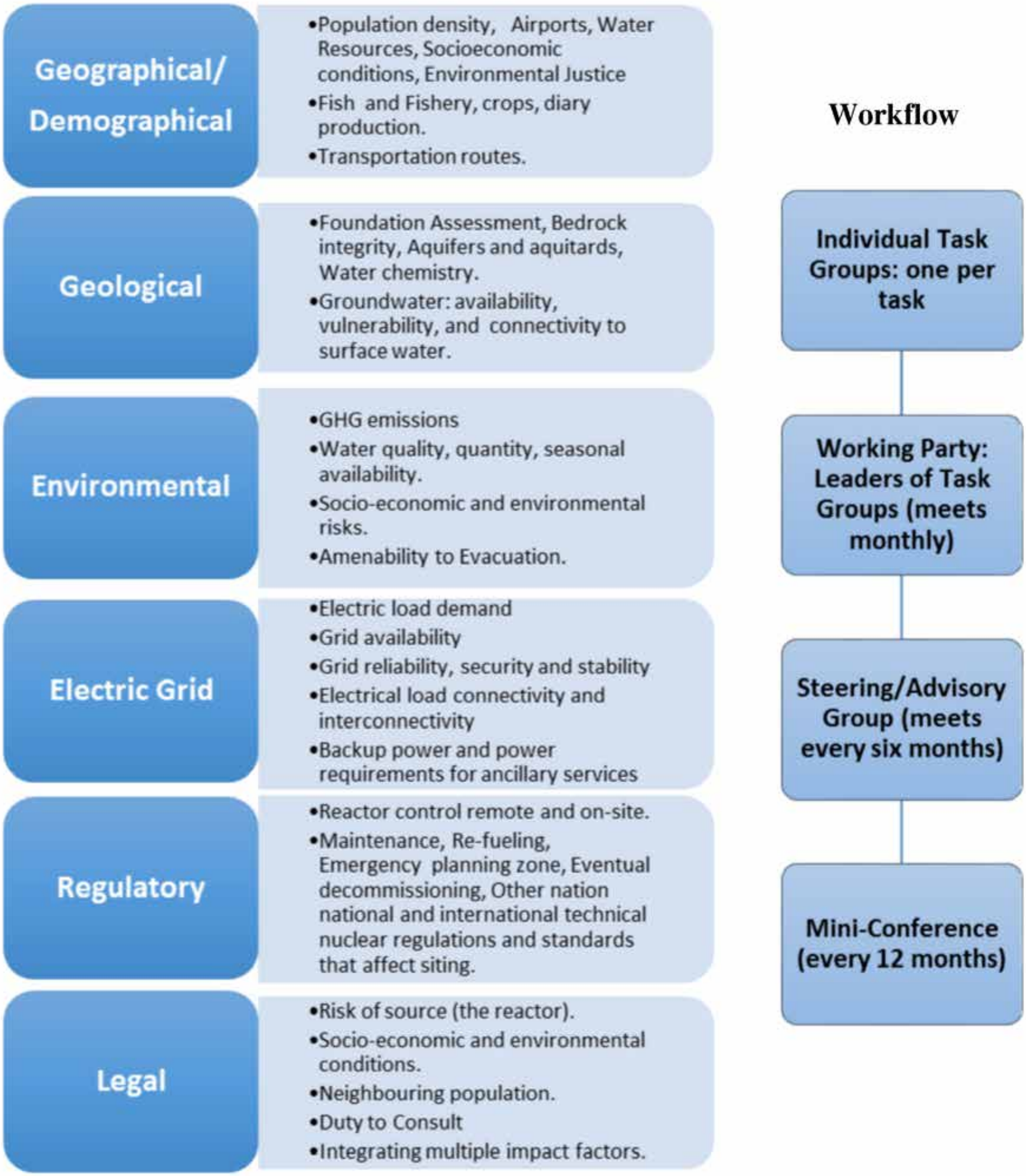

Figure 1: Work areas and work flow.

aspects [7]. The latter study is particularly relevant for a non-nuclear-power jurisdiction, and will also enable the training of highly-qualified personnel that will be needed if and when the Province decides to consider SMRs, Even if this option is never materialized, Saskatchewan can position itself as a leader in an evolving and emerging technology. This paper provide a summary of the scope of this study.

2. Concept

Any major industrial project affects and is affected by its surroundings. These crucial aspects are typically stipulated in site-licensing of nuclear power reactors [8-10]. Therefore, an SMR must be placed in a location where all site-licensing requirements are met. There are also additional siting aspects peculiar to SMRs, such as connectivity or lack of connectivity to an electric grid, remote communication and control if and when needed, transportation routes of spent fuel if not stored on site. Obviously, socio-economic factors play a role in selecting a site for an SMR. There is also a duty to consult with indigenous communities, and respect treaty rights when selecting a site for an industrial project.

This study aims at producing series of overlapped maps that show the most viable sites, in terms of a number of siting options and restrictions, discussed in the next Section. In addition to examining these aspects, the work is to be done purposefully by graduate students and emerging researchers to train highly-qualified personnel and develop the necessary expertise. The wide scope of the study also enables dialogue among workers in various disciplines, and indirectly creates awareness of the merits of nuclear power and the thoroughness of the technical practices associated with this technology. This study will also act as a model for use by currently non-nuclear jurisdictions considering nuclear power as an option, and is suited for choosing sites for any mega project that by definition involves interaction with the surroundings.

3. Approach

Several focus areas were identified for this today. Each of those areas are discussed below and each is considered independent of the others. However, the research teams meet regularly to report progress since the initiation of the project in February 2017. In addition, the project has an advisory/steering group at the national level, which meets semiannually to provide feedback and assistance and information. For consistency, a common spatial reference schema was selected for the project, based on the National Topographic Mapping System of Canada. This schema has a hierarchical organization, based on latitude and longitude, to facilitate the siting analyses at a variety of scales and measurement units.

3.1 Geography

Geographical parameters under consideration include population distribution and density; availability of surface water, airports, highways, railways, transmission lines; and restrictions imposed by land use, protected areas, wet lands, agricultural activities, groundwater protection slopes, and flooding. The suitability of sites that are obvious candidates, such as existing mines and power plants, can be assessed in view of the above factors. A geographic information system (GIS) is being constructed to coordinate the interchange and analysis of data between all of the research teams.

3.2 Geology

Regulatory guidelines and geological considerations concerning nuclear reactor site criteria are being studied. These include identification of active seismic zones, the presence or absence of surface faulting, potential ground motion, foundation conditions of the local soils and subsoils, e.g. glacial deposits, and surface and subsurface hydrology. Whilst not located in a recognized seismic zone, an assessment of the Province must include a comprehensive assessment of foundation integrity, the location of known and unknown faults and fracture zones, the potential for small-scale seismic events due to salt collapse, impacts of glaciolacustrine clay-rich deposits on foundation stability, the presence of anthropogenic activities such as mining and water/CO_2 disposal wells, surface and subsurface hydrology and the distribution, thickness and character of the overlying sediment within Saskatchewan.

3.3 Access to water

Most nuclear power facilities are heavily reliant on access to adequate water resources in terms of both quantity and quality. Factors that influence water availability and appropriateness for use are being evaluated. These include calculation of surface and groundwater water volumes available within a reasonable distance to a possible SMR site, identification and cumulative impacts assessment of competing (existing and projected) water consumers, quantification of potential impacts of a changing climate on water availability, identification and quantification (as possible) of siting and design considerations per water-related climate extremes, identification and evaluation of proximate water resources and the potential impact or change to those resources over the course of a sources, evaluation of opportunities for heat extraction through innovative cooling pond design for water reuse and recycling, design of related produced or thermally enhanced water treatment, storage and environmental discharge systems.

3.4 Groundwater

Groundwater systems are being considered from multiple contexts, including; groundwater protection, waste management and water supplies. A series of maps will be produced showing the potential vulnerability of groundwater supplies and connected surface water supplies to contamination from a variety of possible incidents or legacy impacts associated with nuclear power. These maps would be based on existing information from databases maintained by the Saskatchewan Water Security Agency, the Saskatchewan Geological Survey, other government reports and other published data. Contaminant transport simulations will be produced based on a suite of typical settings to provide a better understanding of timelines involved with potential contamination problems.

3.5 Electric grid

Issues related to the electrical grid are being studied, in terms of electric load demand, availability of sufficient water for cooling, connectivity for protection and control, grid availability, grid reliability- security-stability issues, load connectivity and interconnectivity, back-up power and power requirements for ancillary services. Criteria include existing and future connections available to the Saskatchewan electrical grid, as well as opportunities for microgrids using other generation sources such as: renewable energy (wind farms, hydro power), oil-gas fired power units and the potential role of storage under dispatch scenarios. Midwest Reliability Organization (MRO) and North American Reliability Corporation (NERC) regulations and standards related to siting of nuclear power are being taken into consideration.

3.6 Transportation routes

Guidelines needed to address major transportation challenges and requirements are being studied. Maps that evaluate the suitability of sites for an SMR will be provided. Considering the specifications of the highway network in the Province, a multi-objective risk analysis methodology is being developed, taking into account the Packaging and Transport of Nuclear Substances Act, Provincial regulations, and various other factors, including: road geometry, functional classification, pavement conditions, location, and traffic conditions. Several points of interest are being defined across the Province as major origins and/or destinations for transportation of nuclear materials. The province is divided into many smaller zones and each zone is evaluated and ranked based on its risk score representing the and exposure to transportation risks.

3.7 Exclusion zone

An SMR will be equipped with designed barriers to prevent a large release of radioactivity (source term) to be spontaneously released during a hypothetical nuclear reactor accident. However, an exclusion zone around the reactor may be required by regulators: an area under full control of the licensee within which all activities (people and properties) can be restricted. A one-km radius is typical for a large power plant. The much lower of SMRs may allow a smaller radius, and perhaps none at all if buried underground. The size of the exclusion zone and its impact on site selection is being studied, considering national regulatory requirements and international standards.

3.8 Socio-economic and environmental risks

A number of socio-economic and environmental factors influence site selection. These include local socio-economic and environmental conditions, and nearby population. Qualitative information (e.g. social activities, and land-use practices), quantitative data (e.g. reactor power, operation time, meteorological records, census information, and economic data), calculated data (e.g. environmental, economic and social impacts), and empirical data (e.g. inputs from experts and stakeholders) are being examined.

Site selection is inherently linked to a number of impact factors. These factors are interrelated with each other and exhibit various uncertainties, leading to a complex system involving multiple socio- economic and environmental components. To comprehensively examine site suitability, a fuzzy classification-based multicriteria decision analysis method will be advanced based on vulnerability analysis, risk assessment, and evacuation-feasibility evaluation.

3.9 Legal ramifications

The legal aspects of nuclear power generation in Saskatchewan would include general regulatory issues and liability issues as well as the quite distinctive set of issues that might arise in the context indigenous communities. The goal within this project is to develop independent scholarship that is both descriptive of the legal/regulatory regimes that must be followed and how they impact on site selection issues, but also prescriptive in terms of processes that would be advisable to be employed in a possible site selection exercise.

4. Conclusion

This multidisciplinary study will not only provide decision makers with useful information if and when the Province of Saskatchewan decides to acquire an SMR, but it will also provide a framework for similar jurisdictions and for other mega projects. The focus on training highly qualified personnel will also provide human resources for future endeavours and in the process expose many researchers outside the conventional field of nuclear technology with exposure to SMRs and related aspects. The generated databases and learned recognition of critical and non-critical siting factors will constitute a significant contribution of this multi-disciplinary study.

5. Acknowledgments

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Customized Irradiation Sites for Medical Isotope Production

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Abstract

A new medical isotope device based on holmium-166 ($t_{1/2}$ = 27 h) has shown great promise for treating liver metastases, which are associated with many common cancers. The device is prepared by bombarding polylactic acid microspheres containing natural holmium with thermal neutrons in a nuclear research reactor. The objective of this work was to design and validate an appropriate neutron irradiation site for producing this medical device at the McMaster Nuclear Reactor (MNR). Initial neutron irradiations resulted in massive damage to the microspheres. Further experiments indicated that this damage was due to gamma heating within the sample, not site temperature or radiolysis. Passive cooling and gamma shielding were introduced to improve the outcomes of the holmium activation. MNR is now an approved supplier of this medical device for clinical trials in Europe, and will begin supplying this material for North American clinical trials when they launch later in 2018.

1. Introduction

Liver metastases are associated with many common cancers, and can limit both life expectancy and treatment options. Moreover, as the global population ages, the incidence of primary liver cancer is on the rise, and this disease typically has a poor prognosis [1]. Over the last 15 years, researchers in The Netherlands developed a new radioembolic device based on the mixed beta-gamma emitting radioisotope holmium-166 ($t_{1/2}$ = 26.8 h; $E\beta_{max}$ = 1.77 MeV (50%), 1.85 MeV (49%) $E\gamma$ = 81 keV (6.7%)). These "QuiremSpheres" are prepared by incorporating non-radioactive holmium into polylactic acid microspheres, then exposing the spheres to a thermal neutron flux to produce the therapeutic radioisotope via the $^{165}Ho(n,\gamma)^{166}$ nuclear transformation. The radioactive microspheres are then suspended in biologically compatible media, subjected to rigorous quality control testing, and injected into the which then carries them to the liver.

QuiremSpheres have a key advantage over radioembolic devices based on yttrium-90 because the gamma emission from holmium-166 can be used to visualize the microspheres *in vivo* using Single Photon Emission Computed Tomography (SPECT). Moreover, the high holmium content of the spheres also renders them visible by X-ray methods such as CT, since holmium is a heavy element, and by Magnetic Resonance Imaging, since holmium (III) is highly paramagnetic. The multi- modality imageability of QuiremSpheres enables attending physicians to fine-tune treatments to achieve optimal clinical outcomes [2].

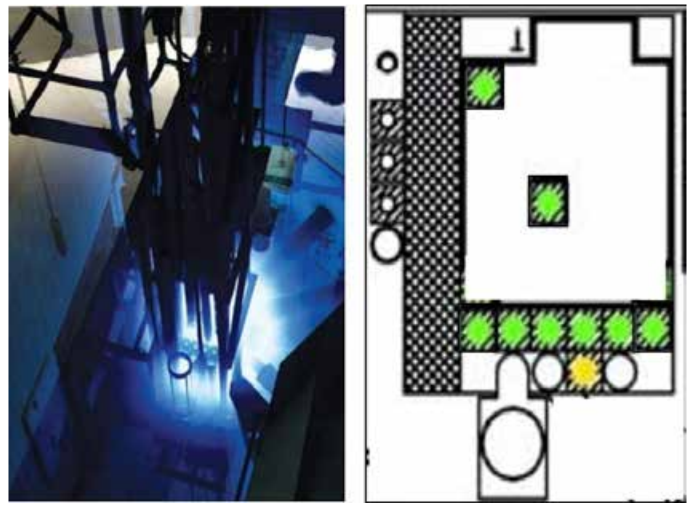

Figure 1: MNR Reactor core (left) and schematic representation of irradiation sites (right).

QuiremSpheres have recently moved from validation studies in the laboratory, into clinical trials in European hospitals. However, due to the limited half-life of holmium-166, if QuiremSpheres are to be deployed in North America, a local production site must be established. The McMaster Nuclear Reactor (MNR) is an obvious candidate due to its numerous in-core irradiation sites (see Figure 1), its high flux ($\Phi \leq 1 \times 10^{14}$ n/cm^2•s), and its open-pool design which facilitates on-line sample insertion and removal. Moreover, MNR is located on the main campus of McMaster University (Hamilton, ON) and is in close proximity to two international airports which will enable rapid distribution to clinical trial sites. Finally, the MNR containment building is connected to a High Level Laboratory Facility that is designed, equipped, and licensed for handling open sources of radioactivity at the TBq level. This will provide an appropriate space for post-irradiation processing of the QuiremSpheres.

1 McMaster University, Hamilton, Ontario, Canada

However, the generation of active QuiremSpheres is complicated by the thermally sensitive nature of their base material, polylactic acid. Extensive work has been carried out at the Technical University of Delft s nuclear research reactor to elucidate the impacts of neutron activation conditions on microsphere quality, but these findings are not readily translated MNR because the neutron irradiation facilities at these two reactors vary significantly.

Thus the objective of this work was to assess the feasibility of producing QuiremSpheres at MNR using existing or custom designed neutron irradiation facilities.

2. Initial neutron activation experiments

A ″patient dose: of non-active QuiremSpheres (600 mg, 19% Ho) was obtained from Quirem. A Ho-166 activity of 8-11 GBq is typically required for patient administration; accordingly, these initial experiments aimed to produce 18 GBq at End of Irradiation (EOI), which in the future would allow sufficient time for processing and quality control testing of the microspheres prior to administration.

Due to the large dimensions of the vial in which the sample was provided, this initial neutron activation was

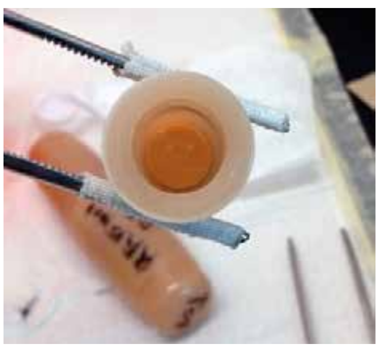

Figure 2: Irradiated microsphere sample showing catastrophic thermal damage.

conducted in site 9C ($\Phi = 9 \times 10^{12}$ n/cm^2•s; shown in yellow on Figure 1) because it can accommodate larger samples than the higher-flux ″capsule″ sites (shown in green). The QuiremSpheres sample was loaded into the reactor core and rotated continuously to ensure uniform exposure of the sample to the reactor throughout the 4 h neutron irradiation. After EOI, the irradiation assembly was stored under water for several days to allow some of the activity to decay prior to sample handling. Upon retrieval of the sample, it was discovered that the microspheres had completely melted and reformed as a solid block inside the irradiation vial (see Figure 2).

Additional experiments showed that when small (~50 mg) amounts of QuiremSpheres are irradiated under identical conditions, the spheres survive the irradiation intact. This finding suggested that dispersing the microspheres during irradiation might improve their viability. In consequence, a second obtained, removed from its sterile vial, and transferred into a thin-walled polyethylene vial with a hollow, thin-walled polyethylene insert in the centre, which forced the spheres into an annular configuration (see Figure 3).

An identical 4 h neutron activation was conducted using this new vial configuration, and greatly improved results were obtained. Upon opening the sample vial and removing the insert, the QuiremSpheres had a powder-like consistency rather than the solid block observed previously. After addition of a buffered saline solution, optical microscopy was used to verify that the sample was still composed of microscopic spherical particles (see Figure 4). This vastly improved result was attributed to the superior heat transfer enabled by sample dispersion and the thinner vial walls.

While the new irradiation geometry solved the problem of thermal degradation, the vial assembly used to achieve this positive result was not compatible with the stringent requirements for Good Manufacturing Practices (GMP) that surround medical device fabrication. Quirem subsequently produced a higher quality vial in a similar configuration, but neutron irradiations of QuiremSpheres in this new vial also failed to produce viable spheres, quite possibly because the thicker walls of the new vial prevented efficient heat transfer from the microspheres to the environment.

3. Neutron activation in water-cooled tube

Having tentatively identified poor heat transfer as a signif-

Figure 3: Thin-walled polyethylene vial with poly insert designed to disperse sample.

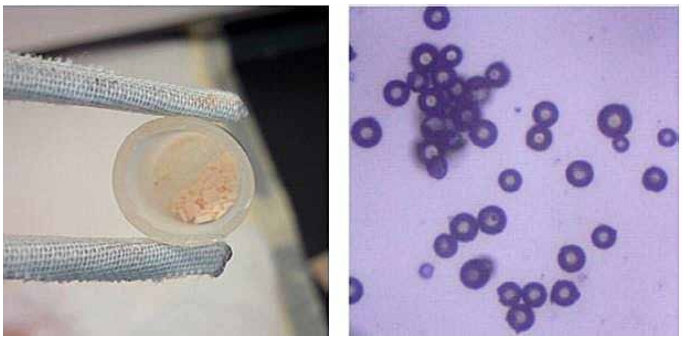

Figure 4: QuiremSpheres after irradiation as a cylindrical annulus.

icant barrier to producing clinical quality QuiremSpheres at MNR, attention was turned to providing a means of cooling the sample during irradiation. Accordingly, a RIFLS tube was modified by inserting aluminium sheeting down its core, then flooding the new smaller-volume tube with pool water. A new patient dose vial obtained from Quirem was fitted with an aluminium pig-tail, to which was attached a small lead weight. This assembly was then inserted into the flooded RIFLS tube and positioned carefully in the maximum flux zone (Figure 5). Following irradiation, high quality microspheres were obtained, indicating that even the limited passive cooling provided by the presence of pool water in the irradiation tube has a significant and beneficial effect.

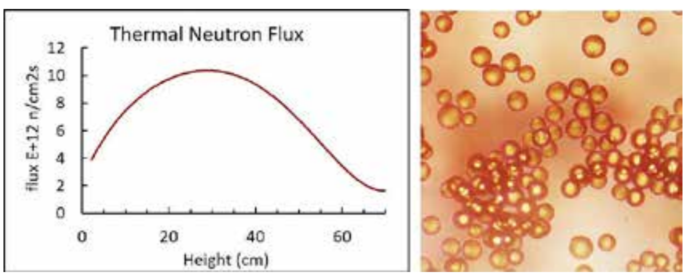

Figure 5: Vertical flux distribution in 9C (left); QuiremSpheres after irradiation in flooded tube (right).

While the "flooded-tube" approach appeared capable of producing clinical quality QuiremSpheres, certain aspects of this methodology were not compatible with GMP-type clean-room protocols. Specifically, immersing the patient dose vial in reactor pool water resulted in contamination of the vial with ultra-trace quantities of a number of radioisotopes, including long-lived silver-110m. Utilization of this approach risks cross-contamination of both the microsphere processing facility and the microspheres themselves with an assortment of undesirable radionuclides.

4. Neutron activation in lead-shielded site

Experiments with the flooded RIFLS tube demonstrated that high quality microspheres can be obtained at MNR if the effects of sample-heating can be countered; however, an alternative approach would be to prevent sample heating from occurring in the first place. As the reactor pool is maintained at < 40°C and the microspheres are thermally stable up to 100°C, the sample melting observed in early experiments was attributed to gamma heating due to proximity to the reactor core.

Thus if the sample could be shielded from the core's gamma emmissions during neutron activation, it might be possible to avoid heating of the sample, which would preclude the need for cooling.

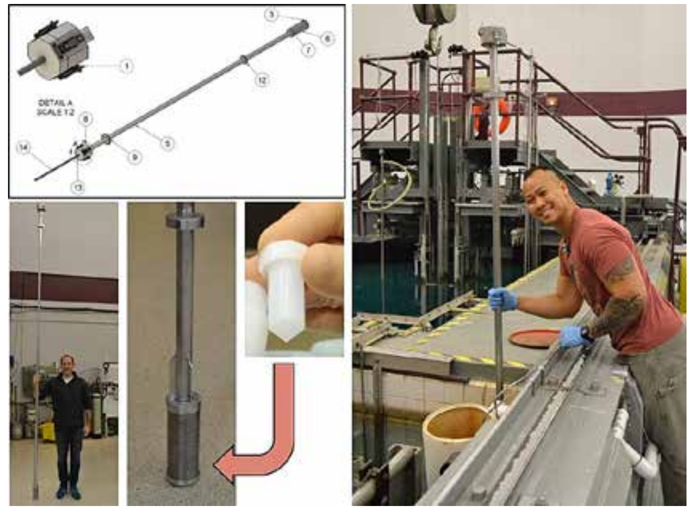

Figure 6: "Holmium rig". Top left: schematic. Bottom left: actual. Bottom centre: close-up of lead- lined sample chamber Right: rig being loaded in reactor pool prior to irradiation.

In consequence, a lead-lined irradiation tube was designed and fabricated (see Figure 6). Modelled on a standard MNR RIFLS tube, a sample can be inserted through the top of this positioned in the lead-lined chamber at the bottom. The tube is then capped, fitted to the standard motor to allow rotation during irradiation, and inserted into position 9C of the reactor core.

The quality of the microspheres obtained from the new "holmium rig" was excellent (see Figure 7), indicating that the lead shielding of the holmium rig eliminates sample heating by reducing the incident photon flux. A series of irradiation experiments indicated that no damage is seen in microspheres irradiated up to 10 h, making it possible for MNR to produce patient doses containing ≥ 40 GBq at EOI. As only 8-11 GBq is required at time of administration, these high activity levels at EOI will enable MNR to distribute QuiremSpheres to hospitals over a large geographical area. To date, MNR has completed the validation process that is required to become a clinically approved supplier of QuiremSpheres for European clinical trials.

5. Rapid-removal lead-shielded site

Following the success of the lead-lined holmium rig,

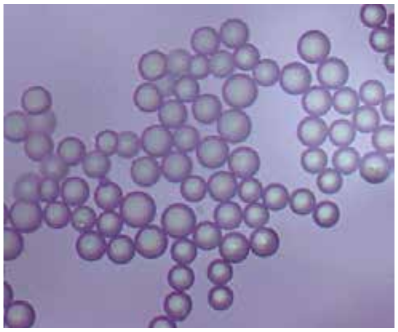

Figure 7: Optical microscope image of QuiremSpheres produced in lead-lined holmium rig.

attention turned to optimizing this process by reducing doses to reactor personnel. Even when empty, the holmium rig produces significant radiation fields at end of irradiation due to the presence of incidental activation products such as sodium-24 within its aluminium matrix. The rig is therefore stored underwater for at

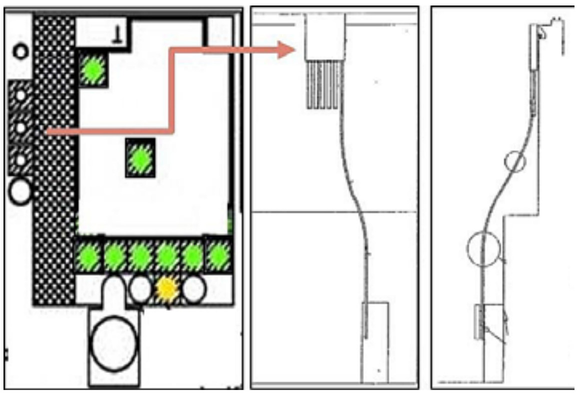

Figure 8: Schematic diagrams (left right): MNR core; head-on Dry Tube; side-on Dry Tube showing irradiation position a bottom behind lead block.

least an hour prior to towing it to pool-side to unload the sample, but even after 2-3 h, significant dose rates remain. For samples such as QuiremSpheres, where it is essential to ship the sample as soon after EOI as possible, this will ultimately imposes an unduly high dose rate burden on MNR operators.

To address this problem, a fixed-position QuiremSphere irradiation facility was designed and installed at the periphery of the MNR core (see Figure 8). This so-called "Dry Tube" primarily from organic polymers, not aluminum, and as such, does not produce the high radiation fields typical of the aluminum-based RIFLS tubes. To initiate irradiation, the sample is lowered on an extraction line to the bottom of the tube, which is located behind a large lead bock that provides gamma shielding of the site. At EOI, the sample is retrieved immediately by retracting the line: activity losses are minimized because no delay to retrieval is required, and personnel doses are minimized because no handling of an activated aluminum irradiation tube is required.

At the present time, characterization of the new Dry Tube facility is ongoing. Preliminary measurements have indicated a thermal neutron flux of approximately 4.6 x 10^{12} n/cm^2•s, which, while lower than that in

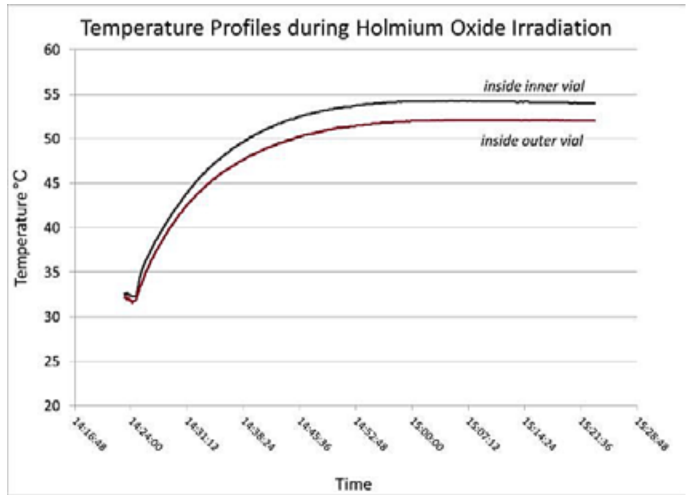

Figure 9: Temperature inside double-encapsulated holmium oxide sample during neutron activation in MNR Dry Tube.

the holmium rig position 9C, will allow activation of QuiremSphere patient doses to clinically relevant levels. A recent thermal analysis (see Figure 9) has demonstrated that the temperature within a double-encapsulated Quirem-provided vial is well below 60°C during irradiation, suggesting that it should be possible to produce clinical-quality QuiremSpheres in this new facilitysss.

Additional details on the progress of the new Dry Tube facility will be presented at the CNS meeting in June, along with the results of initial microsphere activations.

6. Conclusion

Installing a lead-shielded irradiation facility has proved an effective means of reducing gamma heating in thermally sensitive samples. With this new facility in place, the McMaster Nuclear Reactor has been able to achieve the highest activity yet in clinical-quality QuiremSpheres. McMaster is now an approved manufacturer of this device to support on-going clinical trials in Europe. It is expected that McMaster will become the major North American supplier of this promising new radioisotope therapy once clinical trials begin later in 2018.

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Project: Savannah River Site – Salt Waste Processing Facility (SWPF) – Aiken, South Carolina
Atkins is the subcontractor leading SRS SWPF Commissioning and Operations.

Meet the President

John Luxat was elected President of the Canadian Nuclear Society at the beginning of June, 2018 and serves as the 42nd President for the 2018-2019 year. This is a reprise role for him, having served as the 29th CNS President in 2005-2006. He is currently a faculty member of the Department of Engineering Physics at McMaster University in Hamilton, Ontario, where he is a Professor and NSERC/UNENE Senior Industrial Research Chair in Nuclear Safety Analysis and Thermal hydraulics.

John was born in Southern Rhodesia (now Zimbabwe) in 1945, the son of a rugged, peripatetic miner and a mother with immense patience. He was brother to two remarkable sisters, one older and the other younger than him. From an early age until he left for university, he spent the majority of his life in Rhodesian boarding schools where, with time, he successfully completed his Cambridge University "O-Level" examinations, at Jameson High School, in Kadoma, and his Cambridge "A-Level" examinations at Chaplin High

School, in Gweru. Twice a year there were school vacations during which he would spend time at home that, invariably, was located at another remote region "in the bush" where there was a prospective mine being evaluated by his father for possible development and exploitation by one of the large mining corporations operating in Rhodesia. During these periods of vacation he developed skills to entertain himself, including a remarkable ability to operate a record player and reading an eclectic range of literature – some of it pulp fiction then, more gradually, moving onto the classical masterpieces, including Dickens, Thomas Hardy, Maugham, Orwell, Dostoyevsky, Tolstoy amongst others. He has continued these interests throughout his life, albeit that he graduated from record players to CD players and iPods and extended his reading to include Mordecai Richler, John Irving, Philip Roth and many more contemporary authors.

In 1964 he enrolled in the University of Cape Town (UCT) where he studied Electrical Engineering – specifically the Electrical Engineering B stream which was considered to be a research preparation program requiring four years of Physics, Pure Mathematics and Applied Mathematics, interspersed with electrical circuits and electronics (the transistor variety which was the state-of the art at that time). He continued his studies in Electrical Engineering at UCT, enrolling in a Master's degree program and specializing in automatic control systems. His time at UCT was filled with many memorable events, four of which were particularly life-defining.

The first event occurred at the end of his first year

when, after spending an extra month slogging through a mandatory machine shop course, he met Gladys, a beautiful young social science student who was travelling on the same student train from Cape Town to Rhodesia and then onward to her home in Zambia. A romantic relationship, initiated on the two day train journey, was cemented five years later when they married in Zambia in 1969 prior to immigrating to Canada.

The second memorable event occurred in 1966 when the apartheid government banned the President of the National Union of South African Students (NUSAS) and placed him under house arrest, one of many abhorrent punishments they imposed on opponents of their apartheid policies. John participated in a major protest on the grounds of the downtown Cape Town St. George cathedral, during which truckloads of cadets from a nearby naval base arrived and attempted to drive the protesters away using military training fire-crackers and tear gas. The protesters stood their ground and the cadets, tiring of their "games", departed. A month later the protesters were rewarded by NUSAS granting them seats in the UCT Great Hall to attend the Annual Day of Affirmation of Academic Freedom lecture presented by Senator Robert F Kennedy. This turned out to be a famously uplifting speech, referred to as his "tiny ripple of hope" speech, derived from a term he used to describe the effect small acts of goodness can impart on large acts of consequence.

The third and fourth events occurred when sons David and Daniel were born, in 1975 and 1978, respectively.

In August 1969 he and his new wife left South Africa and their childhood homes to start a new life in Canada, initially in Windsor, Ontario. He obtained his Ph.D. degree at the University of Windsor, once again in Electrical Engineering but this time researching adaptive control systems. After graduation in 1972 they moved to Toronto where he had accepted a position at computer consultancy named DCF Systems Ltd. Which later became Gellman, Hayward and Partners Ltd. His first contract was at AECL Power

Projects, Sheridan Park where he developed a plant simulator that was used to test the Bruce NGS A DCC software before being shipped to site. Thus began his osmotic drift into nuclear engineering. Further nuclear contracts arose at AECL, in large measure the result of the reputation for delivering computer software solutions that Dr. Harvey Gellman and Jim Hayward had established. These included developing control software for the High Current Test Facility, a 1970's Chalk River linear accelerator, and the Spatial Modal Kinetics (SMOKIN) code to analyze spatial control of the 1250 MW(e) CANDU reactor concept that was being studied at AECL under Ontario Hydro funding. The latter project led to a contract at Ontario Hydro's Nuclear Studies and Safety Department (NSSD) to further develop SMOKIN for nuclear safety analysis of accidents involving 3-D reactor kinetics behaviour. Six months later, in 1977, he was offered a full-time position at NSSD by then department manager, Dan Meneley.

His career at Ontario Hydro progressed over the years from 1977 to 1993 with increasing involvement in diverse technical areas of nuclear safety analysis, ranging from reactor physics, conceptual design and assessment of special safety systems, thermal hydraulics, fuel and fuel channel behaviour and beyond design basis accidents. This broadened technical involvement was accompanied by increasing responsibilities, moving from Supervising Design Engineer to Thermal Hydraulics Engineer, supervising approximately 30 technical staff, During this period, he became involved in a number of interesting technical activities and challenges which included: attending, as a member of the Canadian delegation, the

IAEA post-Chernobyl accident review meeting held in August 1986; directed a study, including the work performed by Argonne National Laboratory in the U.S.A. and was and was lead author of the report *Analysis of the Consequences of Failure to Shutdown Following a Large Loss of Coolant Accident in a Pickering NGS A Unit*, submitted to the post-Chernobyl Ontario Nuclear Safety Review (the Hare commission) in 1986; spent a year of his life as a member of the Darlington Unit 2 fuel failure investigation team and edited the report *Darlington NGS: Report on the Investigation into Fuel Damage Causes Following the Unit 2 N12 Event*, which was submitted to the AECB in 1992.

In 1993 a major reorganization of Ontario Hydro occurred which resulted in the disbanding of the much admired Design and Development Division which had led the licensing of Pickering B and Bruce B stations, as well as the design and licensing of the flagship Darlington station. As a result of the reorganization he was appointed Senior Technical Consultant in the newly created Nuclear Technology Services Division – an individual contributor position with little formal responsibility in the operational support role of the division. Undeterred, he focused his efforts on advanced nuclear initiatives, and providing leadership within Ontario Hydro in the development of novel, state-of-the-art methods and solutions in diverse nuclear safety technology disciplines. A memorable period occurred between 1994 to 1997 when he was appointed technical lead for nuclear engineering and nuclear safety in a joint AECL Technologies/OH feasibility study for the US DOE and, in a subsequent separate Canada/Russia feasibility study to disposition excess weapons plutonium by utilizing MOX fuel in CANDU reactors (Bruce A was the target station). This led to many weeks-long visits to Washington DC, Moscow and various Russian nuclear laboratories, as well as smoke-filled study contract negotiations with the Russian Ministry of Atomic Energy (MINATOM). This was a very interesting period since it was immediately after the breakup of the Soviet Union, and was referred to by some as the "wild, wild East".

However, the Ontario Hydro Nuclear reorganization was not very effective and a team of American nuclear engineers was hired to conduct a recovery of the nuclear part of the organization. This was a stress-filled time for many in Ontario Hydro Nuclear. However, for John, it resulted in him being brought back in 1998 within the mainstream organizational fold as Manager of Nuclear Safety Technology in the Nuclear Safety Analysis Division. His responsibilities included: development and enhancements of methodology for nuclear safety analysis; developing and implementing governance of nuclear safety analysis and associated engineering and scientific software used in analysis; and technical direction of Ontario Power Generation's nuclear safety R&D program. During this period the formation of Ontario

Power Generation (OPG) occurred.

During 33 years working for Ontario Hydro/OPG he represented the utility on various national and international committees, including: a member of the CANDU Owners Group (COG) Safety & Licensing R&D Technical Committee and various Working Groups; external member of AECL's Products & Services Safety Review Committee; Canadian member of Principal Working Group 2 of the OECD's Committee for the Safety of Nuclear Installations (CSNI) and the subsequent Working Group on Accident Management and Analysis (WGAMA); nominated to the International Atomic Energy Agency (IAEA) working group for the *1997 International Symposium on Nuclear Fuel Cycle: Adjusting to New Realities* and a lead author of a key issue paper on plutonium management.

In 2002 OPG sold off their Nuclear Safety Analysis Division to a UK company, resulting in the formation of Nuclear Safety Solutions (NSS) Ltd. John joined the new company as Vice President, Technical Methods, where he stayed until 2004 when he received an "offer he could not refuse". He left for McMaster University in Hamilton, where he assumed the position of Professor and NSERC/UNENE Industrial Research Chair in Nuclear Safety Analysis and Thermal Hydraulics. At McMaster he conducts research into safety analysis methods such as: supporting fuel channel integrity during design basis accidents; beyond design basis accidents including severe accident behaviour, accident mitigation and risk assessment; and more recently, research in Small Modular Reactors (SMR).

He and Gladys also relocated their home from North Toronto to Dundas, a small village in the west end of Hamilton (actually amalgamated with Hamilton). This was a fortuitous move since it provided him with an extra 90 minutes of sleep in the morning and the benefit of an extra 90 minutes of hypothetical evening relaxation due to the avoidance of daily commuting between the two cities. In this period their two sons graduated from university and established their careers- older son, David, in the nuclear safety area working in Pennsylvania on severe accident analysis and risk assessment, and younger son, Daniel, a lawyer in the Federal Department of Justice's Toronto office working primarily on aboriginal issues.

He is an active member of the CNS, being one of the earliest members (member #211) and the American Nuclear Society (member for 30 years) serving in leadership roles such as President 2005-2006 and 2018-2019, Executive Chair of the CNS Annual Conference in 2005, 2006 and 2018. He is a member of the Executive Committee of the American Nuclear Society Thermal Hydraulics Division (THD), chairs the THD Conference Planning Committee, a member of the THD Program Committee, and a member of the THD Honours & Awards Committee. He served as General Chair & Chair of Organizing Committee for the 14th International Conference on Nuclear Reactor Thermalhydraulics (NURETH-14) held in Toronto in 2011. Currently, he is General Chair of the ANS Embedded Topical Meeting on Advances in Thermal Hydraulics (ATH 18) at their upcoming Winter Meeting in Orlando, Florida, in November 2018. He also chairs the International Organizing Committee for the 25th Conference on Structural Mechanics in Reactor Technology (SMiRT-25) to be held in Charlotte, NC in August 4 – 9, 2019.

He serves or has served on numerous boards and advisory boards including: the Terrestrial Energy Inc. Advisory Board, the Project Advisory Committee of the Sylvia Fedoruk Canadian Centre for Nuclear Innovation, Saskatchewan, Board of Directors and VP, American Association for Structural Mechanics in Reactor Technology (AASMiRT), the Advisory Board of the International Association for Structural Mechanics in Reactor Technology (IASMiRT), Board of Directors of AECL (2008-2013). He currently chairs the International Nuclear Energy Academy (INEA).

Among his honours and awards are: elected Fellow of the Canadian Academy of Engineering (2012), elected member of the International Nuclear Academy (2012), Technical Achievement Award of the American Nuclear Society Thermal Hydraulics Division (2012), CNS/CNA Canadian Nuclear Achievement Award for "Significant Contributions to the Safety Analysis, Successful Licensing and Safe Operation of CANDU Reactors" (2004), Pakistan Nuclear Regulatory Authority, Award for Contributions to Enhancing Nuclear Safety (2004).

Radiation Health Effects

The primary way radiation affects our health is through breakage of DNA molecules. When it does, three things can happen: **1) The DNA is repaired properly; 2) The DNA damage is so severe that the cell dies (**deterministic effects**); or 3) The cell incorrectly repairs itself, but it continues to live (**stochastic effects**). Stochastic cell damage** could have no further effect, or the effect could show up later in life. Cancer and hereditary effects may or may not take place. Epidemiological studies have not been able to show any excess cancers or other diseases in people chronically exposed to radiation at doses lower than about 100 mSv.

Dose (mSv)	Limit or Health Effect
> 5,000	Dose which may lead to death when received all at once
1,000	Dose which may cause symptoms of radiation sickness (e.g. tiredness and nausea) if received within 24 hours
100	Lowest acute dose known to cause cancer
30-100	Radiation dose from a full body computed axial tomography (CAT) scan
50	Annual radiation dose limit for nuclear energy workers
1.8	Average annual Canadian background dose
1	Annual public radiation dose limit
0.1-0.12	Dose from lung X-ray
0.01	Dose from dental X-ray
0.01	Average annual dose due to air travel

The full article can be found at the CNSC Website.

www.cnsc-ccsn.gc.ca/eng/resources/radiation/introduction-to-radiation/radiation-health-effects.cfm

GENERAL news

(Compiled by Colin Hunt from open sources)

More Than 5,100 People Toured the Bruce Power Site This Past Summer

More than 5,100 people took advantage of the Bruce Power Summer Bus Tour Program, which ran in July and August. Visitors came from across Canada (from Newfoundland to British Columbia), across North America (including Texas and Florida) and the world (including Australia and Scotland).

"Every summer, we continue to be blown away by the interest and demand we see for our bus tour program," said Chris Mercanti, Manager, Community Relations. "This year, we offered three bus tours per day. We were excited to see the enthusiasm people had, not just for the program, but also for learning more about nuclear power."

The Summer Bus Tour Program has continued to increase in popularity year-over-year since it began in 2014.

The Bruce Power Visitors' Centre has resumed its regular hours of Monday to Friday, 9 a.m.-4 p.m. Groups are always welcome, and bus tours can be arranged if they meet certain specifications. Call the Visitors' Centre at 519-361-7777, email BNPDVisitorCentre@brucepower.com or visit www.brucepower.com/visit-us.

OPG Investing in Pickering Unit 1

Ontario Power Generation's (OPG) Pickering Nuclear Station Unit 1 was safely shut down on September 1, 2018 to begin a planned maintenance outage that will help ensure reliable, low cost electricity for the province.

"The Pickering station provides 14 per cent of the electricity Ontario depends on and our staff knows the key role it plays in the electricity system," says Glenn Jager, OPG Nuclear President and Chief Nuclear Officer. "This work will ensure the units are ready to deliver the power Ontario needs."

Unit 1 is the third planned outage at Pickering following successful Unit 4 and 5 outages completed earlier this year. During this time, staff have completed all required work with zero injuries, which is a testament to the strong safety culture that exists at the station and throughout OPG's Nuclear organization.

During the outage, OPG will invest $77.3 million in maintenance and inspection projects. This is part of OPG's plan to improve Pickering's performance to ensure this important baseload electricity asset continues to provide clean energy. OPG is applying for a licence at Pickering to operate until 2024. The continued operation of the Pickering station will save Ontario electricity customers up to $600 million and avoid 17 million tonnes of carbon emissions.

OPG and Bruce Power Working Together to Deliver Low Cost Electricity to Ontario Families and Businesses

On August 27, 2018, Ontario Power Generation (OPG) and Bruce Power released their 2018 collaboration report, Powering Ontario Together. The report highlights innovative, collaborative initiatives that will drive efficiencies and deliver reliable, low cost electricity to Ontario's families and business for the long term.

"OPG and Bruce Power have a history of collaboration. It's great to see our teams finding efficiencies and working together to create the best possible outcomes for our refurbishment projects. Together, we'll continue to provide the province of Ontario with low-cost, carbon-free and reliable electricity for decades to come," says Mike Rencheck, Bruce Power, President and Chief Executive Officer.

The report details collaboration, environmental benefits, and economic impacts resulting from refurbishment projects at OPG's Darlington nuclear generating station and Bruce Power.

Darlington to Become New Source of Life-Saving Medical Isotopes

A collaboration between Ontario Power Generation's (OPG) subsidiary Canadian Nuclear Partners (CNP) and a subsidiary of BWX Technologies, Inc. (BWXT) will make Darlington Nuclear the first large-scale commercial nuclear power station worldwide to produce molybdenum-99 (Mo-99) and will help ensure the world's long-term supply of this critical medical isotope that is used in over 30 million life-saving diagnostic and medical treatments each year.

Molybdenum-99 (Mo-99) is the parent isotope of technetium-99 (Tc-99m) which is used for skeletal, brain and organ imaging to detect and diagnose harmful diseases, including heart disease and cancer. Canada's National Research Universal (NRU) reactor ceased regular production of Mo-99 in 2016 leaving North America without a large-scale domestic supply of Mo-99, and requiring hospitals and health providers to import this radioisotope from Europe, Africa and Australia.

Returning Mo-99 and Tc-99m production to Canada will result in a continuous domestic and North American supply of this life-saving medical tool. Darlington's CANDU reactors allow for the insertion and removal of medical isotope targets while producing electricity, allowing for a continuous supply of Mo-99. BWXT will process the targets from Darlington to produce Tc-99m generators.

Subject to required Canadian regulatory reviews and approvals, production of Mo-99 at Darlington is expected to start by the end of 2019. "By working together and sharing information, OPG and Bruce Power are improving efficiencies on our respective refurbishment programs and throughout our nuclear station operations," said Jeff Lyash, OPG President and CEO. "OPG's refurbishment of Darlington's Unit 2 reactor is now over 60 per cent complete, and remains on time and on budget while generating thousands of jobs and billions of dollars in economic benefits for Ontario."

Pickering Relicensed to 2028

The Canadian Nuclear Safety Commission (CNSC) yesterday announced its decision to grant a new ten-year operating licence for Ontario Power Generation's (OPG) Pickering plant. The plant is scheduled to operate until the end of 2024.

OPG applied to the CNSC for a licence renewal for the six-unit plant in August 2017, following the government of Ontario's approval in January 2016 of the plant's continued operation to 2024 to ensure a reliable source of low-carbon electricity while major refurbishment work is under way at OPG's Darlington plant. The first two units - Pickering 1 and 4 - are planned to close in 2020, with units 5-8 closing in 2024. Pickering 2 and 3 have remained in safe shutdown since 1997.

The CNSC said its decision following a two-part public hearing earlier this year was based on OPG's stated intent to cease commercial operations at Pickering on 31 December 2024. This is to be followed by post-shutdown activities and stabilisation work to 2028. The commercial operation of any Pickering reactor unit beyond 2024 would require further authorisation from the Commission, it said.

Pickering's new licence will run from 1 September 2018 to 31 August 2028. The CNSC has also authorised the company to operate units 5-8 up to a maximum of 295,000 equivalent full power hours.

OPG President and CEO Jeff Lyash said the company was "very pleased" with the regulator's decision, which he said would save Ontario's electricity customers up to CAD600 million (USD460 million) and preserve 7500 jobs across the province.

"Today's decision reflects our continued investment in Pickering to improve its already strong performance, and the dedication of our staff to nuclear safety and ensuring safe and reliable operations to 2024," he said.

Ontario's 18 nuclear units - eight at Bruce, four at Darlington and six at Pickering - provide over 60% of the province's electricity. The four Darlington units are undergoing a multi-year CAD12.8 billion refurbishment with the first unit, Darlington 2, scheduled for completion in 2026. Six of the eight Candu units at Bruce are also to undergo refurbishment in a CAD13 billion programme beginning in 2020.

Tumour Treatment Isotope to be Made at Bruce-8

Bruce Power is set to place medical-grade cobalt into unit 8 of its nuclear power plant in Ontario, meaning all four Bruce B units will now produce high specific activity (HSA) cobalt, which is used to treat brain tumours worldwide.

HSA cobalt is used as an alternative to traditional brain surgery and radiation therapy for the treatment of complex brain conditions through a specialised, non-invasive knife, which uses gamma radiation to focus 200 microscopic beams of radiation on a tumour or other target. It minimises damage to healthy tissue

and lowers side-effects compared to traditional therapy in some cases.

Bruce Power-8 entered a planned maintenance inspection programme on 1 September, during which HSA cobalt rods will be installed.

"HSA cobalt is at the forefront of innovative new medical technologies, and we're proud of the part we play in delivering this life-saving radiation therapy," Mike Rencheck, Bruce Power's president and CEO, said. "As a long-time supplier of cobalt-60, we have been helping to keep our hospitals safe for decades, and now, with production of HSA cobalt, we will have a greater impact on human health across the globe."

New Brunswick to Test Emergency Plans

NB Power and the New Brunswick Emergency Measures Organisation (NBEMO) are to carry out Synergy Challenge 2018, a full-scale exercise to test the province of New Brunswick's readiness to respond to a simulated nuclear emergency at the Point Lepreau nuclear power plant.

Canada's nuclear regulator, the Canadian Nuclear Safety Commission (CNSC), requires a full-scale exercise takes place every three years to test the province's readiness in response to a large-scale emergency. Synergy Challenge 2018, which will take place over 3-4 October, will be the first time a Canadian nuclear power plant has entered the recovery phase of an exercise focused on the final stage of emergency management.

About 1000 people representing more than 35 agencies and organisations are expected to take part in the multi-tier and multi-jurisdiction event, which will test emergency preparedness, response and recovery capabilities, decision-making and collaborative effectiveness among NB Power, NBEMO and emergency response partners. It aims to validate current on-site and off-site nuclear emergency plans.

Nuclear Key to Ontario Prosperity

The Ontario Chamber of Commerce (OCC) has called on the leaders of the Canadian province to leverage its nuclear sector as part of a blueprint to help keep Ontario "open for business". The report also aligns with government policy to support refurbishment and life extension work at Bruce and Pickering nuclear power plants.

Blueprint for making Ontario open for business is a 90-page collection of letters directly addressing each of the province's cabinet ministers, sent by the OCC on the 16 July resumption of the province's legislative session. The Ontario Progressive Conservative Party, which was elected to government in a general election held earlier this year, had centred its campaign message on a call to ensure that Ontario is "open for business", the OCC noted. The blueprint contains both immediate policy actions to support business and foundational recommendations for long-term prosperity.

Addressing Premier Doug Ford, the OCC said the nuclear fleet is one of Ontario's key advantages. "Not only does the nuclear industry contribute to the economy by providing less costly and more reliable electricity, it creates jobs across Ontario, it has a high-tech supply chain and contributes to health research and innovation through the development of critical isotopes," it said.

In its letter to Minister of Energy, Northern Development and Mines and Indigenous Affairs Greg Rickford, the OCC says this advantage could best be leveraged through the completion of the ongoing CAD12.8 billion (USD9 billion) refurbishment of Ontario Power Generation's Darlington nuclear power plant; moving forward with Bruce Power's Life-Extension Project; and the promotion of Ontario's nuclear expertise domestically and abroad.

Russia Starts Hot Tests at Novovoronezh II-2

Hot functional tests started on 1 September at unit 2 of the Novovoronezh II nuclear power plant in south-

west Russia, Rosatom has announced. This is the most important stage of commissioning, which precedes the physical start-up of the unit to confirm its reliable and safe operation, the state nuclear corporation said.

The 144 hot tests will take about 50 days to complete, Vladimir Kazansky, deputy chief engineer for the construction of new units at Novovoronezh II, said. They will include running the four main circulation pumps at a coolant temperature of 280 degrees Celsius and a pressure of 16.0 MPa. They will also involve checking the power supply, steam pipes, safety systems and reactor control and protection systems, he added.

Also known as Novovoronezh 7, the unit is a VVER 1200/392M pressurised water reactor (PWR) unit with a design net capacity of 1114 MWe. It is the second of two such units at Novovoronezh II - the lead project for the deployment of the AES-2006 design incorporating a Gidropress-designed PWR, an evolutionary development from the VVER-1000.

Completion of Fuel Loading at Tianwan 4

The process of loading of all 163 fuel assemblies into the core of unit 4 at China's Tianwan nuclear power plant has been completed. The Russian-supplied VVER-1000 is scheduled to begin operating by the end of this year.

Fuel loading was started on 25 August and completed on 2 September, China National Nuclear

Corporation (CNNC) announced today.

Rosatom said at the start of fuel loading that once all the assemblies had been loaded, then start-up and commissioning work would be carried out. The reactor will then be brought to the "minimum controllable power level", followed by the start of power generation.

Tianwan Phase I - units 1 and 2 - was constructed under a 1992 cooperation agreement between China and Russia. First concrete was poured in October 1999, and the units were commissioned in June 2007 and September 2007, respectively.

Chinese AP1000 Reaches Full Power Operation

Unit 1 of the Sanmen nuclear power plant in China's Zhejiang province has reached full power operation for the first time. The unit became the world's first AP1000 to achieve grid connection and power generation.

Sanmen 1 reached 100% power for the first time at 2.10pm today, China National Nuclear Corporation and State Nuclear Technology Corporation announced.

Hot testing of Sanmen 1 - which simulated the temperatures and pressures that the reactor's systems would be subjected to during normal operation - was completed in June last year. The loading of fuel assemblies into its core began on 25 April. The unit achieved first criticality - a sustained chain reaction - on 21 June. On 27 June, nuclear-generated steam was used for the first time to successfully rotate the turbine at rated speed.

The unit has been undergoing gradual power ascension testing until all testing is safely and successfully completed at 100% power. Sanmen 1 is scheduled to enter commercial operation by the end of this year. New nuclear power reactors in China are usually considered to be in commercial operation upon completion of a demonstration test run of 168 hours of continuous operation at full power.

In September 2007, Westinghouse and its partner the Shaw Group received authorisation to construct four AP1000 units in China: two at Sanmen in Zhejiang province and two more at Haiyang in Shandong province. Construction of Sanmen 1 began in April 2009, while first concrete for Sanmen 2 was poured in December 2009. Construction of Haiyang 1 and 2 began in September 2009 and June 2010, respectively.

Contract for Recycled Fuel for Chinese Candus

Canada's SNC-Lavalin is to supply its 37M Natural Uranium Equivalent (NUE) fuel to units 1 and 2 of the Qinshan Phase III nuclear power plant in China's Zhejiang province. The engineering service contract and a licensing agreement mark the first commercial use of the fuel - a mixture of depleted and recycled uranium - outside Canada.

SNC-Lavalin said its work under the contract - signed with China National Nuclear Corporation subsidiary Third Qinshan Nuclear Power Company (TQNPC) - includes design definition, design verification, update of reactor nuclear design and safety case, regulatory support and licensing.

Candu pressurised heavy water reactors (PHWRs) are usually fuelled with natural uranium. Since 2008, Canada and China have proven, through an in-core irradiation demonstration in the Qinshan Phase III Candu 6 reactors, that NUE fuel can be used successfully as a natural uranium substitute. The first commercial demonstration of the use of fuel containing recovered uranium from used pressurised water reactor (PWR) fuel was in Qinshan Phase III unit 1. In March 2010, 12 NUE fuel bundles were inserted into the reactor, followed by a further 24 such fuel bundles. The trial use of the fuel ran for one year.

In August 2012, SNC-Lavalin subsidiary Candu Energy, the TQNPC, China North Nuclear Fuel Corporation and the Nuclear Power Institute of China agreed to expand their joint project to demonstrate the use of NUE fuel at the Qinshan plant.

SNC-Lavalin says that only a few changes are required to current operating Candu reactor designs, safety parameters and licensing case to use NUE as a substitute for natural uranium.

Cameco Shutdown Extended Indefinitely

Cameco is extending the suspension of production at McArthur River and Key Lake "for an indeterminate duration", CEO Tim Gitzel announced yesterday. The Saskatchewan operations have been out of production since January.

Gitzel's announcement accompanied Cameco's second quarter results, which Gitzel said reflected the impact of a weak uranium market and actions taken by the company aimed at increasing long-term shareholder value.

"We continue to expect to generate strong cash flow this year as we draw down inventory and focus on operating efficiently. However, we have not seen the improvement needed in the uranium market to restart McArthur River and Key Lake," Gitzel said.

"This means we will extend the suspension of production at McArthur River and Key Lake for an indeterminate duration."

Gitzel said the decision had been a difficult one, since it will result in the permanent layoff of about 550 site employees, including those temporarily laid off since January, as well as a reduction of about 150 positions at the company's corporate offices. A reduced workforce of around 200 employees will remain at the McArthur River and Key Lake sites to keep the facilities in a state of safe care and maintenance. Cameco's share of the care and maintenance sites are expected to be between CAD5-6 million per month once the layoffs take effect.

Fuel Removal Work Starts at Japan's Monju reactor

Work has started to remove fuel assemblies from a sodium-filled storage tank at the Monju prototype fast breeder reactor (FBR), the Japan Atomic Energy Agency (JAEA) has announced. Once all these assemblies have been placed in a water-filled pool, removal of assemblies from the reactor itself will begin.

JAEA submitted a detailed plan to decommission Monju, in line with the government's basic policy, to the Nuclear Regulation Authority (NRA) in December 2017. The plan comprises four stages. In the initial stage, JAEA will transfer all fuel to an on-site storage pool by fiscal 2022. In the second and third stages, the liquid sodium coolant will be extracted from Monju and related equipment will be dismantled. The reactor building will be demolished and removed by fiscal 2047 in the final stage. The NRA approved that plan in March this year.

JAEA has announced that work to remove the 160 fuel assemblies stored within the sodium-filled storage tank has now begun, following the completion of simulated training between 19 and 28 August. Removal of the first fuel assembly began at 10.30am today. Sodium will be washed away from the removed assemblies before they are placed in the new storage pool.

JAEA plans to remove one assembly per day and expects to have moved 100 assemblies from the storage tank to the pool by the end of this year. It also plans to start extracting some 760 tonnes of sodium from the reactor's secondary cooling system by year-end. This will be placed in the storage tank for later disposal. Some 960 tonnes of sodium from the reactor and the primary circuit will be removed at a later stage.

Work to remove the 370 fuel assemblies from Monju's sodium-filled core is scheduled to begin next year. These will be placed in the storage tank prior to being transferred to the storage pool.

A key part of Japan's nuclear energy programme, the 280 MWe Monju FBR in Tsuruga City, Fukui Prefecture, initially started in 1994. However, it was shut down after just four months when about 700 kilograms of liquid sodium leaked from the secondary cooling loop. It eventually restarted in May 2010 but has not operated since refuelling equipment fell into the reactor vessel during a refuelling outage later that year. In December 2016, the government formally announced its decision to decommission the idled Monju reactor. The decommissioning of Monju will take 30 years and cost more than JPY375 billion (USD3.7 billion), the government estimates. This includes JPY225 billion for maintenance, JPY135 billion for dismantling the plant and JPY15 billion for defuelling and preparations for decommissioning.

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Scholarships in Nuclear Science and Engineering at Canadian Universities

The Canadian Nuclear Society (CNS) is pleased to offer scholarships to promote Nuclear Science and Engineering to students at Canadian universities.

Two scholarships are offered in 2019: One graduate school entrance scholarship of $5,000 and two undergraduate summer research scholarships of $3,000 each.

Graduate School Entrance Scholarship: $5,000

This entrance scholarship is designed to encourage undergraduate students to enter a graduate program related to Nuclear Science and Engineering at a Canadian university.

Eligibility

You must be enrolled in a full-time undergraduate program at a Canadian University and be a member of the CNS.

The duration of the graduate program must be at least two years and is expected to lead to a Master's or a PhD degree.

Undergraduate Student Research Scholarship: $3,000

This scholarship is designed to encourage undergraduate students to participate in research in Nuclear Science and Engineering during the summer months.

Eligibility

You must be enrolled in a full-time undergraduate program at a Canadian University for at least two years and be a member of the CNS.

The scholarship is to be matched by $2,000 from the supervisor for a total of $5,000.

The recipients of the scholarships will be selected on the basis of their academic standing and other information to be supplied with the application.

The Scholarship Committee of the Canadian Nuclear Society will collect and review the submissions, and make the award decisions.

Details of the scholarships and the procedure for application can be found on the CNS website at

www.cns-snc.ca/Scholarships

The deadline for submission of the application is **February 18th, 2019**.

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Bourses en science et génie nucléaire dans les universités canadiennes

La Société Nucléaire Canadienne est heureuse d'offrir des bourses afin d'encourager les étudiants dans les universités canadiennes à étudier la science et le génie nucléaire.

Deux bourses sont offertes en 2019: une bourse de 5,000$ à l'entrée aux études supérieures, et deux bourses de recherche d'été (de 3,000$ chaque) pour étudiants poursuivant la licence.

Bourse d'entrée aux études supérieures : 5,000$

Le but de cette bourse est d'encourager les étudiants à s'inscrire aux études supérieures en science et génie nucléaire dans une université canadienne.

Éligibilité

L'étudiant(e) doit être présentement inscrit(e) plein-temps à un programme poursuivant la licence dans une université canadienne, et doit être membre de la SNC.

L'échéancier du programme en études supérieures doit couvrir une période minimale de deux ans, et devrait mener à une maîtrise ou à un doctorat.

Bourse de recherche pour étudiants poursuivant la licence : 3,000$

Le but de cette bourse est d'encourager les étudiants poursuivant la licence à participer en recherche en science et génie nucléaire pendant l'été.

Éligibilité

L'étudiant(e) doit être inscrit(e) plein-temps à un programme d'au moins 2 ans poursuivant la licence dans une université canadienne, et doit être membre de la SNC.

Cette bourse doit être complémentée par un montant de 2,000$ de la part du directeur de la recherche, pour un total de 5,000$.

Les gagnant(e)s des bourses seront sélectionné(e)s à partir de la qualité de leur dossier académique, ainsi que d'autres données à être fournies en même temps que la demande de bourse.

Le Comité des bourses de la Société Nucléaire Canadienne recevra et étudiera les candidatures, et attribuera les bourses.

Les détails des bourses et les procédures de demande sont disponibles sur le site web de la SNC à

www.cns-snc.ca/bourses

La date limite pour la soumission de demande de bourse est le **18 février 2019**.

Publications

The IAEA is pleased to announce the publications of:

Regulations for the Safe Transport of Radioactive Material (2018 Edition)

IAEA Safety Standards Series No. SSR-6 (Rev.1)

The transport of radioactive material is an essential activity worldwide. Both safety and security during transport are matters of national and international importance. This publication is the latest edition of the IAEA Safety Requirements for the safe transport of radioactive material. It is supported by six IAEA Safety Guides which provide explanation and guidance for the SSR-6 requirements to facilitate harmonized implementation. The SSR-6 Regulations apply to the transport of radioactive material by all modes on land, water, or in the air, including transport that is incidental to the use of the radioactive material. Transport comprises all operations and conditions associated with, and involved in, the movement of radioactive material; these include the design, manufacture, maintenance and repair of packaging, and the preparation, consigning, loading, carriage including in-transit storage, unloading and receipt at the final destination of loads of radioactive material and packages. These requirements form an integral part of regulations worldwide, therefore SSR-6 and its associated guidance documents are a requisite source of guidance information for governments, regulators, and all individuals involved in the aforementioned activities of transport of radioactive material.

STI/PUB/1798, 165 pp.; 7 figs.; 2018; ISBN: 978-92-0-107917-6, English, 49.00 Euro

Electronic version can be found: https://www-pub.iaea.org/books/iaeabooks/12288/Regulations-for-the-Safe-Transport-of-Radioactive-Material-2018-Edition

A Methodology for Establishing a National Strategy for Education and Training in Radiation, Transport and Waste Safety

Safety Reports Series No. 93

This publication provides Member States with a detailed methodology to establish a national strategy for education and training in radiation, transport and waste safety, in order to build competence in a sustainable and timely manner. Guidance is provided on assessing education and training needs, giving consideration to the national legal and regulatory framework for education and training, and the current and future facilities and activities; designing the national education and training programme based on the needs; and optimizing national resources to complement external assistance. A practical example of the application of the methodology is generated for a hypothetical country, outlining the chronological sequence of the actions to be taken, their timeframe, including the role and contribution from the different national stakeholders. This methodology has been tested in the field during 20 regional workshops attended by about 300 participants from more than 80 Member States.

STI/PUB/1778, 66 pp.; 2 figs.; 2018; ISBN: 978-92-0-102217-2, English, 41.00 Euro

Electronic version can be found: https://www-pub.iaea.org/books/iaeabooks/11086/A-Methodology-for-Establishing-a-National-Strategy-for-Education-and-Training-in-Radiation-Transport-and-Waste-Safety

Dependability Assessment of Software for Safety Instrumentation and Control Systems at Nuclear Power Plants

IAEA Nuclear Energy Series No. NP-T-3.27

This publication defines a framework that represents the state of the art in assessment methodologies for safety and instrumentation and control software used at nuclear power plants. It describes an approach for developing and communicating assessments based on claims, argument and evidence. The assessment of software dependability, which encompasses properties such as safety, reliability, availability, maintainability and security, is an essential and challenging aspect of the safety justification. Guiding principles for a dependability assessment are established to provide the basis for defining an assessment strategy and implementing the assessment process. Sources of evidence for the assessment are provided and lessons learned from past digital instrumentation and control system implementation in areas such as software development, operational usage, regulatory review and platform certification are also described

STI/PUB/1808, 80 pp.; 10 figs.; 2018; ISBN: 978-92-0-101218-0, English, 38.00 Euro

Electronic version can be found: https://www-pub.iaea.org/books/IAEABooks/12232/Dependability-Assessment-of-Software-for-Safety-Instrumentation-and-Control-Systems-at-Nuclear-Power-Plants

Topical Issues in Nuclear Installation Safety

Safety Demonstration of Advanced Water Cooled Nuclear Power Plants

Proceedings of an International Conference Held in Vienna, 6–9 June 2017

This publication presents the proceedings of the international conference on topical issues in nuclear safety. The conference provided a unique forum to present and discuss the latest approaches, advances and challenges in the demonstration of the safety of nuclear power plants that are planned to be licensed and constructed in the near future, in particular those using water cooled reactors, including small and medium sized or modular reactors. The proceedings include the key insights and recommendations summarized by the Conference President, the executive summary of the conference including the key outcomes and recommendations attained together with the full conference programme.

STI/PUB/1829, 656 pp.; 232 figs.; 2018; ISBN: 978-92-0-104618-5, English, 57.00 Euro

Electronic version can be found: https://www-pub.iaea.org/books/IAEABooks/12286/Topical-Issues-in-Nuclear-Installation-SafetyTopical Issues in Nuclear Installation Safety

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https://www-pub.iaea.org/books/IAEABooks/12286/Topical-Issues-in-Nuclear-Installation-Safety

Sustaining a Nuclear Security Regime

IAEA Nuclear Security Series No. 30-G

This publication addresses the sustainability of all aspects of a national nuclear security regime, including those relating to nuclear material and nuclear facilities, other radioactive material and associated facilities, and nuclear and other radioactive material out of regulatory control. The publication is relevant for States that have established a nuclear security regime as well as for States that are in the process of establishing one. It includes guidance on how to address challenges in sustaining a nuclear security regime over time. It also addresses the initial development and implementation of the regime, particularly where sustainability can be built into it as part of its design.

STI/PUB/1763, 26 pp.; 2018; ISBN: 978-92-0-111816-5, English, 25.00 Euro

Electronic version can be found: https://www-pub.iaea.org/books/IAEABooks/11168/Sustaining-a-Nuclear-Security-Regime

Calendar

2018

Sept. 30-Oct. 3 — **PBNC 2018**
San Francisco, CA, USA
pacificnuclear.net/pnc/pbnc
ans.org/meetings/c_2

October — **Student Job Fair for the Nuclear Industry**
UOIT/Durham College North Oshawa Campus
Organized by the Durham Region, UOIT, Toronto, Sheridan Park & Golden Horseshoe Branches in collaboration with UOIT, Durham College and OCNI
Contact: Canadian Nuclear Society Office
Tel: 416-977-7620
cnssnc@on.aibn.com
www.cns-snc.ca

October 28-30 — **XXIX Interamerican Congress of Chemical Engineering,**
incorporating the "68th Canadian Chemical Engineering Conference" Toronto, ON
www.csche2018.ca

Fall — **Waste Management, Decommissioning and Environment Restoration for Canada's Nuclear Activities**
cns.snc.ca

Fall — **International Conference on Simulation Methods in Nuclear Engineering**
cns-snc.ca

Fall — **International Technical Meeting on Small Reactors**
cns-snc.ca

Nov. 11-15 — **2018 ANS Winter Meeting**
Orlando, FL, USA

2019

February — **CNA Nuclear Industry Conference and Tradeshow**
Westin Hotel
Ottawa, Ontario
cna.ca/2019-conference

March 10-13 — **11th International Symposium on Supercritical Water Cooled Reactors (ISSCWR-11)**
Vancouver, BC
Organized by: CNS NS&E Division
Contact: Canadian Nuclear Society Office,
Tel: 416-977-7620
cns-snc@on.aibn.com
www.cns-snc.ca

March — **Nuclear 101 Ottawa**
Organized by: CNS Education and Communication Committee
Contact: Canadian Nuclear Society Office
Tel: 416-977-7620
cns-snc@on.aibn.com
www.cns-snc.ca

Spring — **Reactor Physics Course**
Contact: Canadian Nuclear Society Office,
Tel: 416-977-7620
cnssnc@on.aibn.com
www.cns-snc.ca

March — **CANDU Technology & Safety Course**
cns-snc.ca

May — **Nuclear 101**
cns-snc.ca

May-June — **1st Innovative Materials, Chemistry and Fitness-For Service Solutions for Nuclear Power Systems Conference**
Organized by: CNS MCF Division
Contact: Canadian Nuclear Society Office
Tel: 416-977-7620
cns-snc@on.aibn.com
www.cns-snc.ca June 9-13, 2019

ANS Annual Meeting
Minneapolis, MN
Organized by: ANS
www.ans.org/meetings

June 23-26 — **39th Annual CNS Conference & 43rd Annual CNS/CNA Student Conference**
Westin Hotel, Ottawa, Ont
Contact: Canadian Nuclear Society Office
Tel: 416-977-7620
cns-snc@on.aibn.com
www.cns-snc.ca

July 21-24 — **International Conference on CANDU Fuel**
Hilton Meadowvale Hotel, Mississauga, ON
Organized by: CNS FT Division
Contact: Canadian Nuclear Society Office,
Tel: 416-977-7620
cnssnc@on.aibn.com
www.cns-snc.ca

September 8-11 — **Waste Management, Decommissioning and Environment Restoration for Canada's Nuclear Activities**
Ottawa Marriott Hotel, Ottawa, ON
Organized by: CNS E&WM Division
Contact: Canadian Nuclear Society Office
Tel: 416-977-7620
cns-snc@on.aibn.com
www.cns-snc.ca

2017-2018 CNS Council • *Conseil de la SNC*

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When am I Going to See a Commercial SMR Operating in Canada

by NEIL ALEXANDER

Excitement about Small Modular Reactors (SMRs) continues to build around the world. There are more than 100 concepts in development and with the potential for lower costs arising from factory construction they could be our post refurbishment future. They could also increase the role of nuclear in meeting energy needs by opening up new markets such as industry and small communities with their lower power outputs and higher temperatures.

Be they fast or thermal, molten salt, TRISO or conventionally fueled, with gas, water, metal, salt or even heat pipe cooling they are a paradigm shift not seen in the industry since it was forged into a ploughshare out of the swords of the second world war.

And the great news is that many people see Canada as a potential leader. In the CNSC we have a reputable regulator, that is more than competent to regulate an SMR with an innovation embracing non-prescriptive safety-based system.

We have remote markets where there is no competition with cheap gas and where wind and solar cannot provide the reliable supply that is needed.

And we have a tremendous research infrastructure at Chalk River that could support any development. And an experienced supply chain that could support commercial deployment.

Many of the stars align and this has not gone unnoticed by Natural Resources Canada who have led the industry in the development of a roadmap, the results of which, we should see shortly. It hasn't gone unnoticed by Canadian Nuclear Laboratories who are running a siting exercise that looks at deployment of one or more of these reactors at one of their licensed sites. It has not gone unnoticed by New Brunswick who are putting their money where their mouth is and investing with two reactor developers in technology that might meet their needs. And it has certainly not slipped the attention of the developers, ten of which have entered into the CNSC's Vendor Design Review process.

But the question still remains. When is it going to happen?

And that may have nothing to do with what is going on within the industry and a lot more to do with social and legal changes outside our influence.

In the 50s/60s/70s/80s if you wanted to build a factory, or a power plant or a transmission line or a pipeline you bought the land, filled out the paperwork, borrowed the money and got on with it (yes, I am exaggerating to make a point but its not far from the truth).

But through ignorance and/or greed the trust people placed in the system to protect them was betrayed and has been lost. I suspect it won't be coming back anytime soon. Now we have an obligation, legal and moral, to carry the public with us.

The sad fact is that this affects good projects as well as bad. Projects don't wear a label and the public must find out for itself which is which.

And it turns out that it doesn't matter how important a project might be, or if the claims are right, how much safer it makes us, public will, enforced through the law, can stop any project. If you don't believe me look-up Trans Mountain Pipeline (TMP).

Consultation is now enshrined in Canadian law, and what TMP teaches us is that you have to treat it very seriously.

So my prediction for when we will see a commercial SMR operating in Canada….not until after we have consulted with the people and found that they want one. We have not done that…..yet!

Canadian Nuclear Laboratories | Laboratoires Nucléaires Canadiens

What does the world need in clean energy, that it doesn't have today?

We invite you to learn more about our vision for the future at www.cnl.ca.

We believe nuclear technology is at the heart of a clean energy future, and CNL is positioned to help it every step of the way. From supporting the world's current nuclear fleet, to exploring the possibilities of hydrogen-powered transportation, or our invitation to site Canada's first small modular reactor, CNL is delivering results across a range of clean energy technologies.

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