CANADIAN NUCLEAR SOCIETY

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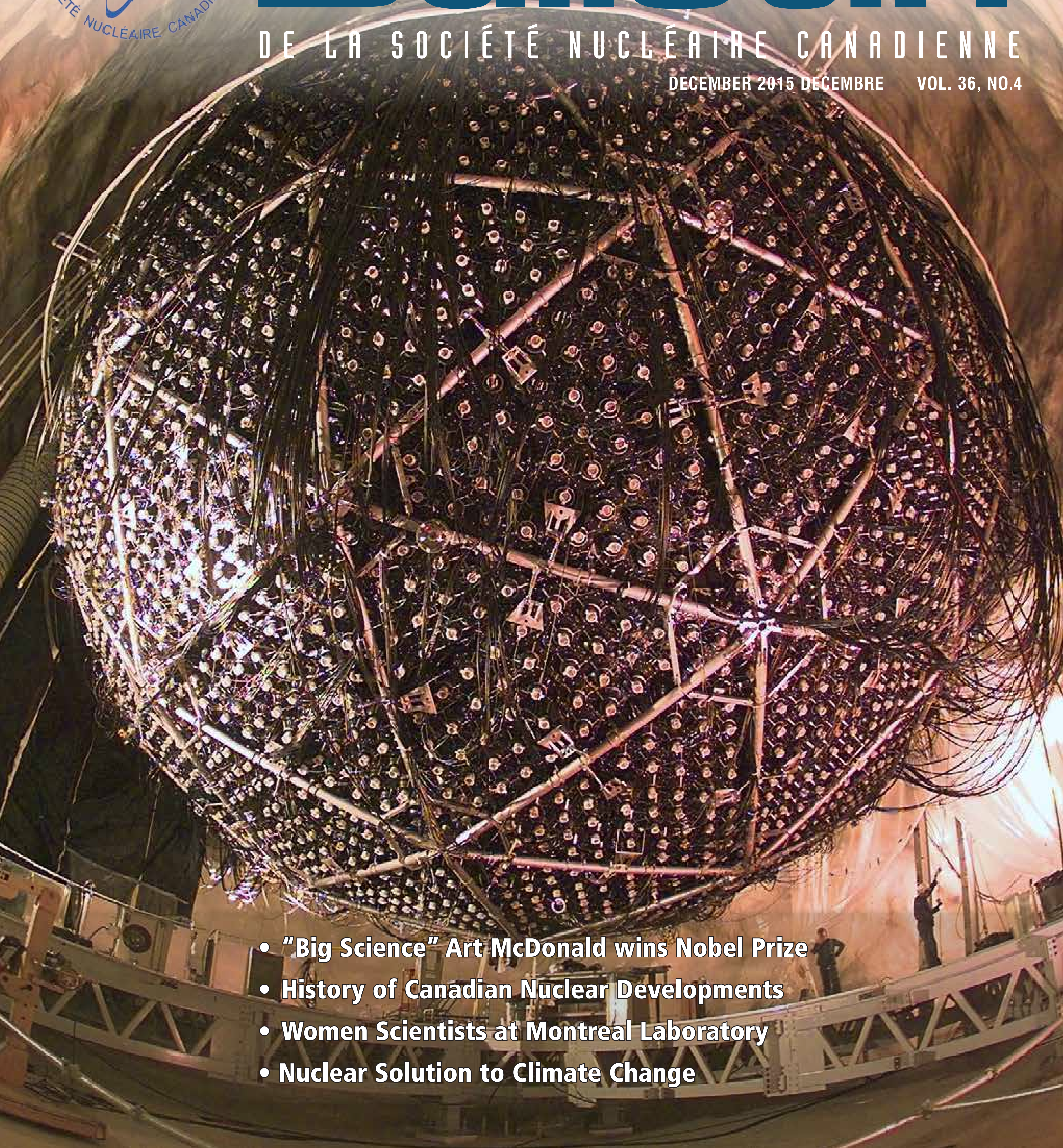

- "Big Science" Art McDonald wins Nobel Prize
- History of Canadian Nuclear Developments
- Women Scientists at Montreal Laboratory
- Nuclear Solution to Climate Change

Editorial

A $200 Billion Dollar Lie?

Recently the New York State Attorney, Eric Schneiderman, is raising questions as to whether the big oil companies had knowledge of the climate change (warming) effects of burning fossil fuels as far back as the 1970s. Exxon Mobil received a subpoena from Schneiderman to submit documents to determine if Exxon lied to investors and consumers, or withheld information about the effects of climate change. Exxon, naturally, has denied such implications that it lied. Of course many argue that such a tactic is politically motivated while environmentalists are praising the attorney general for seeking the truth.

Like most energy companies Exxon performed or funded research on the effects of burning fossil fuels on climate change, including economic impacts of global warming, melting ice and re-drawing coast lines. However, the pertinent question relates to how the results of such research were used to influence investors. Hence, the attorney general is calling on the century old Martin Act, which does not require proof of intent, but rather if securities were influenced by fraudulent, omitted or misleading information.

This will be a difficult task. For example, omission of information may have occurred, but would not be relevant to the case if the information was already in public domain. Thus, Schneiderman will need to prove that Exxon (and other similar companies) had information that the rest of the world hadn't.

Even if Schneiderman is successful, a legal battle is unlikely. It would be bad publicity for the oil companies (especially during the leadership race of US Republicans who are financially supported by big oil). Furthermore, one of either the state or the oil companies would become bankrupt over legal fees (guess which). Instead, as is the American way, there would be an out-of-court settlement. For example, a former New York attorney general won a $100 million out-of-court settlement with Merrill Lynch over broker conflicts of interest, as well as a $1.4 billion settlement with several securities firms over stock research.

Does all this sound familiar? Consider leaded gasoline and paints. Lead, known to be poisonous since 500 BC, was introduced into automobile gasoline in 1922 despite outcries of potential health effects. In the 1930s the oil and automotive industries rejected scientific evidence of harmful health effects, claiming there was no proof. Children harmed by chewing on lead-based paints were either blamed on irresponsible parents or claims that the children had pre-existing health problems. In the 1960s, with increasing air concentrations of lead, industry experts claimed only workers were at risk for lead poisoning, and that because lead has always been naturally in the air, it must be safe. Although lead began to be phased out due to the use of catalytic converters (that are ruined by lead) it wasn't until 1995 when lead was completed banned from automobile gasoline. It is still used today in aviation gasoline.

Here is another example of industry rejecting science: tobacco. Their CEOs stood up in the courts and said forthright that smoking did not cause lung cancer. They based their statements on research - that is, their research. That big lie cost the tobacco industry about $200 billion.

Note that $100 billion is the world funding goal to avert the consequences of global warming. Compare that to the approximately $50 billion that just one of the oil companies, British Petroleum, readily coughed up in fines and fees after their major spill in the Gulf of Mexico! They are still raking in the profits.

In This Issue

We are honoured to feature Nobel Prize winner Art McDonald's amazing discoveries based on his "Big Science" at the Sudbury Neutrino Observatory. Furthermore, he and his colleagues have been honoured with the prestigious 2016 Breakthrough Prize in Fundamental Physics for their various papers contributing to the knowledge of neutrino oscillations. Work began in the 1970s and CNL has now retained Art as a special advisor.

We have reports from three conferences on Fusion Technology, Modelling and Simulation and the International Nuclear Components Conference.

A special paper on the importance of nuclear energy in reducing anthropogenic greenhouse gas emissions is included with kind permission of the European Physical Journal. We also have two items of history, both relating to the early developments leading to our CANDU success. One pertains to the building of the NRX during WWII, and the other to the forgotten women scientists who made significant contributions to the war effort at the Montreal Laboratory.

As well as a selection of General and CNS news Jeremy Whitlock laments the "good old days" in his Endpoint (last page).

As another year comes to a close we wish everyone a safe and happy holiday and success for the New Year. As always, your comments and letters are welcome.

From The Publisher

The end of a year is nearly always cause for reflection. 2015 will mark the completion of more than 35 years for the Canadian Nuclear Society (CNS). Founded in 1979 as a branch of the Canadian Nuclear Association (CNA), and becoming an independent, not-for-profit corporation in 1998, the CNS has become the principal society for professional workers in Canada's nuclear industry.

Early on, the CNS established a number of regular and repeating technical conferences which continue to this day. Indeed, technical conferences remain the principal method by which the CNS carries out one of its principal purposes: the dissemination of expert technical knowledge among the industry's scientists and technical workers.

During the past few years, our industry has been rocked by a number of policy choices made by various Canadian governments. The first was the Ontario government's decision in 2006 not to pursue new nuclear construction in the wake of the impending closure of the Pickering nuclear power station.

This decision meant that there would be no new construction of new nuclear plants in Canada in the near future. It meant that increasingly the utility owners of the remaining nuclear stations would turn greater attention to the long term preservation and use of existing power reactors. And with Canada's existing facilities, the utilities are making very large capital investments to enhance their performance and longevity. Both OPG and Bruce Power are undertaking billions of dollars in investment in the Darlington and Bruce nuclear power stations to extend their useful lives to approximately mid-century.

It meant significant changes within the industry. Development of new reactor types, such as the Advanced CANDU Reactor (ACR), was dropped almost immediately.

For the CNS, this also meant a change in emphasis. Our technical conferences would be less concerned about new reactors beyond CANDU and more about enhancing the value of the existing facilities. Our conference program in 2015 showed this effect. These topics were of great interest at all four of our major conferences this year: the CNS Annual Conference, the CANDU Maintenance Conference, the 17th Environmental Degradation Conference, and the International Nuclear Components Conference.

The second major government policy decision was that of the federal government to restructure Atomic Energy of Canada Limited (AECL) into private management. The process started with the privatization of the power reactor division at Sheridan Park, and it has been completed this year with the assumption by private management of Canadian Nuclear Laboratories (CNL).

It is interesting to note that CNL's new management also views a large part of its mandate as providing research and technology to enhancing the value of existing reactors.

The CNS has also had to undergo a transition during the past several years in response to these various government decisions. The focus of the Society now is to broaden its appeal to the working nuclear sites across Canada. It has undertaken new initiatives to do this, perhaps best manifested this year with the start of the first CNS Fire Safety and Emergency Preparedness Conference (FSEP) this past summer. Despite the inherent difficulties in a start-up of a new activity in a new field in which the CNS had relatively little prior exposure, FSEP was such a success that we can expect very large growth in this and related areas for years to come.

The CNS also has a much more prominent public image than in bygone years. The Society now intervenes in public hearings where nuclear science and technology forms the centerpiece of the topic under consideration.

Through all of this transition, the CNS has remained financially strong, and most importantly, with a stable membership. It continues to add to its programs. It continues to attract large numbers of young professionals and students to its events and into its branches. This is only possible because they see the nuclear industry in Canada is a strong and vibrant future career, and that the CNS is a place where they can learn and grow from the skills and experiences of others.

For the past 35 years, the CNS has grown from humble beginnings to a strong, independent society. Given the prospects before us today, there is reason to suppose that the next 35 years will be equally promising.

C.G.H.

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Outside view of completed Sudbury Neutrino Observatory detector.

Photo courtesy of the Sudbury Neutrino Observatory.

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La SNC procure aux Canadiens intéressés à l'énergie nucléaire un forum où ils peuvent participer à des discussions de nature technique. Pour tous renseignements concernant les inscriptions, veuillez bien entrer en contact avec le bureau de la SNC, les membres du Conseil ou les responsables locaux. Les frais d'adhésion par année de calendrier pour nouveaux membres sont 82.40$, et 48.41$ pour retraités.

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Nobel Prize Winner Returns Home to Tell a Fascinating 'Big Science' Story

"I don't want to do run-of-the-mill physics, I want to do something memorable."

ART MCDONALD, circa 1970

By CLEMENTE ANGIOLILLO[1] and RUXANDRA DRANGA[2]

When the Royal Swedish Academy of Sciences announced Arthur (Art) McDonald as a co-winner of the 2015 Nobel Prize for physics for a discovery the committee said "changes our view of the universe," his former Atomic Energy of Canada Limited (AECL) colleagues and friends greeted the news with a smile and nostalgic reminisces of Art's days at Chalk River Laboratories (CRL). Among them are Davis Earle, a retired CRL physicist and resident of Deep River who started working with Art in 1973; and Bhaskar Sur, currently the Director of Canadian Nuclear Laboratories' (formerly AECL) Nuclear Science Division. Earle's early work with Art took place in the heady days of basic physics research when they paired up for experiments to study two-photon decay in neutron-proton capture using neutrons from the NRU reactor. Sur started working on the Sudbury Neutrino Observatory (SNO) experiment in 1989 when he was at Lawrence Berkeley National Laboratory in Berkeley, California and continued to work on SNO directly with Art at Queen's University and later with Davis Earle at CRL. Ultimately, under Art's leadership, SNO would make a major breakthrough on the study of the behavior of an elementary and enigmatic particle of the universe – the neutrino.

"This achievement is the result of the synthesis of over 30-years of work on particle physics, astrophysics and nuclear science that saw early germination at Chalk River Laboratories," says Sur. "Later on, preliminary SNO results led to a major leap forward on how to measure sub-atomic phenomena that were never used to this extent before and have also provided new insights into the 'Standard Model' of physics, and indeed in our fundamental understanding of the entire universe," Sur adds emphatically.

Even the Royal Swedish Academy of Sciences, which bestows the prize annually, acknowledged the 'earth shook' when it noted that the Standard Model of particle physics, which described the innermost workings of matter and resisted all experimental challenges for more than 20 years to this point, was now known to be incomplete. Neutrinos, produced in the core of stars by a fusion reaction, were described in the Standard Model as having zero-mass. Art's work showed that this assumption was incorrect and revealed that they do have mass as well as other amazing characteristics. The SNO experiments essentially rewrote the balance sheet of the universe and have implications for its origins and nature. After the light-carrying particles known as photons, neutrinos are the most abundant particles in the universe as oceans of them are left over from the Big Bang, and many more are produced in stars and in nuclear reactors. They race through the earth and our own bodies like wind through a screen door and they also come in three different identities, or "flavours," (a technical colloquialism) – which was the key to their eventual unmasking.

On October 16, 2015, Art McDonald returned home to Deep River's Mackenzie Community School where former colleagues and current CNL staff packed the Childs Auditorium to the rafters to hear Art talk about the SNO experiment that would define his long career. The focus of his talk was the amazing story of an ambitious, risk-laden project for which McDonald served as Director since 1989, which required the building of the most sensitive neutrino detector created to date. Overall, the project is a remarkable engineering achievement in its own right; a massive construction project that resulted in the creation of an ultra-clean, 10-storey-high cavity, two kilometers underground in INCO Ltd's Creighton nickel mine in Sudbury. In the centre of the cavity was a 12-meter diameter acrylic vessel containing 1,000 tons of heavy water (worth $300 million and on loan from AECL). If that doesn't sound ambitious enough, SNO would be the first neutrino detector with the ability to detect all three flavours of neutrinos (electron, muon, and tau) and distinguish electron neutrinos from the other two. The depth of the detector's location was essential to the study as it reduced interference from cosmic rays by many orders of magnitude. Additional steps were required to minimize interference from other sources of radiation and, in fact, the levels of radiation at the centre of the vessel are believed to be the lowest on earth. Once the facility was established, the rest is history. Although the road to the Nobel Prize was laden with challenges and missteps along the way, the project would yield tremendous results to the team's knowledge of the universe. For CNL, which has

1 Clemente Angiolillo works at CNL's Chalk River Laboratories as a writer and communications officer.

2 Ruxandra Dranga is the CNS Education and Communication Committee Chair and has been involved with the CNS Chalk River Branch over the past 6 years in various roles.

been a forerunner in the establishment of the global nuclear industry since World War II and continues to be on the vanguard of nuclear science and technology, it illustrates how history reaches forward and supports the organization's brand today. Art and many former AECL employees, like Davis Earle, made incredible contributions to the SNO experiment, and it is difficult to conceive of the experiment's success without those contributions and time spent at Chalk River Laboratories.

Bolstering Canada's 'big science' brand

Malcolm Harvey, a former Director of Physics at CRL who worked with Art, recounts a memorable conversation he had with McDonald in the early 1970's when Art came into his office and hinted at the 'big science' work that he wanted to pursue. After settling into a chair in Harvey's office, Art confided something to Malcolm that he has never forgotten to this day: "I don't want to do run-of-the-mill physics," he uttered in a plain-spoken, unanimated tone, "I want to do something memorable." Harvey recounts that moment with Art with a sense of pride and as if the conversation happened yesterday. Personal achievement and professional admiration aside, the Noble Prize is also a win for 'big science' in Canada, whose representative institutions are very few and far between in the nation, and would include CNL's Chalk River Laboratories; TRIUMF in British Columbia; Saskatoon's Canadian Light Source; and of course SNO, which was initially a grand experiment and more recently has spun-off SNOLAB. For CNL specifically, Art's win is a shining reminder that some of Canada's, indeed the world's, greatest scientific minds have strode through its doors, and CNL can proudly claim to have employed four of the world's Nobel laureates for extended periods: John Cockcroft, CRL's first Director when CRL was still under the auspices of the National Research Council of Canada; Geoffrey Wilkinson, a chemist who was at CRL in its early days; Bertram Brockhouse, who did his pioneering work at the NRX and NRU reactors and devised an ingenious method and technologies to probe the crystal structure of materials; and now of course Art McDonald for SNO.

'Big science' is a big investment: Davis Earle reflects on the early days

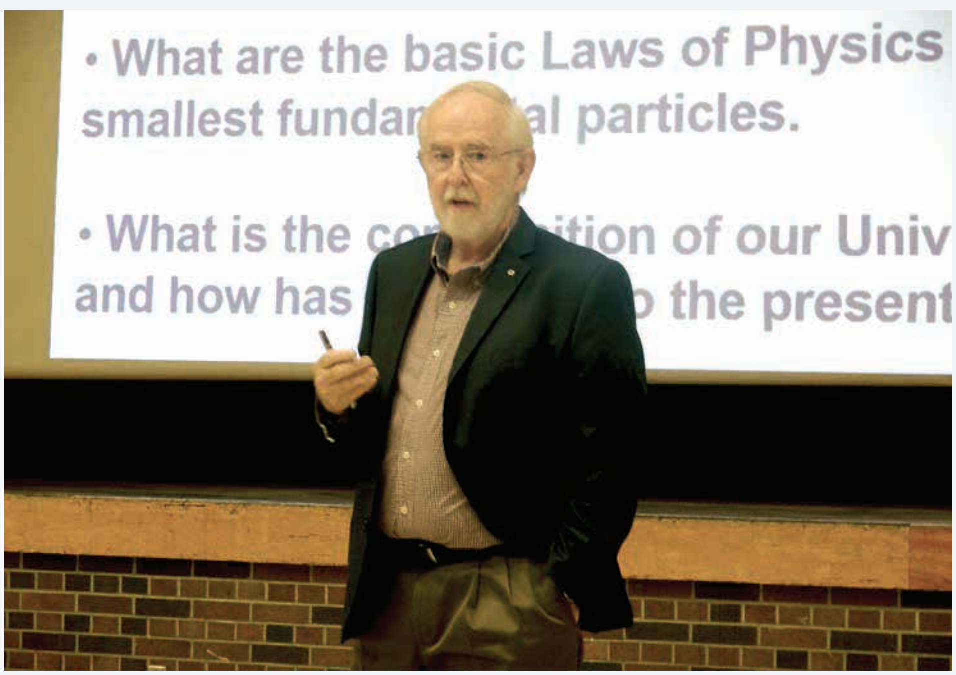
Art came to Chalk River in 1969 as a postdoctoral fellow and progressed to Senior Research Officer prior to his departure in 1982, and although Davis Earle is not familiar with Art's early work, he vividly recalls the latter years of his career at CRL. They collaborated on a number of experiments culminating in a search for parity violation in deuterium using the electron accelerator at Chalk River. At the time, the Russians were actively pursuing this line of study and their initial conclusions contradicting the Standard Model turned out to be in error according to Earle as he reflects on the early days of the project.

"Although we were unable to get the statistical sensitivity required, we were realizing what it takes to look for very small signals, and it was just at this time that a suggestion by Professor Herb Chen from the University of California, Irving of a solar neutrino experiment using Canadian D_2O and an existing Sudbury mine arrived on our doorstop. At the time we thought 'this is just the kind of basic research we were looking to pursue' and we jumped at the opportunity," Earle exclaims. "I basically turned to it full time as I was doing basic research from the day I walked into CRL, essentially curiosity driven work that contributes to knowledge as opposed to applied research work for industry. By 1984, Art was at Princeton and in addition to teaching he invested considerable time into the Sudbury experiment. Other university professors also quickly came on board as advocates and as early contributors to the project. To get it going, we had to convince funding agencies that: a) it is a good idea with potential; and b) we can do it–that essentially it is worth the investment and the results would contribute to our knowledge. That took another six years and it wasn't easy as we were competing with other good ideas for the same scarce dollars. But because we had a good idea, and the heavy water–compliments of AECL–as well as the availability of the existing Creighton mine, we felt we had a leg up on the competition for funding dollars and the other experiments we were competing with had to admit our idea was also a worthy one to support."

Ultimately the team got the money to build and early data revelations were an amazing journey for Art, Davis and company. Earle says one important lesson learned from the experience was that funding agencies sometimes don't always appreciate that it is not enough to simply fund such big projects. Once you commit to funding 'big science' research projects that are breaking new ground in construction and installation, you also have to be prepared to add funds when there are setbacks. "We were 'boldly going where no one had gone before' and cost overruns are a reality," he adds. "In addition, these projects are not-for-profit with no source of income, thus operating funds must also be provided."

Great science and great scientists enrich us all. They enable technologies that ease our lives, or, as in Art's case, they show us what's beyond our horizons and the disciplines that ask the biggest questions and find the deepest explanations are the fundamental sciences. Looking back on Art's work serves as a testament to what is possible when you set high ambitions, work hard to build support for an intrepid project and assemble the right people as part of a team. It takes drive and dedication to convince groups to support a project with such obvious risk, much less challenge existing scientific knowledge and to make breakthrough discoveries, or what Art framed as wanting to "do something memorable" and not "run-of-the-mill." Surrounded by family and friends, young and older, on that night Art seemed larger than life among former colleagues and the assembled crowd, and his story of true discovery brought another reward his way–the admiration of peers who are proud to see one of their own achieve such a pinnacle.

Pictured in 1986 in front of building 508 at Chalk River Laboratories, Nobel Prize winner Art McDonald, posing confidently on the far right, and Davis Earle, on the far left, flank the Sudbury Neutrino Observatory's founding team. The initial spokesman for a solar neutrino experiment using Canadian heavy water was Professor Herb Chen (fifth from right), who proposed the concept in 1984 and tragically succumbed to cancer only a year after this photo was taken.



Almost three decades after posing for the grainy, black and white photo with the SNO group, Art would return to Deep River to tell his amazing story of discovery that would define his career and earn him the Nobel Prize.

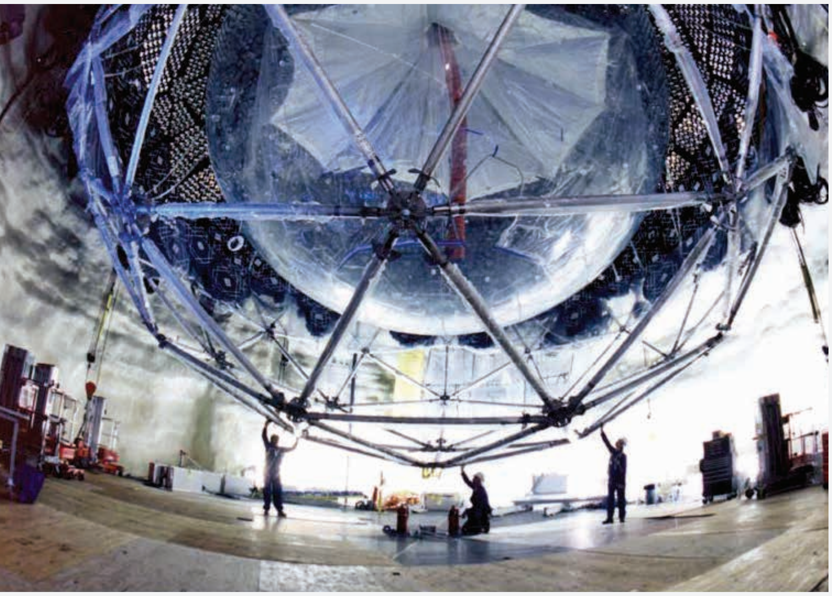


Photo courtesy of Sudbury Neutrino Laboratory.

Located two kilometers below the earth's surface the depth of the detector's location was essential to the study as it reduced interference from cosmic rays by many orders of magnitude. Additional steps were required to minimize interference from other sources of radiation and the levels of radiation at the centre of the vessel are believed to be the lowest on earth.

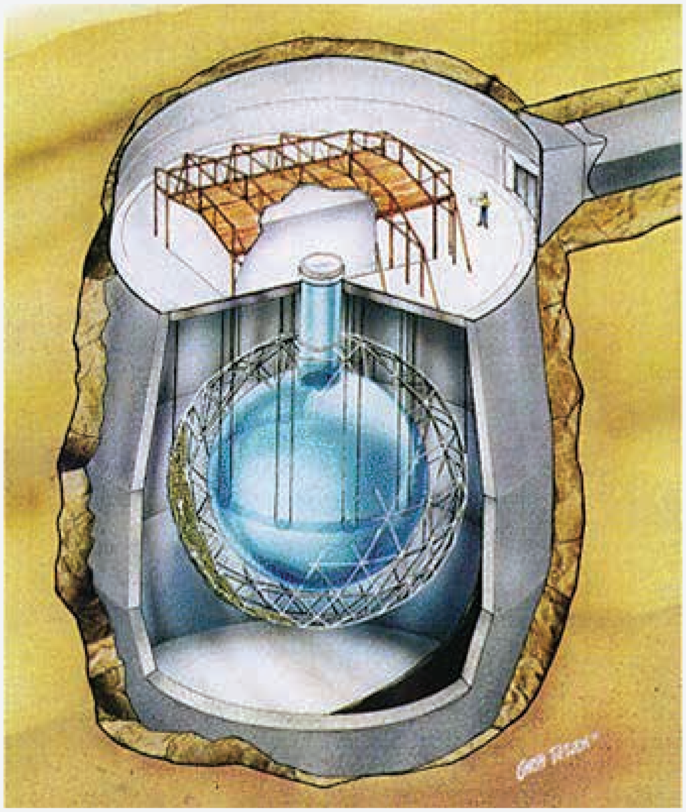


Photo courtesy of Sudbury Neutrino Laboratory.

CNL Researchers Honoured with the 2016 Breakthrough Prize for Fundamental Physics

(2015 November 20) With the ink barely dry from the international headlines celebrating Art McDonald's win of the Nobel Prize for pioneering work on neutrino's, the individual collaborators on the Sudbury Neutrino Observatory (SNO) experiment –an ambitious, highly-engineered experimental project constructed at the bottom of a former Inco nickel mine– have now been honoured with the biggest prize for basic physics research–the 2016 Breakthrough Prize for Fundamental Physics. On the list of prize winners are current CNL employee Bhaskar Sur, Director of CNL's Nuclear Science Division; as well as Guy Jonkmans and Xin Dai, recent employees of CNL's Applied Physics branch and Radiation Protection Research and Instrumentation branch respectively, among many other notable CRL luminaries who have retired or moved on to new challenges like Davis Earle, and Gwen Milton, just to name a few.

"The unique aspect of the Breakthrough Prize is that that they have recognized all of the authors on discovery publications for the five neutrino experiments around the world that have contributed to our understanding of neutrino oscillations," says Sur. "Some 1,377 team leaders and members will share a portion of the $ 22 million prize for revealing a new frontier beyond the Standard Model of particle physics," he adds.

When parsed and distributed the funds don't amount to very much Sur tells us, but peer recognition is highly-valued in the science community as well as the acknowledgement of an organization with a global scope and high ideals. The committee behind the Breakthrough Prize notes that "the disciplines that ask the biggest questions and find the deepest explanations are the fundamental sciences. The Breakthrough Prizes honor important, primarily recent, achievements in the categories of Fundamental Physics, Life Sciences and Mathematics. Knowledge is humanity's greatest asset. It defines our nature, and it will shape our future."

Our congratulations to winners of this prestigious prize.

CWFEST-2015 Features World-Leading Science in Fusion

By COLIN HUNT

Fusion science and technology returned to the Canadian Nuclear Society's conference roster with CWFEST-2015, on October 18 in Ottawa. CWFEST (Canadian Workshop on Fusion Energy Science and Technology) featured eight of the world's leading experts in fusion from across North America in a half-day workshop. More than 40 delegates and speakers were in attendance.

In his opening remarks, Dr. Blair Bromley noted that this was the second time that the workshop has been held as an embedded event within another CNS conference. The previous event was in 2013, and he expressed confidence that the next one would be in 2017.

There were two speakers on the topic of laser ignition. The first, Dr. Robert Fedosejevs of the University of Alberta, outlined the various technical routes by which fusion can be achieved. He observed that his group is making good progress in their research with some new possible developments to explore.

Later in the program, Dr. Sandra Brereton from Lawrence Livermore National Laboratory (LLNL) outlined the startup and operation of the National Ignition Facility, which has been operational since 1997. The large complex, roughly the size of a football field, hosts 192 lasers all focused into a single beam of 1 u mm of approximately 1.8 mj.

She noted that the facility achieved 300 shots during 2015, and the target was to surpass 400 in 2016. She also indicated that the purpose of the facility was to explore fusion, not simply to produce net energy.

One interesting talk was on hybrid fusion-fission reactors (HFFR) given by Dr. Bromley. Based on work being done at Chalk River Laboratories, such a reactor concept would feature both fission and fusion processes going on in a reactor at the same time. The reactor concept would use thorium fuel for both power and breeding. Because of its high temperature operation, it would use gas coolant.

Another interesting talk was given by Brendan Cassidy of General Fusion. General Fusion is the only private sector company in Canada engaged in fusion research and development.

Also a large part of the workshop was a couple of presentations on tritium. Dr. Hugh Boniface of CNL provided an update on tritium handling technology. Dr. James Klein of Savannah River National Laboratory provided an update on next year's large international conference on tritium.

The workshop was concluded with a panel discussion by all speakers. The central question to them was how to move fusion from research to development. It was agreed that the current ITER project in France should not be the only way forward, as there were a variety of other promising prospects. It was also agreed that significant development would require a much greater devotion to the support of fusion development.

Simulation Conference Draws Strong Canadian and International Audience

By COLIN HUNT

One of the Canadian Nuclear Society's (CNS) longest established technical conferences commenced in Ottawa on Sunday, October 18 2015. With well over100 delegates in attendance, the 7th International Conference on Modelling and Simulation in Nuclear Science and Engineering was a five-day event culminating in a tour of Chalk River Laboratories.

The conference included a strong international contingent, with three plenary speakers from China and a number of speakers from the United States and South Korea.

The conference was opened by Fred Dermarkar, President and CEO of the CANDU Owners Group (COG). In his opening remarks, Mr. Demarkar showed the great importance of accurate simulation based on real world events. He noted that just three months prior to the accident at Fukushima, Japan, a probabilistic safety analysis had shown plant owners Tokyo Electric Company that no safety upgrades were necessary for the plant.

Mr. Demarkar indicated that the study was flawed because a number of different possible events had been excluded from consideration, including in-plant flooding. From this example, he indicated that it was essential that unexpected results from a study be reported along with the main conclusions.

Mr. Demarkar was followed by Mr. Rick Didsbury, General Manager Research and Development, Chalk River Laboratories. He offered a view of the future direction of nuclear research and development in Canada. He noted that over the past 20 years there has been a very slight increase in R&D spending, with most of this spending being done by the public sector. Historically, this research investment had resulted in a proliferation of companies, organizations and research institutes primarily driven by CANDU technology.

However, all this is changing, according to Mr. Didsbury. He said it is now unclear that new nuclear in Canada will necessarily be CANDU. While there is no new nuclear construction in Canada at this time, what will be increasing will be decommissioning activity. Specifically this means Gentilly 1 and 2, Douglas Point and Pickering.

There will also be large scale decommissioning at Chalk River Laboratories as well. Over the next 10 years, 122 buildings will be demolished and removed. Mr. Didsbury described them as old, "decrepit" buildings, many of them dating back to immediate post-War construction. They will be replaced by a number of newer, much larger buildings dedicated to nuclear research and advanced fuel cycles.

At this time, the nuclear industry faced two principal difficulties, according to Mr. Didsbury, not just in Canada but by all nuclear engineering companies. Principally these were "modest coal acceptance", and longer lead times and greater capital requirements than alternatives to nuclear. He indicated that the response to these challenges would come from research and development driven by the business case of energy supply. Also integral as part of the solution was collaboration on a larger scale than seen thus far.

Conference Chair Dr. Elizabeth Varin told the CNS Bulletin that she was very happy with the conference attendance, and with the scope and diversity of both the program and the speakers. She credited Lawrence Leung and Wei Shen for their outstanding work in attracting strong participation from China and South Korea.

The greater diversity of the program marked a number of other changes as well. Previously the simulation conference had always been a symposium with little representation from utilities. The 2015 conference was much different, according to Dr. Varin. This year's event had drawn strong participation from institutions outside Canada such as Idaho National Laboratories in the US, and strong participation from industry. It had also attracted strong sponsorship.

Dr. Varin also noted increased industry interest in simulation. This she attributed in part to the fact that experimental setups are more difficult, scarce and expensive than was the case in earlier times.

INCC Provides First Industry Speaking Opportunity for New CNL CEO Mark Lesinski

By COLIN HUNT

New President and CEO of Canadian Nuclear Laboratories (CNL) Mark Lesinski provided the keynote opening address to the International Nuclear Components Conference (INCC) on November 1, 2015. Speaking to the conference, Mr. Lesinski provided a brief historical overview of Atomic Energy of Canada Limited (AECL) before outlining the future direction of CNL under its new private sector management group.

He outlined three key missions for CNL at this time. The first was decommissioning followed by reconstruction. Mr. Lesinski noted that many of the buildings are over 50 years old, in poor condition, and need to be removed to make room for new research facilities. In total, CNL has approximately $3 billion in old liabilities to be cleaned up.

Replacing the old facilities will be a new $100 million science and technology facility at Chalk River Laboratories to carry out the future work of CNL.

"The federal government recognized that it needed to move to commercial efficiency for its nuclear laboratories," Mr. Lesinski said. The remaining two priorities are research and development in science and technology for government and for industry.

At this time, Mr. Lesinski said that CNEL (Canadian National Energy Alliance), the new managing company, is still conducting due diligence and site assessment of the CRL facilities. It has a 10-year contract to manage the facilities for the federal government. He indicated that he expects the Chalk River site to be completely renovated during that time. The plan is to take down 122 existing old buildings, and construct new facilities.

"At the end of 10 years, CRL will be one of the top nuclear research and development sites in the world that will attract talent from around the world," Mr. Lesinski said.

Mr. Lesinski also addressed briefly the future of the NRU research reactor. At this time, he indicated that CNL is seeking an 18-month extension of its operating licence to 2018. He noted that NRU had scaled back considerably its isotope production in recent years, and was now functioning much more in a backup supply role.

Opening the conference, Conference Chair Mr. Dan Gammage noted there were two principal goals to be achieved during the three-day event. The first was to exchange ideas and solutions about the nuclear industry's materials and components problems. These were primarily focused around degradation and corrosion in key plant components such as steam generators. The second goal was to provide for a transfer of knowledge between generations to younger people working in the industry and to students.

In his introductory remarks to the first technical session, Dr. Peter King noted that as little as 2 parts per billion concentration in feed water can result in deposition of as much as 100 kilograms of material in the steam generators on an annual basis.

"Anything which enters the system by the feed water tends to stay there," Dr. King said, "And it is all deposited in the steam generators."

Methods of dealing with deposition problems lie in three principal areas: water chemistry blowdown and physical maintenance to remove them.

An overview of US history of steam generator performance was provided by Ryan Wolfe of the Electric Power Research Institute (EPRI). As the second keynote speaker following Mark Lesinski, Mr. Wolfe noted that many US nuclear plants have installed steam generators made of Inconel 690TT rather than 600TT. He observed that stress corrosion cracking in 690 alloy steam generator tubes has begun to be observed just as it was previously detected in 600 alloy tubes.

Overall, INCC attracted over 100 delegates and speakers and more than a dozen exhibitors and sponsors. Following the opening plenary session were two days of technical sessions. INCC is the current version of the Canadian Nuclear Society's (CNS) long running steam generator conference series.

Why Nuclear Energy is Essential to Reduce Anthropogenic Greenhouse Gas Emission Rates

By AGUSTIN ALONSO[1], BARRY W. BROOK[2], DANIEL A. MENELEY[3], JOZEF MISAK[4], TOM BLEES[5], and JAN B. VAN ERP[6]

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Abstract

Reduction of anthropogenic greenhouse gas emissions is advocated by the Intergovernmental Panel on Climate Change. To achieve this target, countries have opted for renewable energy sources, primarily wind and solar. These renewables will be unable to supply the needed large quantities of energy to run industrial societies sustainably, economically and reliably because they are inherently intermittent, depending on flexible backup power or on energy storage for delivery of base-load quantities of electrical energy. The backup power is derived in most cases from combustion of natural gas. Intermittent energy sources, if used in this way, do not meet the requirements of sustainability, nor are they economically viable because they require redundant, under- utilized investment in capacity both for generation and for transmission. Because methane is a potent greenhouse gas, the equivalent carbon dioxide value of methane may cause gas-fired stations to emit more greenhouse gas than coal-fired plants of the same power for currently reported leakage rates of the natural gas. Likewise, intermittent wind/solar photovoltaic systems backed up by gas-fired power plants also release substantial amounts of carbon-dioxide-equivalent greenhouse gas to make such a combination environmentally unacceptable. In the long term, nuclear fission technology is the only known energy source that is capable of delivering the needed large quantities of energy safely, economically, reliably and in a sustainable way, both environmentally and as regards the available resource-base.

1. Introduction

The need to reduce anthropogenic greenhouse gas (AGHG) emissions is of great urgency if catastrophic consequences caused by climate change are to be prevented. However, while the United Nations Framework Convention on Climate Change (UNFCCC), through its various meetings of the Conference of the Parties (COP), has emphasized the role of renewable energy sources, it barely mentions nuclear energy and the important contribution that it is already making in reducing AGHG emissions and could increasingly be making in the future. This is difficult to understand because nuclear fission is the only major energy source that could sustainably, reliably and economically provide the large quantities of clean energy that will be needed to make substantial progress in reducing AGHG emissions.

When addressing issues related to the long-term energy policy, two important questions need to be asked, namely:

- Is it possible to replace all or most fossil-derived energy with *renewables* and, if so, would this be sustainable and economically viable?
- Is nuclear energy sustainable and what should its role in the energy mix be?

The term *sustainable* is generally understood, Brundtland Commission [1], to mean *"meeting the needs of the present without compromising the ability of future generations to meet their own needs"*. In the context of energy options, 'sustainable' implies the ability to provide energy for indefinitely long time periods (i.e., on a very large civilization spanning time scale) without depriving future generations and in a way that is environmentally friendly, economically viable, safe and able to be delivered reliably. It should thus be concluded that, in this context, the term 'sustainable' is more restrictive than the term 'renewable', as large scale renewable systems backed by fossil fuels cannot be considered clean sources of electricity. On the other hand, nuclear energy from fission of uranium and plutonium is sustainable, meeting all of the above-mentioned criteria as discussed later.

The energy consumption in industrial nations may be roughly divided in three equal parts, namely:

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- generation of electrical energy;
- heat in industrial processes and space heating;
- and transportation.

Nuclear fission is a low AGHG emission energy source that is already widely deployed for generation of electrical energy. Therefore, one effective way to reduce fossil fuel consumption and AGHG emissions would be by increasing the number of nuclear power plants for electrical energy generation.

It would be well within realistic limits to aim for replacement of the major part of the world's fossil fuel-based electrical energy generating capacity. Industrial nations should take the lead in this change because they are more capable of doing so, having already developed the necessary technological and mature economic base. In parallel to this major change in the generation of electrical energy, the use of fossil fuels for transportation should be reduced by greater reliance on nuclear-derived electrical energy as well as on liquid fuels produced synthetically by means of nuclear power plants. Also the use of nuclear-derived process heat for industrial application and services should be encouraged [2]. Gradual conversion of the electrical generating capacity from fossil fuel-based to nuclear fission would be the way offering least economic disturbance.

2. Intermittent 'renewables' when applied to the electric grid

Wind and solar energy have served humanity well during centuries and in many applications, including grinding wheat, pumping water, sawing wood, drying foods and producing sea salt. Wind also served as an important energy source for transportation, making possible the exploration of the entire world by means of ships propelled by the wind. The common characteristic of these applications is that they are not time-constrained: if there is no wind today, the tasks can wait to be finished tomorrow or the ships will arrive somewhat later. This is not possible if intermittent renewable energy sources are used for base-load delivery of electrical energy to the grid, as strict demands have to be fulfilled instantaneously and completely.

2.1 Grid-connected 'renewables' with gas-fired backup are not sustainable

Intermittent 'renewables' are, in certain applications, not 'sustainable' because not all necessary criteria are being met. Intermittent 'renewable' energy sources, *when used for large-scale delivery of energy to the electric grid,* require the availability of energy storage facilities or flexible backup power plants capable of rapid output adjustments. This is because wind turbines and solar/photovoltaic plants will vary their output between 0% and 100% of nameplate capacity, as it can be observed

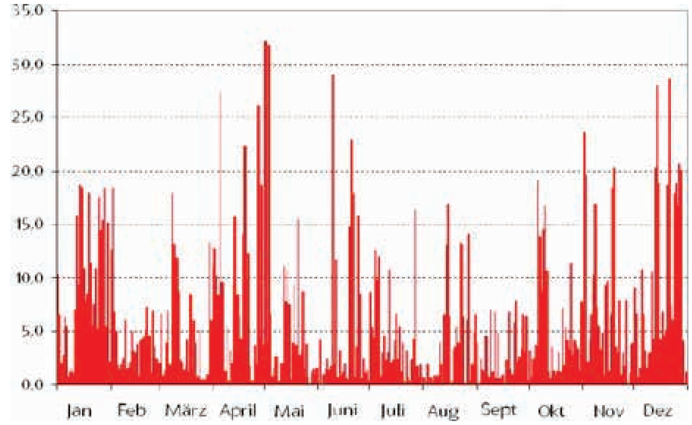

Fig. 1. Intermittence of wind energy in E.ON-grid in Germany (from Ref. [3]).

in the typical example given in Figure 1.

As energy from the grid is generated and consumed simultaneously, there can be no mismatch if grid stability and frequency are to be maintained within strict tolerances. The backup power is usually provided by gas-fired stations because technology for storing large amounts of electricity is not yet available. Although reversible pumped hydro- power stations can be used to store potential energy, there are siting, technical and economic limitations that prohibit their widespread use. Gas-fired plants emit carbon dioxide and are associated with leakage of methane (the primary component of natural gas) into the atmosphere, which is a strong AGHG emitter. Only if the backup energy is delivered by hydro-electrical energy plants or similar means to store and control the generated energy, then grid- connected intermittent 'renewables' can be qualified as sustainable.

2.2 Grid-connected 'renewables' are not economically viable

Averaged over a year, wind/solar photovoltaic systems deliver from 25% to 45% of their nameplate production capacity. Therefore, the backup power plants or energy storage facilities will have to deliver the remaining 75% to 55% of the energy. Seasonal variability is another major, yet rarely acknowledged, impediment to all-renewables scenarios, as it is seen in Table 1.

Advocates often dismiss the issue of seasonal variability, pointing out that the wind blows more in the winter when solar output is minimal, and asserting that wind and solar balance out on a daily basis because wind blows more at night. However, these generalizations do not hold up to scrutiny. While some areas of the world do have more wind in the winter, others do not.

The backup power for wind/solar photovoltaic plants depends in most cases on combustion of less expen-

Table 1. Seasonal variability of wind-generated electrical energy in Texas, USA. Highest and lowest monthly generation values (GWh).

Year	Highest value (month)	Lowest value (month)	Ratio (high/low)
2009	1,993 (April)	1,341 (July)	1.44
2010	2,721 (April)	1,589 (Sept.)	1.75
2011	3,311 (June)	1,694 (Sept.)	1.95
2012	3,131 (March)	1,821 (Aug.)	1.74
2013	3,966 (May)	2,023 (Sept.)	1.96

Source: Private communication, P. Peterson, Prof. Nuclear Engineering, Univ. of California at Berkeley, USA

sive natural gas. Storage may be of various types: potential energy storage capacity may be created by pumping up water or compressing air, small scale storage could be achieved in condensers and batteries. However, most energy storage facilities are not cost-effective for base-load application and often have undesirable environmental impacts. Also, storage is associated with energy losses. Consequently, grid- connected wind/solar photovoltaic installation will usually rely on gas-fired backup power plants.

Many wind and solar photovoltaic installations are far removed from the load centers, requiring additional long-distance transmission lines, sized for their peak output, which are then under-utilized by from 55% to 75%. Furthermore, the backup power plant will have to operate in stand-by mode, ready to adapt to the varying output (from 0% to 100%) of the intermittent energy source. This results in a penalty on the overall thermal efficiency of the backup plant, which can be as high as 20%. Grid-connected wind and solar photovoltaic installations will thus be dependent on subsidies because redundant and under-utilized investments are necessary (i.e., for the intermittent energy source, for the backup source and for the additionally required transmission capability). In view of the above-given reasons, it has to be concluded that the combination of an intermittent energy source and its back- up power plant will not be able to achieve economic viability, as illustrated in Table 2. However, in isolated locations and some processes without access to a large electric grid, intermittent energy sources either directly or combined with storage capacity may be economically viable.

Table 2. Average power plant operating expenses for USA electric utilities (mS/kWh).

	2008	2009	2010	2011	2012
Nuclear					
Operation	9.9	10.0	10.5	10.9	11.6
Maintenance	6.2	6.3	6.8	6.8	6.8
Fuel	5.3	5.4	6.7	7.0	7.1
Total	21.5	21.7	24	24.7	25.5
Intermittent plus gas turbine					
Operation	3.8	3.0	2.8	2.8	2.5
Maintenance	2.7	2.6	2.7	2.9	2.7
Fuel	64.2	52.0	43.2	38.8	30.5
Total	70.7	57.6	48.7	44.5	35.7

Source: USA Energy Information Administration

Much confusion exists concerning the generating cost per kWh for wind kWh generated by wind or solar photovoltaic installations that is consumed or stored locally and the cost of a kWh delivered to the electrical grid. In the latter case, it is necessary to account for the investments in the backup power and transmission capacity. The difference between these two prices is very substantial; the cost per kWh delivered to the grid in most cases being several hundred percent higher than the 'bare' cost. As an example, Table 2 shows that for the combination of intermittent energy source with gas-fired backup power, the cost for fuel per kWh varies between 5 and 12 times the cost for operation and maintenance.

2.3 Grid-connected 'renewables' have deleterious consequences

Grid-connected intermittent energy sources will cause grid disturbances that will deleteriously affect the grid's reliability, particularly if the installed capacity of the intermittent sources becomes a high percentage of the grid's total capacity. Delivery unreliability of the electrical grid can have serious economic and social consequences as has been observed when long-lasting blackouts occurred in large urban areas. To date, in most grids, 'renewables' have only reached a relatively low market penetration and so have been able to rely mostly on existing marginal capacity, or on large import−export capacity of interconnected other grids.

Problems will emerge when the percentage of grid-connected intermittent energy sources exceeds the existing marginal capacity (without availability of adequate dedicated back-up power capacity) and it becomes necessary for the base-load plants to function as back-up plants. This mode of forced 'accommodative' operation penalizes nuclear power plants more than it does fossil-fired plants because the capital-cost component of the generating cost for the former is relatively high and the fuel cost component is low, whereas for the latter the reverse is true, as shown in Table 3.

This practice of distorting the energy market by subsidies and supporting regulations has serious

Table 3. Generation cost breakdown (%).

Component	Nuclear	Coal	Gas
Capital	59	42	17
Fuel	15	41	76
Operation & Maintenance	26	17	7

Source: OECD/International Energy Agency

and undesirable consequences, resulting in closure of base-load generating capacity (including nuclear power plants), loss of grid reliability and higher net greenhouse gas emissions. This issue is of particular relevance for countries having an interconnected grid with an adjacent country that is relying (or is planning to rely) to a large extent on intermittent 'renewable' energy sources. In this respect, the question should be raised whether a country with a large installed wind/ solar electrical generating capacity should be required to pay a connection fee to compensate adjacent countries for the use of their interconnected electric grids for providing backup power capacity.

It is often claimed by advocates of 'renewables' that the problems associated with the intermittency of wind and solar energy can be overcome by performing more research and carrying out more engineering development. Unfortu- nately, no level of research and development will be able to overcome the fact that the sun does not always shine and that the wind does not always blow. Not even the much-praised 'smart grid' can change this inconvenient fact.

2.4 The relevance of methane as a greenhouse gas

Methane, CH_4, the main component of natural gas, is a potent greenhouse gas as compared to carbon dioxide, CO_2; making it one of the six gases considered in the Kyoto Protocol, the second in importance. To measure the relative climate importance of the two gases, the International Panel on Climate Change (IPCC) has introduced the concept of *global warming potential* (GWP) [4] which is defined (glossary) as:

"**Global warming potential (GWP)**, index based on radiative properties of greenhouse gases measuring the radiative forcing following a pulse emission of a unit of gas of a given greenhouse gas in the present day atmosphere integrated over a chosen time horizon, relative to that of carbon dioxide. The GWP represents the combined effect of the different times these gases remain in the atmosphere and their relative effectiveness in causing radiative forcing."

The *radiative forcing* of a greenhouse gas is itself defined [4] (glossary) as:

"**Radiative forcing**, change in the net, downward minus upward, radiative flux (expressed in W.m-2) at the tropopause or top of the atmosphere due to a change in an external driver of climate change, such as, for example in the change in the concentration of a gas or the output of the sun."

The GWP of any gas is calculated through the expression

$$GWP_m(t) = \frac{\int_{t_r}^{t_h} a_m C_m(t)dt}{\int_{t_r}^{t_h} a_c C_c(t)dt}, \qquad (1)$$

where sub-index m represents methane and c carbon dioxide; a is the radiative forcing of the gas and $C(t)$ the time function, which represents the evolution of the gas in the atmosphere after the release of a pulse emission of a unit of gas. The integration goes from the time of release, t_r, to the selected time horizon, t_h. Function $C(t)$ takes into account the rather complicated chemical reactions and other removal processes that take place among the different constituents in the atmosphere causing the disappearance of the released gases.

Each integral term in the definition is also called the *absolute global warming potential* (AGWP) of the concerned and the reference gas and is measured in $W/m^2/y/kg$. To estimate the magnitudes defined above, the IPCC has provided the graph reproduced in Figure 2.

It is accepted that a pulse release of methane in the atmosphere will be removed exponentially with time by getting involved in chemical reactions with hydroxyl radicals (OH) present in the atmosphere. The coefficient in the exponential function is the inverse value of the so-called *turn over or global atmospheric lifetime* of methane, represented by symbol T. This symbol is given the value of 11.2 + 1.3 years. The $AGWP_{CH_4}$ is then obtained by the equation:

$$AGWP_{CH_4} = \int_0^t a_m e^{-\frac{t}{T}} dt = a_m T\left(1 - e^{-\frac{t}{T}}\right). \qquad (2)$$

In less than a century, the AGWPCH4 reaches an asymptotic value, $a_m T$, which is the product of the *radiative forcing* of methane multiplied by the assumed lifetime of methane in the atmosphere measured in $W/m^2/y/kg$. Note that the graph in Figure 2 is reduced by a factor of 10.

The behavior of carbon dioxide in the atmosphere includes a variety of phenomena, which could not be represented by a single lifetime; as seen in the blue curve, the $AGWP_{CO_2}$ is less than the one for methane because its radiative forcing is smaller; moreover, carbon dioxide in the atmosphere never reaches an asymptotic value because a small fraction of the carbon dioxide emitted is not removed from the atmosphere by natural processes, while the rest of the processes are described by exponential functions with long lifetime.

The ratio of the two curves is the GWP_{CH_4}, a decreasing function with increasing time horizon; when the time horizon approaches the time of release the GWP_{CH_4} tends to 120, which should be interpreted as the radiative forcing of the methane relative to the one of carbon dioxide. From the graph it is deduced that the GWPCH4 values are about 63, 21 and 3, obtained from calculations, for respective time horizons of 20, 100, and 500 years. The IPCC recommends using a time horizon of 100 years.

The methane contents in the atmosphere started to grow since 1750, the year considered as the start of the industrial revolution; at that time, the methane content in the atmosphere was 0.722 ppm; it grew exponentially until about 1980, in the 1990s the rise slowed down and reached the value of 1.893 ppm in 2011, an increment of some 1.171 ppm, i.e. an average increase of 138%. This value is compared with the same temporal increment of carbon dioxide in the atmosphere from 280 ppm in 1750 to the current 395 ppm, an increment of 115 ppm, i.e. an average increase of 36%. From these values, it is deduced that from the year 1750 to now, i.e. 260 years, for which the GWP_{CH_4} is around 10, the increase in the climatic relevance of methane has been 40 times larger than that for carbon dioxide. This proves the relevance of methane as a greenhouse gas.

As in 1750, the atmospheric content of methane was probably in equilibrium and mainly caused by natural sources, it is considered that the noted increment is mainly due to anthropogenic reasons. The cause of the increase has to be attributed to direct atmospheric releases of natural gas during its geological extraction, purification, flaring and venting, liquefaction and transport, as well as storage, manipulation and use of the gas in electricity-generating station and from poor gas combustion. There is much literature, even regulations, on the mass fraction of natural gas leakages from all these operations. Values are quoted [6] from 2% to 10% of natural gas releases when the complete fuel cycle is considered: from the source to the power plant.

When natural gas is used instead of coal or to back up the intermittency and variability of wind/solar photovoltaic systems for load-based electricity generation, the expected climatic effect from the natural gas directly released to atmosphere, also called the *fugitive methane,* has to be added to the corresponding release of carbon dioxide from the natural gas combustion process. To determine the relevance of the radiative forcing of the leaked natural gas, the IPCC [4] has introduced the concept of equivalent carbon dioxide emission (glossary):

"**Equivalent carbon dioxide emission**, the amount of carbon dioxide emission that would cause the same integrated radiative forcing over a given time horizon as an emitted amount of a greenhouse gas or the mixture of greenhouse gases. The equivalent carbon dioxide emission is obtained by multiplying the emission of the greenhouse gas by its global warming potential for the given time horizon".

Table 4. Ratio between the greenhouse gases from a gas-fired station including methane leakages and from a coal-fired plant of equal power.

ψ	GWP/t_h		
	120/as.	63/20	21/100
0.02	0.93	0.73	0.57
0.04	**1.37**	0.95	0.65
0.06	**1.80**	**1.18**	0.90

The use of the equivalent carbon dioxide concept when applied to methane permits to compare the GWP of a given coal station with the one for a gas-fired installation of the same power when gas leakages are included. That relation is obtained from the following algorithm:

$$R_{m/c} = m\left\{1 + \psi\frac{M_{\mathrm{CH_4}}}{M_{\mathrm{CO_2}}}(\mathrm{GWP}(t_{\mathrm{h}}))\right\}, \tag{3}$$

where m is the ratio between the masses of carbon dioxide generated in the combustion of methane and coal per unit of energy generated in the respective electrical power plants, it depends on the quality of the fossil fuels and the efficiency of the plant, the average value of ½ is frequently used in calculations; ψ is the fraction of fugitive methane directly discharged to the atmosphere from leakages in the natural gas cycle; M_{CH_4} / M_{CO_2} is the ratio between the molecular mass of methane and carbon dioxide needed to estimate the methane carbon dioxide equivalent, and GWP(t_h) the global warming potential of methane for time horizon (t_h). In Table 4, estimations are presented for different leakage fractions, the asymptotic and horizon times of 20 and 100 years, corresponding to the GWP (t_h) of 120, 63 and 21.

It is observed from the table that for gas leakages of 2%, the breakeven, although close, is not reached even for the asymptotic value, while for leakages of 4%, the breakeven is close for a time horizon of 20 years. Leakages superior to 6% could not be accepted even for time horizons of 100 years. The results clearly indicate that replacing coal-fired with gas-fired plants does not provide any relevant climate reduction unless gas leakage is reduced to less than 2%.

Likewise, the climatic effect of a gas-fired backup power is obtained by adding the carbon dioxide equivalent of the fugitive methane to the carbon dioxide generated during the fraction of the time that the backup power is needed. In this case, the ratio between the methane/carbon dioxide equivalent due to the fugitive methane and the carbon dioxide release from the combustion of the gas in the backup plant is given by the equation:

$$R_{m/c} = \left\{ \psi \frac{M_{\mathrm{CH_4}}}{M_{\mathrm{CO_2}}} (GWP(t_h)) \right\}. \tag{4}$$

In Figure 3, estimations are presented for different leakage fractions, the asymptotic and horizon times of 20 and 100 years, corresponding to the GWP(t_h) of 120, 63 and 21.

As in Table 4, it is also observed that for gas leakages of 2%, the breakeven, although close, is not reached even for the asymptotic value of the GWP, while for 4% leakage breakeven is close for the 20-year GWP. It is then concluded that for leakages above 2% and certainly superior to 4% it will be climatically advantageous to backup wind/solar photovoltaic systems with coal-fired instead of gas-fired plants.

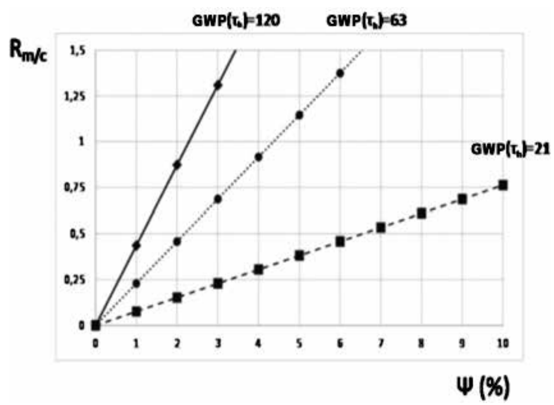

Fig. 3. Ratio between the carbon dioxide equivalent for fugitive methane and the carbon dioxide emitted in a wind/solar photovoltaic system backed by a gas-fired plant.

3. The essential role of nuclear energy in reducing greenhouse gas emissions

Nuclear fission energy is capable of replacing most of the stationary tasks now performed by the combustion of fossil fuels. Other than the generation of electrical energy, it may equally well be used for production of process heat and hydrogen as well as for desalination. However, many environmental organizations and governments oppose the application of nuclear energy. Among the reasons usually given are:

- nuclear energy is not sustainable;
- nuclear energy is not economically viable;
- and nuclear energy is not safe.

3.1 Nuclear energy from fission is sustainable

Today's commercially available uranium-fueled nuclear power plants can provide the world with clean, economical and reliable energy well into the next century on the basis of the already-identified uranium deposits. Furthermore, nuclear reactors operating with fast neutrons are able to fission not only the rare uranium isotope U-235 but also the Pu-239 isotope generated from the transmutation of the abundant uranium isotope U-238. Thus, the deployment of fast-neutron fission reactors transforms uranium into a truly *inexhaustible energy source,* because of their ability to harvest up to one hundred times more energy from the same amount of mined uranium as the commercially available thermal reactors can achieve [7,8].

Table 5. Percent sensitivity of generating cost to a 50% increase in fuel price.

Nuclear	IGCC	Coal Steam	CCGT
3	20	22	38

IGCC: integrated gasification combined cycle; CCGT: combine cycle gas turbine. Source: WEO '06/OECD/IEA World Energy Outlook 2006

This fast-neutron fission technology has already been proven, all that is further needed is to develop it to a commercial level and deploy it widely [9]. The amount of depleted uranium that is available and stored at enrichment plants in a number of countries, together with the uranium recoverable from used fuel elements, contains enough energy to power the world for several hundred years without additional mining. Afterwards, mining of small quantities of uranium in future centuries, including extracting uranium from lower-grade ores and, if necessary, from seawater, could satisfy global energy needs economically for as long as human civilization will endure.

3.2 Nuclear Energy from fission is economically viable

Conditions for economic viability of nuclear energy are:

- presence of a *level playing field,* i.e., an open market that is not skewed in favor of some technologies by means of subsidies and/or by a legally imposed priority access for delivery to the electrical grid at a fixed high price;
- standardization of the plants, built in series and supported by a standardized supply chain;
- a long-term governmental energy policy (stable over a time period of several decades) including, among other features, good (unbiased, accurate, evidence-based) public information;
- a stable and streamlined licensing process that is technology-neutral, risk-informed and capable of resolving promptly any safety issues that may arise during construction and operation;
- and gradual introduction of the concept of payment for *external costs,* applied to all energy technologies and based on common standards.

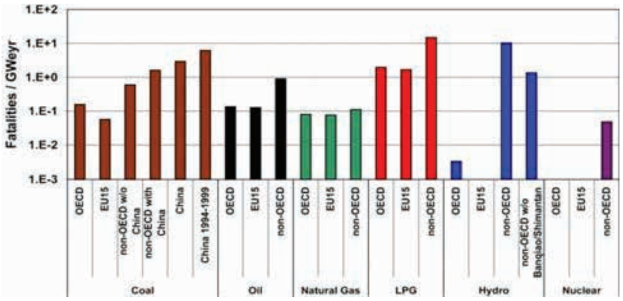

Fig. 4. Comparison of energy-related damage (fatalities per GW/y). Based on historical experience of severe accidents in OECD, non-OECD countries and EU-15 (from Ref. [13]).

The fact that nuclear energy is economically viable has been shown, among others, by the national energy program in France where the unit price of electricity in a market supplied about 75% by nuclear fission is among the lowest worldwide. An important additional benefit of this reliance on nuclear energy is that per capita emission of greenhouse gases in France is among the lowest for industrial nations worldwide and many times lower than in otherwise similar countries that have no nuclear power plants and that rely on a mix of fossil fuels and renewables.

An important aspect of long-term commercial viability of power plants is the future development of their respective fuel costs. Nuclear power plants rank best in this respect because their sensitivity to fuel-cost increases is small as seen in Table 5.

The current temporary abundance (in the USA) of low- cost natural gas may seem to make gas-fired stations appear to be economically attractive. However, this will change because it can be expected that gas prices will rise substantially during the 60+ lifetime of new-build nuclear power plants.

Thus, the fuel supply side of nuclear power reactors eliminates any doubt concerning its sustainability. As to the materials used in the construction of nuclear power plants, it is noted that none of them is in short supply (and most are readily recyclable), so that they too do not constitute a sustainability impediment.

3.3 Nuclear energy from fission has a low environmental impact

Numerous scientific comparisons have shown that nuclear fission is among the energy sources that are least polluting and have the lowest overall environmental impact [10]. Operating nuclear power plants do not produce air pollution nor do they emit CO_2. Any CO_2 that is associated with nuclear finds its origin in the mining of uranium and in the production of structural materials necessary for the building of the nuclear plants; small amount of CO_2 are released during the periodic testing of emergency diesel generators and on the use of external power during refuelling outages and maintenance.

Table 6. Mortality rates (deaths per TWh) from energy sources.

Coal global average	100	50% global electricity
Coal China	160	75% China's electricity
Coal USA	15	44% USA electricity
Oil	36	36% global/ 8% electricity
Natural gas	4	20% of global electricity
Biofuel/biomass	24	21% global energy
Solar (rooftop)	0.44	<1% global electricity
Wind	0.15	~1% global electricity
Hydro-global average	1.4	15% global electricity
Nuclear global average	0.04	17% global electricity

Source: Updated data from: World Health Organization

Annually, the 435 operating nuclear power plants prevent the emission of more than 2 billion tons of CO_2. By contrast, coal-fired stations emit worldwide about 30 billion tons of CO_2 per year and cause health effects and premature death through air pollution and dispersion of pollutants, including mercury and other poisonous materials [11]. It is to be noted that nuclear power plants emit less radioactive material than do coal-fired stations (uranium and other radioactive isotopes are found naturally in coal ash and soot) [12]. The most severe environmental impact associated with nuclear energy is due to the mining of uranium. However, the need for uranium mining will be reduced after fast reactors have become commercially available, as may be expected within the coming decades.

New methods for efficiently recycling the used fuel will reduce the radioactive hazards as well as the volume of the waste that must be kept isolated from the environment. New technologies have been actively developed to reduce the level of radioactivity of a repository containing this type of waste so that the activity of the waste, after a few centuries, will be comparable to that of the natural uranium deposits that are widely distributed around the world. Furthermore, modern waste isolation technology will equal or exceed the level of isolation originally provided by nature for radioactive ores. In this way the waste will be reduced to a historical time scale of a few hundred years, rather than a geological time scale of hundreds of thousands of years. Furthermore, it is important to note that this waste will be disposed of in an environmentally inert form, i.e., ceramic or vitrified solids that will not start leaching any material into the environment for thousands of years, long after their radioactivity will have dissipated. On the other hand, large amounts of solid and gaseous waste from coal-fired stations (including mercury and heavy metals) will remain poison- ous in perpetuity and they are neither kept well-guarded nor well separated from the environment.

3.4 Nuclear energy from fission meets high safety standards

Nuclear fission is among the safest energy technologies in terms of health effects and fatalities as seen in Figure 4. This is true notwithstanding the three major nuclear accidents that have occurred, namely the 1979 Three Mile Island (TMI) in the USA, the 1986 Chernobyl in Ukraine, and the 2011 Fukushima in Japan. Of these three, only the Chernobyl accident caused a number of fatalities, namely among those persons that were directly exposed to high radiation levels during the urgent initial part of the clean- up operation.

The total number of nuclear-caused fatalities is relatively small (less than one hundred) compared to the number of annual fatalities in the coal and oil/gas industry as seen in Table 6 where there are included the global average values of the mortality rate per billion kWh due to all causes as reported by the World Health Organization (WHO).

Both the accident at Chernobyl and that at Fukushima caused considerable land contamination and required evacuation of the population. However, in both cases the major part of the evacuated areas has/had radiation levels that are lower than the normal background level in many regions around the world, raising the question of how much evacuation was really necessary and for how long. In the case of TMI-2, there was no land contamination, but a short-term evacuation was imposed as a cautionary measure. It should be noted that land contamination is not limited to severe nuclear accidents; it has also occurred following severe accidents in the chemical industry, in which the contaminants were extremely deadly and long lasting (e.g. Bhopal, India; Seveso, Italy).

The radioactive isotopes of iodine (I-131, half-life 8 days) and cesium (Cs-137, half-life 30 years) have dominating importance in accidents in which the containment is breached and radioactivity is released into the environment. The short half-life of I-131 and its biological accumulation in the thyroid requires simple precautions, such as ingesting a small dose of potassium iodine, to prevent its health effects. However, Cs-137 will stay in the environment for a longer time period that is determined by its effective soil removal half-life, i.e., the combination of its radioactive half-life and the rate of removal from the soil surface by natural processes and by adding manure and fertilizers as it has been done in regions contaminated by the Chernobyl releases. This latter process can be accelerated by removal of a thin layer of the top soil in areas where the radiation level exceeds the allowable radiation level, as it is being practiced in soils contaminated by the Fukushima Daiichi accident.

Natural background radiation varies greatly over the world (depending on soil composition and the location's elevation) but higher background has not been found to be correlated with higher rates of cancer in the population. The average background radiation at sea level in much of the world is about three milli-Sievert (mSv) per year whereas that in many regions around the world is considerably higher. As an example, at Ramsar in Iran, the background radiation level is about 138 mSv per year, i.e. about 46 times higher than the average background. Nevertheless, the incidence of cancer in the local population of regions with high background radiation has not been observed to be higher than the normal rate.

The economic damage associated with nuclear accidents can be substantial, as was demonstrated in the above- mentioned three major accidents. This potential for severe economic damage is a strong incentive on the part of the owner/operator of the nuclear power plant to observe extreme caution, observing strictly all safety-related rules and regulations and maintaining a strict safety culture (even without continuous monitoring by the relevant regulatory organization).

As is normal in the evolution of any technology, also the new designs of nuclear power plants incorporated many new safety-related improvements, mainly coming from the worldwide system of analysing, reporting and incorporating operating experience conducted by the World Association of Nuclear Operators (WANO) created after the Chernobyl accident. WANO also conducts periodic external peer reviews of the operational safety of each one of the operating power plants in the system.

The International Atomic Energy Agency (IAEA) produces safety principles, safety requirements and safety guides created by international consensus, to help countries to create their own regulatory regimes, maintains and distributes an Incident Reporting System (IRS) to share operating incidents and an International Nuclear Event Scale, (INES), where events, incidents and accidents are also performs independent evaluations of the operational and safety culture of the requested plant and on the regulatory completeness and practices of the regulatory organization. The Agency is also depositary of the many existing international conventions, of which the *Nuclear Safety Convention* is among the most relevant.

These international activities, together with the national research and advances in technology and regula- tion, have created a high level of safety assurance for future nuclear power plants and substantial safety improvements in currently operating nuclear stations.

Public opposition to nuclear energy is in part due to fear of radiation caused by recollection of the effects of nuclear weapons used during World War II and by sensationalized media coverage of nuclear incidents. Another cause of the public fear of radiation is the use of the scientifically unsubstantiated linear-no-thresh-old (LNT) hypothesis in which it is erroneously assumed that the biological effects of nuclear radiation are linear even at very low radiation doses [14].

4. Conclusions

Nuclear power plants are capable of sustainably and reliably supplying the large quantities of clean and economical energy needed to run industrial societies with minimal emission of greenhouse gases.

The world's industrial nations should take the lead in transforming the major part of their electrical energy generating capacity from fossil fuel-based to nuclear fission- based.

Wind/solar photovoltaic systems with gas-fired backup power stations will not be able to reduce the rate of greenhouse-gas emission, even for relatively low atmospheric gas leakage rates.

Distorting the electricity market with subsidies and by legislation to attract intermittent energy technologies into applications for which they are not well suited, is costly, economically wasteful and counter-productive.

Countries that depend on imported natural gas should be aware that they carry full responsibility for their part of the global consequences of the associated atmospheric leakage of methane, including the leakage taking place outside their borders.

Only in specific cases and for some isolated locations without access to an electric grid, may the use of intermittent energy sources for electrical energy generation be economically viable.

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Cyber Security
Compliance to the new CSA 290.7 Standard

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Abstract

Since 2008, the Canadian Nuclear Safety Commission (CNSC), similar to regulators of other critical industries, has requested their licensees to implement cyber security programs and conduct self- assessments without the benefit of an industry specific cyber security standard that provides common metrics for coverage and effectiveness of their programs. However, for the nuclear industry, a new CSA standard 290.7 entitled "Cyber security for nuclear power plants and small reactor facilities" [1], released in December 2014, will have the CNSC looking to facility operators to be compliant to the new standard.

This paper will discuss initiatives at Canadian Nuclear Laboratories to develop of a suite of tools, techniques, and best practices that can be used by the regulator and industry for assessing compliance and effectiveness of cyber security technology and implementations.

1. Introduction

Nuclear operators and regulators are faced with the never ending challenge of navigating the overwhelming, ever increasing, and continuously evolving volume of information across many industrial sectors to develop and maintain the knowledge, understanding, and capabilities required to design and implement cyber security solutions that are effective, practical, maintainable, and compliant.

In recognition of the need for cyber security solutions, Canadian Nuclear Laboratories (CNL) has been doing research to understand the cyber security landscape, with the primary goal of identifying tools, techniques, and best practices that will assist both the regulator and nuclear operator in implementing industry compliant solutions. In particular, the 2014 release of the new CSA standard entitled "Cyber security for nuclear power plants and small reactor facilities" [1], compels the nuclear industry to action.

As with most standards, CSA 290.7 captures requirements without prescribing any particular solutions. The challenge for users of the standard and enforcers of the standard is to come to agreement on what compliance should look like, measuring effectiveness of various detection and protection technologies, and understanding what defence-in-depth strategies are suitable for supporting the availability and integrity of information. Indeed, the list is long for the number of areas that the standard addresses and extends from policy and planning, to risk and vulnerability management, to incident planning and preparedness to name a few.

CNL has extensive experience managing IT infrastructure as well as developing, deploying and maintaining distributed control systems used in safety applications. Both domains are vulnerable to cyber threats. As a prelude to the work described in this paper, CNL has conducted a broad review of over 50 standards, guidelines, and regulations from recognized institutions covering safety, cyber security, and industrial communication networks including wireless communications. In particular, an analysis was performed to determine the application of these standards to small reactor remote monitoring and control via satellite communication technologies. This work resulted in recommendations being made to the CNSC to support their efforts for developing a regulatory position for securing remote communications to a small remote reactor facility.

CNL is currently undertaking a multi-year research project that builds on the cyber security work previously done, in order to provide state-of-the-art, relevant and practical cyber resources for regulators and nuclear operators. These resources will significantly contribute to their cyber security knowledge base and capabilities and will be used to enhance the security posture of Canadian nuclear facilities and critical infrastructure. The focus of this research is to develop best practice guidance, tools, and methodologies that will be used for assessing network architectures and system components against the requirements of CSA 290.7 [1] while accounting for various levels of risk and vulnerability. This work will be informed by system architectures currently in use at CANDU plants in order to ensure that discoveries and recommendations are relevant to operators. For example, it is recognized that it may be impractical to modify qualified systems or replace legacy hardware such that optimal

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solutions to cyber threats may not be realistic to implement. CNL's research will take these constraints into consideration and seek to find best in class alternatives and compliant solutions as evidenced via testing.

Testing is conducted using a demonstration test facility that has been assembled to emulate defence-in- depth architectures and the deployment of candidate cyber security products. A subsequent iteration of the test facility will model network architectures employed at a plant, and provide a platform that supports data gathering for the purposes of evaluating the capability and effectiveness of cyber security products and tools and measuring compliance to the requirements in CSA 290.7.

For the regulator, not only is it difficult to keep up with the latest in cyber threats and defences but they are faced with the challenges of sifting through and assessing large volumes of written material from each facility describing their security case. A goal of the research is to identify assessment capabilities and measurement criteria that can be adjusted to accommodate different levels of risk or vulnerability. As such, CNL's research efforts aim to take a systematic approach to developing assessment criteria for each of the CSA 290.7 requirements that takes into account, for example, layers of physical security, the presence of highly trained personnel, legacy systems, etc. As well, opportunities for automation will be investigated in order to provide real-time auditing and situational awareness of the plant's overall cyber security posture and status.

Although it is recognized that cyber security solutions and practices are already being successfully employed at our nuclear facilities, this research will endeavor to identify and share best practices, provide evidence based testing and assessments and where appropriate, identify new technology and designs that could more effectively respond to emerging threats. The following illustrate some of the areas where researchers will be looking to industry to capture current technology and practices as a basis for conducting evaluations in order to identify already compliant practices and technologies as well as potential gaps and opportunities for improvement. The results will contribute to the requirements for the test facility and the preparation of a resource guide for complying to CSA 290.7:

1. What tools or processes are used to inspect/identify all active ports or nodes on a system? How would one know that all devices and connections have been identified?
2. What tools or processes are used to manage passwords, encryption keys, software versions and configurations at each device? How would one know that unauthorized changes have not been made in the field?
3. What testing is done or evidence provided to ensure that networks are properly decoupled?
4. What exercises have been done to test the cyber emergency response team, operators, managers, or staff? What are the criteria for measuring the effectiveness of an incident response and evaluating the coordination between supporting departments including physical security, personnel security, information protection, corrective action, supply chain, operations and maintenance, etc?
5. What testing is being done or evidence provided to ensure that any and all wireless devices or access points are known and secured? Are wireless scans being conducted, if so where and how often?
6. What processes or tools are employed to verify that firewalls and detection/prevention systems are configured properly and have not been modified? What best practices are being employed to configure the systems and are these the most effective? How often are these systems updated and verified?

The remainder of this paper is organized as follows. Section 2 describes the methodology of a technology survey undertaken by CNL in order to identify potential products that can be used to aid a system in becoming compliant to CSA 290.7, to aid nuclear operators in demonstrating compliance to CSA 290.7, and to aid the regulator in evaluating compliance to CSA 290.7. Section 3 describes CNL's Cyber Secure Industrial Remote Monitoring and Control Demonstration System. Conclusions and future work are presented in Section 4. Finally the references used by this paper are presented in Section 5.

2. Technology Survey

The technology survey is a systematic analysis of the latest products and technologies associated with protecting enterprise and control system networks from current and future cyber threats. The survey is conducted with consideration of the unique requirements and system architectures at nuclear plants and with the objective of identifying those products and technologies that show promise in supporting the achievement or evaluation of cyber security compliance.

Assessing products is a multi-step process. Firstly, the candidate product is categorized into one or more product type categories (i.e., access and identity management, boundary protection devices, detection devices, network and network-related devices, and security management). Secondly, the candidate is assessed against recognized security standards. The assessment leverages previously existing standards with a focus on FIPS-140 and the Common Criteria, since these standards have wide industry and government acceptance. It should be noted that claimed adherence to a standard such as FIPS-140 or Common Criteria is not a guarantee of suitability for use in a CSA 290.7 system as a product may have usage limitations, maintenance restrictions, or other attributes that would preclude its use in a plant environment. Finally, research is done to determine if there are any known exploits against the product by checking publically available databases that track this information.

The results of the market analysis is a matrix documenting features, limitations, vulnerabilities, assurance level, and associated costs. Ultimately, after gaining experience with various products, understanding their strengths and weaknesses and in what application or configuration they are best suited; recommendations will be made on how a particular tool or type of tool can be used to support compliance to 290.7, or the evaluation of compliance to 290.7.

In order to capture the breadth of information that this research will explore, the following sections describe the product types under investigation.

2.1 Product Type

As previously indicated, a product types can be one of access and identity management, boundary protection devices, detection devices, network and network-related devices, and security management.

2.1.1 Access and Identity Management

Access and identity management tools give the right individuals access to the right resources at the right times for the right reasons. They are broadly classified as access and identity managers and biometric systems and devices.

Access and identity managers are used to control cyber assets within a company's internal network. Services provided by access and identity managers may include directory services, access control, password managers, single sign-on, and security tokens.

Biometric systems and devices are used to authenticate individual using unique biometric properties of the individual such as eyes, fingers, or voice print. Biometric devices can accurately authenticate employees for physical access through doorways, entrances to restricted areas, and act as username and password credentials on workstations.

2.1.2 Boundary Protection Devices

Boundary protection involves the monitoring and control of information on an internal network to keep cyber assets protected from both cyber security risks originating in the outside world as well as possible internal risks. Boundary protection devices are categorized as intrusion prevention systems (IPS), host intrusion prevention systems (HIPS), endpoint all-in-one security solutions, wireless intrusion prevention systems (WIPS), and unified threat management (UTM) systems.

An IPS detects, prevents, and logs intrusions using a set of policies and rules. For example, denying connections from a range of IP addresses known to host malware or limiting the range of ports that allow incoming connections are rules that can be configured in an IPS to mitigate potential incoming sources of cyber attack. An IPS will typically be used as the entry point for defence from the internet to the internal corporate LAN. To provide high availability, a failover unit can be placed after the first unit to provide redundant protection should the first unit fail to operate properly.

A HIPS is similar to an IPS except that the HIPS prevents threats at the host level and are thus usually seen on workstations and servers on the corporate LAN.

Endpoint all-in-one security solutions are software that run on a host workstation or server that implements a combination of security solutions such as anti-virus, anti-malware, firewall, data loss protection (DLP), file and removable media protection, application control, device control, and cold boot attack protection. Such integrated solutions must be designed to use minimal computer resources in order to ensure that computer performance is maintained in order to avoid adversely affecting employee productivity.

A WIPS is an IPS that protects against wireless intrusion threat vectors by continuously scanning all wireless bands capable of connecting to Wi-Fi endpoints. Proper implementation of a WIPS significantly reduces the risk inherent to wireless technologies by controlling access so that only approved devices are allowed on the network, and otherwise isolating or completely denying access to non-approved devices.

UTM devices are all-in-one threat management systems that combine the functionality of an IPS device with anti-virus, anti-malware, anti-spam, web filtering, state-inspection firewall and IPSec VPN. As such, UTM devices are typically used to prevent threats from the Internet from making their way onto the corporate LAN. As with IPS devices, UTM devices are often partnered with redundant devices in order to minimize downtime in the event of a failure with the primary device.

2.1.3 Detection Devices

Detection devices detect cyber intrusions at the host and network level and are typically classified as file activity monitors, intrusion detection systems (IDS), or multi-engine anti-virus solutions.

File activity monitoring is used on a host workstation to detect designated unauthorized file and folder changes such as permission changes, moves, copies, and deletions.

IDSs are similar to the previously discussed IPS systems, except that an IDS is only able to detect threats while an IPS is able to both detect and attempt to clean or fix the threat. Because of limited functionality compared to IPS systems, IDS systems are slowly being phased out in favour of IPS systems.

Multi-engine anti-virus solutions aim to increase the virus detection rate through diversity – running multiple anti-virus scanners from multiple vendors simultaneously.

2.1.4 Network and Network-Related Devices

Network and network-related devices are the devices that connect disparate devices into one integrated network, and range in complexity from a simple switch connecting multiple end-user devices to a virtual private network (VPN) connecting external users to the internal corporate network via virtual "tunnels".

Firewalls are devices with a set of rules that are used to control connections in and out of a network. A firewall can consist of a hardware-only device or a software firewall needing to run on a server. Since the Internet is a high-risk entry point into a corporate network, firewalls are typically used to control incoming and outgoing connections as needed.

Routers are used to route and restrict traffic between different networks.

Switches route traffic between devices on the same network. There are two types of switches: unmanaged and managed. An unmanaged switch simply routes traffic as requested whereas a managed switch provides the ability to configure, manage, and monitor network traffic.

Virtual private networks (VPN) allow for the corporate network to be securely extended across the Internet, allowing employees to connect to the corporate network via a secure encrypted line through the internet.

2.1.5 Security Management

Security management is the identification of an organization's cyber assets, followed by the development, documentation, and implementation of policies and procedures for protecting those cyber assets [2].

Incident response is the ability for a corporation to detect, respond and recover from a cyber attack. Various tools are available for detecting and logging intrusions and performing forensics in order to identify the source of the intrusion and whether data was compromised. Incident response as a service is also available, which is a subscription-type service with 24/7 support via Internet and telephone support.

Finally, system information and event management (SIEM) gives the ability to gather logs from each cyber asset and analyze them in a way that provides feedback to determine if a cyber attack is underway or has already happened. SIEM can be provided as software, appliances, or via a subscription service, although the latter may not be a viable option for organizations that do not want to share information with a service provider over a public network. SIEM tools are also used to log security data and generate reports for compliance auditing purposes.

2.2 Common Criteria and FIPS-140 Methods

Common Criteria provides and assurance level as to how well a product complies with cyber security standards. Specifically, a Common Criteria evaluation involves testing a product at an independent and certified testing facility and then evaluating and accrediting the product for conformance to the Common Criteria for IT Security Evaluation (ISO Standard 15408). Products are granted a certificate with an Evaluation Assurance Level (EAL) [3] which quantifies the product's adherence to Security Assurance Requirements (SAR) on a scale of 1 (low) to 7 (high). A SAR describes the procedures taken during development and evaluation of the product to assure compliance with the claimed security functionality [4].

FIPS-140-1 and 140-2 are a set of security requirements for cryptographic modules. There is a Cryptographic and Security Testing (CST) laboratory that performs conformance testing of cryptographic modules to ensure compliance to the requirements set forth in the National Voluntary Laboratory Accreditation Program (NVLAP) [5]. Modules validated as conforming to FIPS 140-1 and FIPS 140-2 are accepted by the Federal Agencies of both the United States and Canada for the protection of sensitive information. It should be noted that unvalidated cryptography is viewed by NIST as providing no protection to the information or data. The Canadian Government provides a listing of approved cryptographic algorithms via Communications Security Establishment Canada. For the purposes of the technology survey, the outcomes for products that have been assessed under Common Criteria or FIPS-140-1 and 140-2 are captured in the product evaluation matrix.

2.3 Vulnerability Assessment

The final part of a product evaluation is a vulnerability assessment. Vulnerabilities were identified by searching for exploits that have been identified in the real world. Sources of vulnerability include the National Vulnerability Database (NVD) maintained by the National Institute of Standards and Technology (NIST) which is sponsored by the U. S. Department of Homeland Security (DHS), as well as the Canadian Cyber Incident Response Centre which circulates security bulletins that communicate information about security updates to software that were found to be vulnerable to specific flaws in software design, use or implementation.

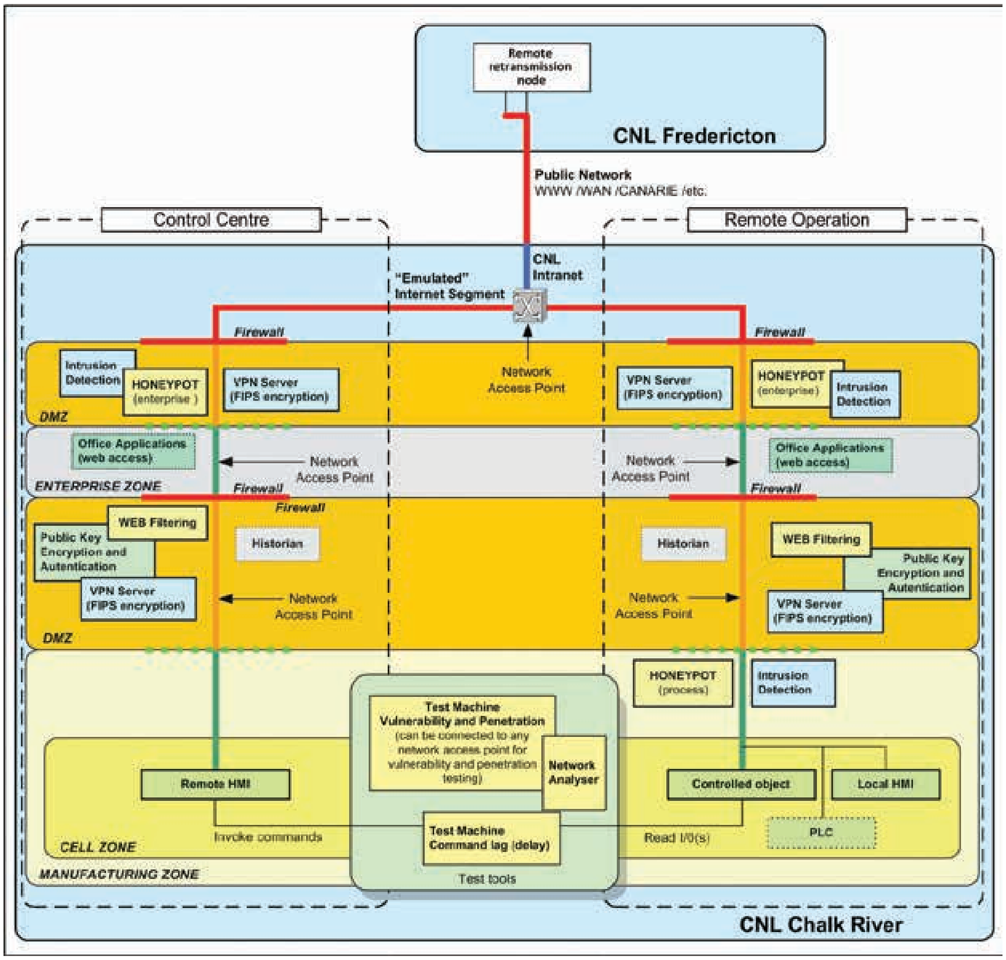

Figure 1: Demonstration System Architecture

ous work done by CNL on Cyber Security for Remote Monitoring and Control of Small Reactors [6] which assessed the possibility of using satellite communications for the remote monitoring of small unmanned reactors in remote locations such as remote northern communities or mining camps.

As shown in Figure 1, the demonstration system is logically divided into "Control Centre" and "Remote Operation" partitions. The "Control Centre" partition simulates the location where the system operators are physically located, while the "Remote Operation" partition simulates the system under control. For realistic simulation of remote operations, communications can be routed between CNL's Deep River, Ontario location and CNL's Fredericton, New Brunswick location. To simulate longer delays, such as would occur over satellite communication links, test tools can be used to interject command lags.

Both the simulated control centre and the remote system under control are segmented into zones. Adjacent zones are separated by Demilitarized Zones (DMZ). The boundaries of each zone are protected by paired firewalls. Paired firewalls prevent direct communication between the zones. The effectiveness of this solution is illustrated in Figure 2 which is a reference architecture that originates from the NIST guideline [7].

Zones are an effective way to group assets according to their security importance and allows for the applications of security measures by zone as opposed to being applied uniquely to each separate equipment item. This requires that cyber assets be inventoried to ensure that no equipment is overlooked that, while benign in of itself, may in fact be a conduit to more sensitive information or safety-important cyber assets and thus require security at the same level of the cyber asset to which it is connected. The inventory includes identifying the importance of each asset, personnel who interface with each asset, current safe-guarding practices, etc., so that a complete profile of the state of each asset can be determined and used to drive the development of a security strategy [6].

The reference architecture shown in Figure 2 demonstrates the scenario in which analysts working on the

3. Cyber Secure Industrial Remote Monitoring and Control Demonstration System

The Cyber Secure Industrial Remote Monitoring and Control Demonstration System is a prototype cyber security demonstration system at CNL. It is designed to give CNL an initial testing capability for evaluating cyber tool functions and features and how they might be used to support CSA 290.7 compliance. The demonstration system has been designed around a reference architecture that uses a defence-in-depth strategy as required by CSA 290.7, allowing for different cyber security products (intrusion detection systems, firewalls, web filters, Virtual Private Networks (VPN), etc.) to be tested against postulated threat vectors. Lessons learned and experience gained through the design and operation of the demonstration system will be used in the implementation of the full-scale cyber secure test bed.

The strength of the demonstration system is that it not only allows for simulation of a traditional industrial control system (ICS) in which the ICS is in a segmented zone within the corporate network, but that it also allows for simulation of the remote monitoring and operation of the control system. This builds on previ-

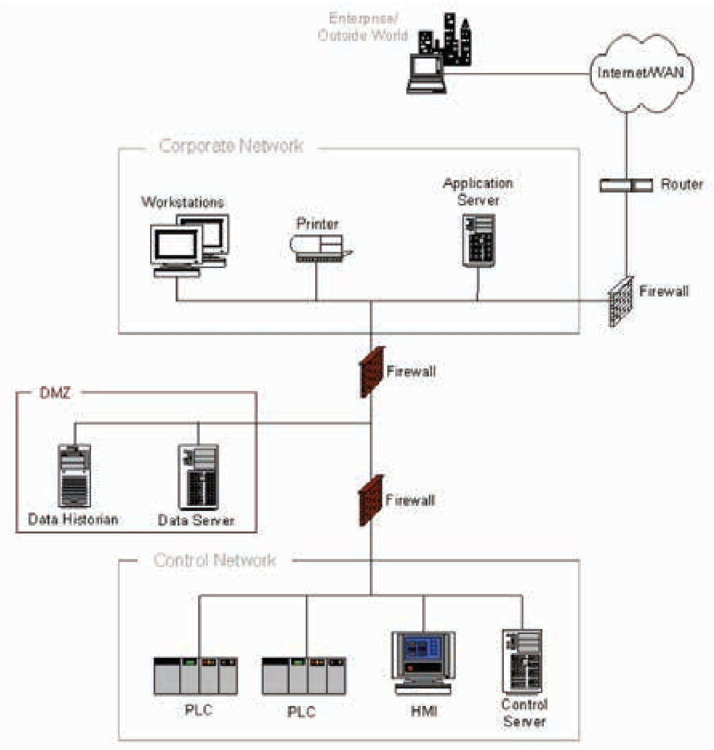

Figure 2: Paired Firewalls between Corporate Network and Control Network

main corporate network require process values from the control network. Rather than access the control network directly, the analyst accesses a data historian in the DMZ and the data historian is able to receive values pushed up from the control network while the paired firewalls prevent the corporate and control networks from directly communicating with each other.

Using the zone-based security approach, lower-level security zones are prevented from communicating to higher level zones. In the demonstration system, both the simulated control centre and the simulated system under control are at the same zone, but because they are physically separated, any communication between the control centre and the system under control must pass through zones with a lower level of security.

This apparent conundrum is resolved using virtual point-to-point (P2P) tunnelling protocols and VPN communications. The P2P connection combined with traffic encryption make it possible to virtually extend private networks over shared communications; VPN servers hosted in different zones allow for establishing virtual P2P connections between the zones.

4. Conclusions and Future Work

CNL is leveraging previous research and experience in cyber security by embarking on a multi-year research effort into cyber security for nuclear power plants and small reactor facilities. The ultimate goal of this research is to identify the tools, techniques, and best practices that can be used to assist facility operators in implementing cyber security solutions that are effective and practical and that can be used by the regulator to assess implementation plans.

In the past fiscal year, CNL's cyber security research program has begun to identify potential products that can be used for access and identity management, boundary protection, cyber intrusion detection, network protection and management, and security management. As well a Cyber Secure Industrial Remote Monitoring and Control Demonstration system was constructed as a first iteration at assembling a test bed in order to support testing of cyber secure architectures and products under various risk conditions.

The next phase of research will build on these results. Firstly, knowledge obtained during the construction of the demonstration system will be used to design a full-scale cyber secure test bed. To the largest extent possible, this will be done with actual plant network designs in mind to ensure that results obtained are relevant to nuclear operators. Using the test bed, promising cyber security products and tools identified through the technology survey will be systematically exercised and evaluated. The research will yield practical solutions that take into account the unique strengths and constraints of the nuclear industry.

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The Genesis of NRX – First Stop on the Road to CANDU

By JAMES E. ARSENAULT, P.Eng.

1. Introduction

The CANDU (Canada Deuterium Uranium) reactor family is traceable to World War Two and to certain principal players. They gave Canada an early entry into the world of practical nuclear energy with the NRX (National Research Experimental) reactor, developed under the auspices of the ABC (America, Britain, Canada) countries.

The principal players on the NRX project were, in alphabetical order: James Chadwick, C.D. Howe, Leslie R. Groves and C.J. Mackenzie. Their careers up to about 1940 are outlined in Section 10.

2. Development of Nuclear Science

Early progress in atomic knowledge was centered in the great laboratories of Europe, although many nations had contributed since the 1886 discovery of radioactivity in France by Henri Becquerel. By late 1938 experiments by Otto Hahn and Fritz Strassmann in Berlin had led to some peculiar chemical results which remained unexplained until Lise Meitner and her nephew Otto Frisch concluded that, in theory, atoms of uranium had been split by neutron bombardment, accompanied by the release of a great amount energy, in accordance with Albert Einstein's famous formula. By early January 1939, Frisch and others proved experimentally that this was the case and the work became disseminated widely in the scientific community around the world through various publications [Rhodes, 1987]. In March Fréderic Joliot-Curie with Hans Halban and Lew Kowarski, in France, published a paper suggesting the prospects for a large-scale energy release by a chain reaction and from this point the race was on to develop methods to tap this source of energy for both military and civilian purposes. Most of Joliot-Curie's experiments included the use of heavy water/uranium slurries [Weart, 1979].

The second great war began in September 1939 and the development of atomic energy for military purposes took priority, although work was done also on civilian uses. Subsequently, the French, including their precious cans of heavy water from Norway, were integrated into the expanding United Kingdom (UK) nuclear program and at the time the United States (US), not yet at war, was conducting a similar but muted program, as was Canada.

2.1 United Kingdom

Throughout the early days of the war most scientists in the UK believed that developing an atomic weapon before the conclusion of the war was impossible. However, this was to change when two scientists, Otto Frisch and Rudolph Peierls, at the University of Birmingham, wrote a brief, highly secret paper entitled "On the Construction of a 'Super-bomb'; Based on a Nuclear Chain Reaction in Uranium". This paper eventually made its way into the hands of James Chadwick, who since 1940, had been appointed to a subcommittee looking into the possibility of developing a nuclear weapon. This paper completely described the theory for practical weapon development and immediately changed the prevailing skepticism of the subcommittee which quickly was reorganized into what is known as the MAUD Committee. The Committee then began a concerted effort to sponsor and coordinate the atomic energy research investigations of academic and industrial institutions throughout the UK.

By July 1941 it had compiled (mostly by Chadwick) and produced what has become known as the Maud Report. In this report the path to a weapon and atomic power is given clearly, including practical designs, material requirements, cost and timelines. The report was separated into two areas, weapons (in two Parts and five Appendices) and power (in two Parts and two Appendices) but centered largely on the former. The report notes the work done on heavy water reactors in the UK by Halban and Kowarski (who had escaped from France in 1940), and that their efforts might fare better in the US or Canada. By the autumn of 1941, the MAUD Committee had morphed into the Directorate of Tube Alloys, this new title designed as a plausible cover for the ongoing work and a Technical Committee was formed under Wallace Acres, Research Director of International Chemical Industries (ICI).

By July 1942 it had become apparent, particularly for vulnerability reasons, that it was not feasible in the UK to erect full-scale plants, let alone pilot plants, for the production of bomb material and that work should continue in North America [Gowing, 1964].

2.2 United States

Interest in the development of an atomic weapon began slowly in the US for, after all, the US had not yet declared war and research on it was progressing slowly–but that was to change. In August 1939, Einstein wrote a letter to President Franklin D. Roosevelt warning that Germany was probably on a path to develop a super-bomb and that some action should be taken to monitor the situation. As a result, in October 1939, Roosevelt set up an Advisory Committee on Uranium which soon became known as the Uranium Committee. In June 1940 Roosevelt established the National Defense Research Committee (NDRC) under Vannevar Bush, president of the Carnegie Institution, and the Uranium Committee became a subcommittee of the NDRC known as S-1.

Sponsored research began to show promise toward a practical weapon but there also was much skepticism. In June 1941, Roosevelt established the Organization for Research and Development (OSRD) with Bush as Director and James B. Conant, president of Harvard, took over the NDRC. The MAUD Report arrived in the US at about the same time and, thereafter, interest picked up considerably and especially after December when the U.S. declared war on Japan and its allies, including Germany.

It became increasingly clear that there would be a large engineering effort required to produce a weapon before the end of the great war, so the task was handed to the Army and in August 1942 the Manhattan Engineering District (MED) was established, with headquarters in New York City. In September Leslie Groves was placed in charge of the MED [Sherwin, 1977; Jones, 1985]. By December, Enrico Fermi and his team at the University of Chicago had built the first uranium-graphite pile, which had a self-sustaining chain-reaction, and catapulted the US into the lead role in nuclear matters.

2.3 Canada

The business of uranium was well-developed in Canada, based on the discovery in 1930 of the mineral pitchblende at Great Bear Lake by Gilbert LaBine. Serious mining began in 1932 and a refinery was started at Port Hope for the extraction of radium, mostly for medical treatments, using a process developed by Madame Curie; uranium as a byproduct was merely stockpiled although it did have some applications. Due to the war, business declined, the mine was shut and refinery activity was reduced in 1940.

Keeping up with nuclear publications out of Europe, George C. Laurence at the National Research Council (NRC) in Ottawa began experiments in 1941 with a uranium-carbon pile, to explore the parameters for a self-sustaining chain-reaction. Like Fermi in his early experiments, Laurence determined that purer materials were required to achieve criticality. A recent paper using a software package to simulate Laurence's pile obtained similar results, which is remarkable considering the state of knowledge at that time [Dranga et al., 2014].

Early in 1942, Wallace Acres, in charge of Tube Alloys, began an extensive tour of facilities in North America to promote information exchange and the possibilities of moving UK scientists to these laboratories. He visited C.J. Mackenzie at the NRC in February. The US demurred as they were concerned with security and they now had a clear, although multithreaded, path to a practical weapon. Indeed, they were spending many times the resources as the UK on their MED project. Other visits to Ottawa by UK personnel took place and in September. C.D. Howe, on the recommendation of Mackenzie, decided to accept a team of UK scientists working with heavy water, led by Halban at Cambridge. The project was to be set up as a division of the NRC, complete with laboratory facilities, supplies and administration located in Montreal. In December, scientists from the UK started to arrive in Montreal, the cans of heavy water and experimental equipment followed, and the Montreal Laboratory (ML) began to take shape [Eggleston, 1966].

3. The Montreal Laboratory

The ML was organized along the lines suggested originally by Mackenzie and was operated as a division of the NRC, reporting to him.

3.1 Organization

Halban was appointed Director of the three Divisions: Physics, Chemistry, and Engineering. There were two staff committees: Policy, with Howe and Malcolm MacDonald (British High Commissioner) to represent the Canadian and UK governments, respectively; and Technical, with Halban, Laurence and one other scientist to deal with detailed laboratory direction. For a while the project operated as a special Committee on High Velocity Corrosion and later as a Technical Committee on Radiological Research, to disguise the top secret work of the laboratory [Eggleston, 1966]. The project first operated out of the Windsor Hotel, then expanded to a large old residence at 3470 Simpson Street, and finally occupied two unused medical wings of the University of Montreal.

3.2 Staff

By the beginning of March 1943 the facilities were ready. The staff was increasing, and by May totaled a hundred: 27 professionals from the UK, with six subprofessionals; 20 professionals from Canada with 22 subprofessionals; 25 administrative, secretarial, and trades [Bothwell, 1988]. Of the UK staff, not all were UK citizens and some of the prominent non-UK staff were: Halban (Austria), Paneth (Austria), Placzek (Czechoslovakia), Pontecarvo (Italian), Gueron

(French), Goldschmidt (French), Auger (French). Kowarski did not join the group immediately because of a falling-out with Halban [Weart, 1979].

3.3 Information Interchange

Assuming that the negotiations between the UK and the US had arrived at a state of mutual understanding and cooperation with the ML, in mid-December 1942 Mackenzie sent off a request for materials to US authorities, as they had effective control of them, to allow significant large-scale experiments to be conducted. The list of materials was extensive: 5 tons of uranium oxide, 2 tons of uranium metal, 0.5 tons of uranyl nitrate, 60 tons of graphite, all the heavy water available up to 6 tons. The reply came from Conant in early January and was not encouraging. The long and short of it was that all interchange of information between the US and the ML was to be greatly limited.

Underlying the situation was, firstly, that the US had decided to go ahead with their own heavy-water reactor at the University of Chicago (to be designed by the Du Pont Company), for the production of plutonium. Secondly, the US did not believe that the UK or Canada could produce fissile material in time to be useful in the prosecution of the war. An additional factor was that the US Army was now in charge of the MED and secrecy was of paramount concern and drove it along the lines of tight secrecy and compartmentalization. The many non-UK professionals at the ML would be an especially obvious source of anxiety for Groves, and in addition there were certain agreements between the UK, France and Russia that were thought to be potential sources of information leakage [Eggleston, 1966].

All this took place in the light of a friendly agreement between Churchill and Roosevelt calling for full exchange of scientific information between the UK and the US. By late 1942 the US was spending ten times as much as the UK on nuclear research and development and they concluded that little or no cooperation from the UK was needed to ensure the success of the MED project. Indeed, the US played a game of deception with the UK based on the fact that Roosevelt could carry two contradictory scenarios in his mind at the same time. In one scenario he agreed with Churchill that there should be complete cooperation and with Bush and Conant (including Groves) that there should be little or no cooperation. This accords with the emerging notion that the US would have to lead the post-war world [Farmelo, 2013; Paul, 2000]. The US always wished to maintain good relations with Canada, as it was a source and refiner of uranium.

3.4 ML Progress

The lack of information exchange at the ML was not the only problem that inhibited progress. It soon became apparent that Halban, who had not managed anything near such a large project previously, did not have nor developed appropriate management skills and continually harassed the staff about their inability to carry out his requests. There was little coordination from Halban, and many of the Canadian researchers, including Mackenzie, felt they had little or no influence on the ML direction. Despite the fact that morale suffered under Halban, considerable scientific progress was achieved. The engineering side was mostly concerned with various reactor designs including breeders and getting the heat out of them. Gradually the homogeneous designs based on heavy water and uranium oxide were superseded by heterogeneous designs using uranium rods suspended in heavy water.

The physics group performed experiments on neutron migration and even built a 10-ton graphite pile for the purpose. In addition, electronic instruments were developed for the detection and measurement of radioactivity. The chemistry group studied different methods of removing plutonium from irradiated uranium metal, including solvent extraction. The theoretical physics group studied neutron migration in reactors using transport theory. Support was also built up with outside organizations, including McGill, McMaster and Toronto Universities and the Department of Mines and Resources in Ottawa [Laurence, 1980].

4. Breaking the Impasse

Although the ML had started with great enthusiasm and real progress was made toward the evolution of a self-sustaining reactor, progress did not accelerate due to the many issues outlined above. However, the UK finally recognized that the US had pulled so far ahead that their best advantage was to cooperate as much as possible, rather than to go it alone with little chance of success before the end of hostilities. Morale continued to suffer at the ML and at one point Mackenzie considered that it should be shut down. The overall problem of the UK-US cooperation on nuclear matters reached the highest levels of concern, such that it was placed on the agenda for a conference between Churchill and Roosevelt scheduled in Quebec City.

4.1 Quebec Agreement

The outcome of the Churchill/Roosevelt conference was what became known as the Quebec Agreement. The agreement was signed on 19 August 1943 and it consisted of five provisions and included a coordinating committee.

"Four of its five provisions recited obligations of the US and the UK in regard to 'Tube Alloys' – never to use 'this agency', i.e., the atomic weapon, against each other, never to use it against third parties without each other's consent, never to communicate information

about it to third parties without the other's consent, and to reserve post-war industrial and commercial applications for future negotiation. The fifth provision created a Combined Policy Committee on which the United States was to be represented by its Secretary of War together with Vannevar Bush and James B. Conant, the United Kingdom by Sir John Dill and J.J. Llewellin, and Canada by C. D. Howe. The Combined Policy Committee was designated as the forum through which information and ideas were to be exchanged. So far as 'scientific research and development' was concerned, such exchange was to be 'full and effective'. But information and ideas relating to 'the field of design, construction, and operation of large scale-plants' were to be exchanged in accordance with 'such ad hoc arrangements as may, in each section of the field, appear to be necessary or desirable if the project is brought to fruition at the earliest moment'." [Eayres, 1972]

In anticipation of the signing of the Agreement, the UK had assembled a team of scientists for deployment at various MED laboratories which was implemented after the signing. Chadwick was placed in charge of the UK contingent and worked out of Washington where the Combined Policy Committee (CPC) was headquartered.

4.2 CPC Meetings

The first meeting of the CPC took place on 8 September 1943, however, there was no Canadian representative. Their first action was to appoint a scientific and technical subcommittee, comprised of Chadwick, Mackenzie and Richard C. Tolman, a US scientist. The CPC meetings were held from time to time and there was progressive agreement on all issues except the ML. Discussion went back and forth on issues of security and scientific merit. The security issues revolved around the many non-UK nationals present at the ML.

It was not clear that full-scale heavy-water plants would be able to produce plutonium more efficiently than the 250-MW graphite piles which were about to enter service at Hanford, Washington. The subject of the ML was discussed on 17 February 1944 and at that time Chadwick proposed that a large heavy-water, natural uranium plant to produce plutonium should be built in Canada, with materials to be supplied by the US. The plan was not readily accepted and a subcommittee consisting of Groves, Chadwick and Mackenzie was appointed to look into the issue.

By the end of March the military advisors to Groves produced a report saying that there was not much to be gained by the ML venture and recommended against it. Groves showed the negative report to Chadwick who was thoroughly shocked. Groves offered that Chadwick put forward his own proposals. Chadwick quickly rewrote the report and revised the conclusions in favour of constructing a plant. On 13 April the report was presented to the CPC who recommended construction on an experimental basis, with decision on a full-scale plant to be driven by the results. The project was to be supervised by Mackenzie, Chadwick and Groves [Brown, 1997].

While the discussions on the ML were ongoing it was gradually agreed that a trusted scientist should be put in charge and the name that emerged consistently was John Cockcroft, the UK scientist who first "split" the atom in 1932. In anticipation the UK had arranged for his release from radar work and Cockcroft arrived in Canada in late April. He relieved Halban and reorganized the laboratory.

Shortly after there was a flurry of information exchange meetings with the Chicago group, that continued intermittently thereafter [Arsenault, 2012]. This group had designed CP-3, a 300-kW heavy-water, natural uranium reactor that went critical in May 1944, a world first, but nevertheless it was far different in scale from the 10-MW proposal for NRX. The information exchange did not include plutonium extraction processes and the ML was left on its own to work them out but the US agreed to supply irradiated rods for process development [Gowing,1964]. To promote cooperation with the ML throughout the MED, Cockcroft left on 14 May for a wide-ranging tour of US nuclear facilities, returning on 29 May to concentrate on site selection for the reactor.

5. Site Selection

Even before Chadwick arrived in Canada, work had gone forward with the identification of a suitable contractor for the engineering design of the reactor, laboratories, services, and the town where the employees would live. The contractor would operate them for the NRC, which would direct the research and development.

5.1 The Contractor

Almost the only possible candidate for the job in Canada was Defence Industries Limited (DIL), a crown corporation organized early in the war to construct and operate large munitions plants. Its key personnel had been drawn from Canadian Industries Limited, a subsidiary of DuPont of the US and of ICI of the UK. In mid-April 1944 the government opened negotiations with DIL. When made aware of the nature of such a highly secret project, at first they were reluctant to take on the responsibility for such a complicated and massive enterprise. After much detailed input from all parties, near the end of May DIL agreed to take on the task [Eggleston, 1966]. In late August the actual construction was subcontracted out by DIL to Fraser Brace Limited.

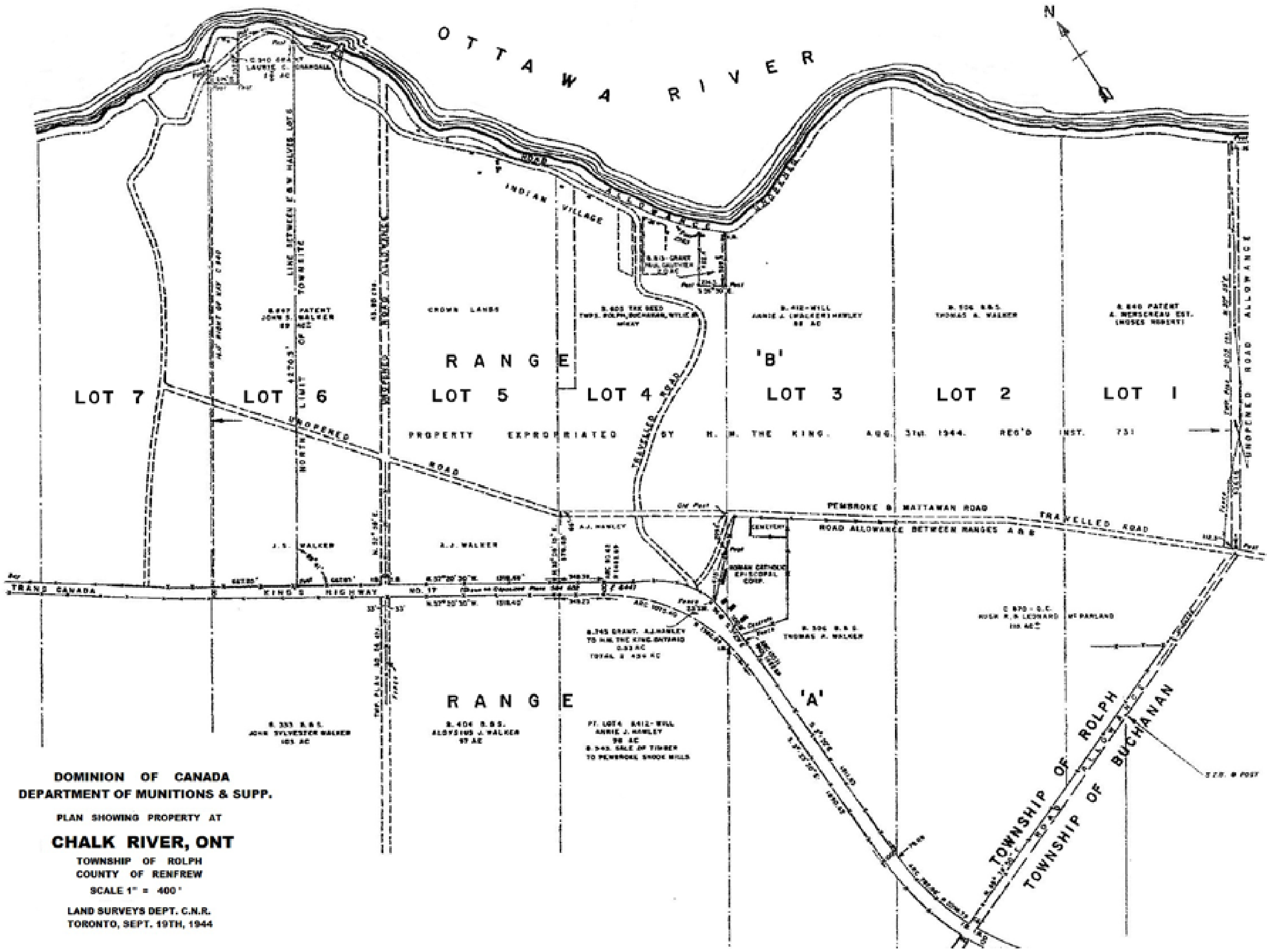

Figure 1: Site drawing for Chalk River

5.2 The Site

DIL operated a large munitions plant at Nobel, north of Parry Sound, Ontario, and initially it was an obvious contender for the reactor site because as the war wound down it was slated for closure. As time went on, this decision was deferred due to the continuing war effort. A site-selection specification had been developed and was applied during an extensive search throughout southern Ontario and Quebec, during the summer of 1944, as G.C. Laurence explains:

"Isolation was desirable to avoid supposed hazards to population from possible explosion or release of radioactive dust into the atmosphere, and to simplify control of secrecy. It was suggested that it should not be less than about ten miles from a town or village. Ample supply of soft and cool water would be required for cooling the reactor, and a large river or lake near the plant would be required to dilute the effluence from the reactor which might contain a small amount of radioactive materials. It was desirable to locate the project not far from a source of labour. It should be easily accessible by rail and highway, and preferably within twelve hours journey from the industrial centres of Montreal and Toronto and the National Research Council laboratories in Ottawa. The terrain should be suitable for a plant site without excessive costs in preparation. A town site would be required if housing was not available nearby. Several thousand kilowatts of electric power would be required." [Eggleston, 1966]

Eventually, Chalk River, on the Ottawa River, emerged as the most desirable site. When C.D. Howe was advised he was taken aback by the cost estimates and requested a review, i.e., a comparison with Nobel. The revisions showed a saving of $1.5M at the Nobel site but on the recommendations of B.K. Boulton (Department of Munitions and Supply) and Mackenzie, Howe decided on Chalk River, which had several advantages other than cost, including clean cooling water and remoteness from habitation [Eggleston, 1966]. After the site was selected and construction began in September 1944 by Fraser Brace Limited, the ML staff were moved gradually to Chalk River as the facilities were built out. Figure 1 shows a site drawing of the Chalk River area as of September 1944 [____, A History, 1970].

"The area occupied by the plant buildings and other facilities comprises, roughly, a rectangle measuring approximately 1500' by 3000', or about 100 acres. In addition, the project has required the construction of a village for living accommodations and services for the operating and directing personnel. This is described as located on a cove in the Ottawa River seven miles west of Chalk River, Ontario, and about 12 miles by road from the plants. The village has been named Deep River." [____, Manhattan, 1977].

6. Design/Engineering

Under Cockcroft, a sense of purpose was restored at the ML, morale improved and administration became less difficult [Laurence, 1980]. The ML evolved from the structure set by Halban to include: Nuclear Physics, Technical Physics, Chemistry, Engineering, Theoretical Physics, Administration, and Extra Mural (university and government institutions). Beginning in late 1942 there were 20 staff (author's estimate), increasing to just over 100 by May 1943, 200 in September 1944, 300 in January 1945, and 400 in July 1945. The peak was reached in August 1945 at 417, then UK personnel began to depart for home [Eggleston, 1966; Cockcroft, 1946].

6.1 Pile Design

Although the ML had explored various reactor design options across a wide range of alternatives, it was not until July 1944 that the choice was narrowed to three options:

"After a month spent on investigating the relative merits of: i. A pile using metal rods sheathed with stainless steel; ii. A pile using aluminium sheathed rods with close spacing to give stability against loss of cooling water; iii. A conventional pile using aluminium sheathed rods and light water cooling; it has been decided to proceed with the third type. This decision was made largely because adequate polymer deliveries could not be guaranteed for the first or second designs. Aluminium sheathing 1/8" thickness will be used to minimise troubles of corrosion and pin holes in welds." [Cockcroft, 1944]. Figure 2 is a simplified line drawing of the NRX reactor [Kennedy, 1956].

As the design of the pile progressed it soon became apparent that the original target date of February 1945 could not possibly be met because of design complexity and limited staff. Accordingly, the NRC proposed that a 'Zero Energy Exponential Pile' (ZEEP) be built at Chalk River to provide much needed experience and information before the pilot plant would be in operation. The US initially objected over concerns based on common use of the limited supply of heavy water, and thought that little was to be learned from such a small

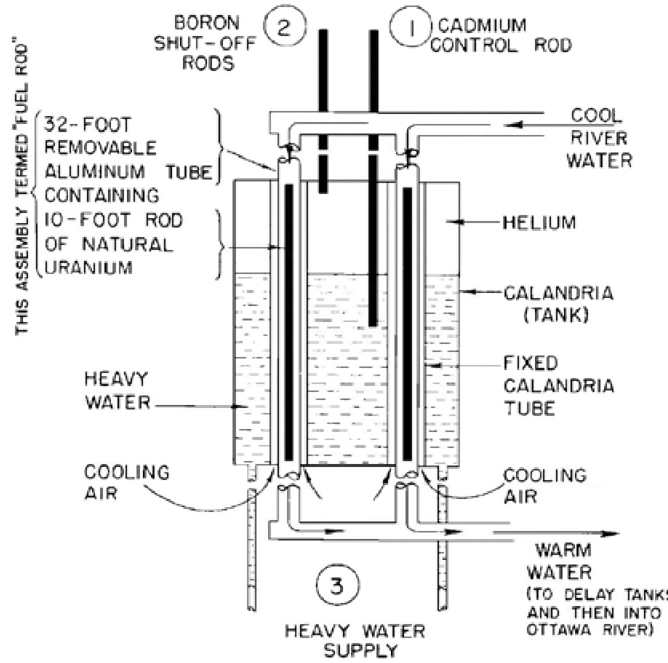

Figure 2: NRX line drawing

pile. However, approval was given by the CPC upon insistence by Canada [____, Manhattan, 1977].

After the go-ahead on 24 August 1944, and two months of a study by a team led by Kowarski (who had been persuaded to join the ML after Halban left), the ZEEP design and construction was completed on 4 September 1945. Criticality was achieved a day later [Eggleston, 1966].

6.2 Pile construction

As already noted, overall construction at the site was much delayed and the original target date set for the completion of the reactor was February 1945, then January 1946, and finally March 1947. To speed progress for all concerned, a series of 43 lectures, "The Montreal Lectures", on the state of nuclear science and engineering applicable to the pile, was presented by the ML scientific staff to the DIL engineering staff [____, Manual, 1945]. As of 31 December 1946, the design and construction was almost completed and start-up of operation was definitely in sight. Three successive estimates of cost had been made prior to 1 December 1945, which increased progressively from 5, to 11, to 18 million dollars. By the end of September 1946, projections including the townsite but not the heavy water, came to 21.2 million dollars. At the same time, annual operating costs were estimated at 4.4 million dollars [____, Manhattan, 1977].

6.3 Pile-as-built Description

Eventually the pile was built amid important organizational changes. Cockcroft left the project to head up the UK nuclear effort at Harwell, together with many of the

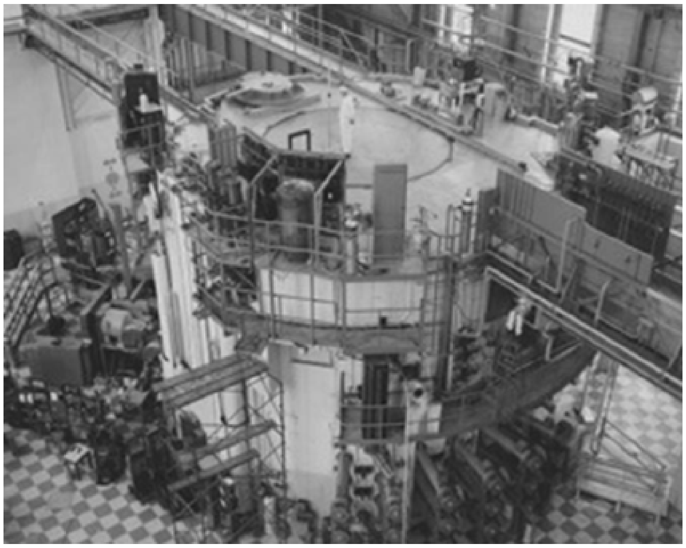

Figure 3: The completed NRX reactor

UK scientists. After the refusal of several candidates, W.B. Lewis, who had deep experience in UK laboratory management, succeeded Cockcroft in September 1946 and went on to an illustrious career in the Canadian nuclear industry, even though he was trained as an electrical engineer. Mackenzie's responsibilities for Chalk River were assumed by David Keys, NRC vice-president (scientific) [Fawcett,1965; Bothwell,1988]. Figure 3 shows a photo of the completed NRX reactor [____, NRX, 2015].

"The chain-reacting unit is a polymer (heavy water), heterogeneous, normal-water cooled, slow neutron pile, designed for 10,000 kw [sic] output, first estimated to require 18.9 tons of heavy water and 10 tons of metal. Originally, in July 1944, an output of 8000 kw, estimated to require 13 1/2 tons of heavy water and 8 1/2 tons of metal, was proposed. As a result of later decisions on some of the design problems, however, influenced by the availability of critical materials, principally heavy water, the design power level was raised to 10,000 kw. For example, the decision to use normal-water cooled, aluminum-sheathed uranium rods rather than heavy-water cooled, stainless steel-sheathed uranium rods allowed a higher power output for a given quantity of uranium and heavy water, or conversely, allowed lesser quantities of these critical materials for a given power output; also, the decision to use a lattice spacing for least critical volume, to conserve critical materials, made possible a higher power level for a given quantity of heavy water. Then after the design of the pile was determined, further estimates indicated that about 16.7 tons of heavy water would allow a power output of 10,000 kw, whereas 18.9 tons of heavy water – the maximum which the design would permit – would allow an output of 21,000 kw. A little over 19 short tons of high grade heavy water were finally made available by the United States; therefore it is anticipated that, within the limits described above, 10,000 to 21,000 kw, the power level for steady operation will be determined by the efficiency of cooling, permissible interior temperatures, radiation, and decomposition problems.

"The estimated production capacities of the pile are likewise subject to variation, dependent upon the power level at which it will be operated. It is estimated that at an average power level of 10,000 kw the pile would produce 7 grams per day of plutonium..." [____, Manhattan, 1977].

7. Operation/Research

The pile achieved criticality at 6:13 am on 22 July 1947. The power level was increased gradually from a few watts to 250 watts in September, to 2 MW by March 1948, to 12 MW by May, and to 20 MW by September. The reactor could be operated at 27.5 MW when the river water was cool enough. The reactor generated a very high neutron flux which was many times the flux in any US reactor at the time and being a dual-purpose design it allowed performance experiments and general research, which made it very flexible and adaptable to changing requirements. Performance experiments could be carried out by varying the uranium rod matrix. For research purposes it had 15 experimental holes from which a beam of neutrons could be extracted and 15 self-serve access channels for the introduction of small material samples for the study of radiation effects [____, Canada, 1997; Glasstone, 1950].

In December 1952, NRX suffered a serious accident in which it was completely disabled and required an extensive rebuild to bring it back on-line by February 1954. Fortunately there were no casualties and the accident contributed to the development of the overarching safety culture prevalent today in Canada's nuclear industry. NRX was designated as a nuclear historic monument in 1986 by the American Nuclear Society. In 1994 Bertram Brockhouse, who had worked at CRL from 1950–1962, shared the Nobel Prize in physics for his work using NRX in the development of neutron spectroscopy.

NRX operated for 45 years, until permanent shutdown in 1993. It is currently undergoing decommissioning [____, NRX, 2015]. Decommissioning can mean many things but can be described generally as the removal of reactor fuel to a local fuel bay (and left for six or seven years), followed by heavy-water removal (usually for processing and reuse), and then dismantling of the reactor. The whole process may take a period of 30 to 50 years [Steed, 2007].

8. Conclusion

The birth of NRX was indeed a close-run thing that came to fruition through the vision, persistence and cooperation among the main players from the US, UK and Canada. For the US, NRX provided a test vehicle to help settle the issue of finding the most efficient method for the production of plutonium, which justified their contribution of heavy water, uranium rods and knowledge (from the University of Chicago laboratories). The UK gained direct experience with the design and construction of a nuclear reactor of significant size, by contributing scientists and engineers to the project, which gave it a base from which to launch their own nuclear development program. Canada gained the most because it acquired a home-grown, state-of-the-art reactor, and an independent, highly capable staff of experienced scientific personnel "second to none".

NRX succeeded admirably in fulfilling Mackenzie's dream of getting in on the ground floor of a new technology, based on materials familiar to Canadian industry, i.e., heavy water and natural uranium. As the war ended, Canada turned its attention to the power-producing side of nuclear energy and NRX was followed by NRU, then NPD, and finally the CANDU family of the present. With its on-line fuelling capability and safety record, the CANDU reactors placed Canada at the forefront of nuclear technology and thus Canada is well positioned to enter the "green" world so dreamed of by the environmental community.

9. Acknowledgements

I would like to thank Lyn Arsenault for her many valuable suggestions and for editing this article through multiple iterations. Thanks to Fred Boyd for his review and constructive comments.

10. Biographies

James Chadwick – physicist and administrator

Born in Bollington, Cheshire, England, in 1891. In 1908 Chadwick enrolled at Victoria University of Manchester one year after Ernest Rutherford arrived there from McGill. Chadwick graduated with a B.Sc., followed by an M.Sc. in 1911. In 1913 he was awarded an 1851 Exhibition Scholarship and he departed for the Imperial Institute of Physics and Engineering near Berlin. He was interned from 1914–1918 and returned to Manchester University after the great war. In 1919 Rutherford moved to Cambridge to become Cavendish Chair of Physics. Chadwick followed and became a research assistant there. He received the Ph.D. in 1923 and became Assistant Director of Research.

In 1930 he co-authored the text Radiations from Radioactive Substances. He discovered the neutron in 1932 and was awarded a Nobel Prize in 1935. In the same year, Chadwick left the Cavendish and became Professor of Physics at Liverpool University. In 1940 he joined a government subcommittee looking into the possibility of a nuclear weapon [Brown, 1997].

Leslie Richard Groves – engineer and administrator

Born in Albany, New York, in 1896. He graduated from the University of Washington in 1914, studied engineering for two years at the Massachusetts Institute of Technology (MIT), went on to West Point and graduated from there in 1918. Periods at the Army Engineer School, the Command and General Staff College, and the Army War College in the 1920s and 1930s completed his extensive education.

He saw duty in Hawaii, Europe and Central America. Groves became Deputy Chief of Construction for the entire US Army and completed building the Pentagon in1942 [Rhodes, 1986].

Clarence Decatur Howe – engineer, politician and administrator

Born in Waltham, Massachusetts, in 1886. He graduated in Civil Engineering from the MIT in 1907 and then became a part-time lecturer there. In 1908 he was hired by Dalhousie University as a full professor of Civil Engineering, at the age of 22. By 1913 he became Chief Engineer in charge of construction for the Board of Grain Commissioners in Ottawa, and became a Canadian citizen.

He started a successful construction company in 1916, was elected to Parliament in 1935, and was promoted into the Cabinet of William Lyon Mackenzie King as Minister of Transport. Howe immediately impressed everyone with his no-nonsense ability to get things done effectively and he became Minister of Munitions and Supply in 1940 [Roberts,1957; Bothwell and Kilbourn, 1972].

Chalmers Jack Mackenzie – engineer, educator and administrator

Born in St. Stephen, New Brunswick, in 1888. In 1909 he graduated from Dalhousie University in Engineering. In 1910 he headed west and, with a partner, opened an office in Saskatoon but then went to work for another engineer and became a full partner in Maxwell and Mackenzie. He began part-time teaching at the the University of Saskatchewan (UoS) in 1912 and then went to full-time in 1913. In 1914 he attended Harvard, completed a Master's degree in Civil Engineering and then enlisted in the Army and was shipped overseas. In the great conflict of 1914 to 1918 he was awarded the Military Cross and returned to Canada in 1919.

In 1919 he became Dean of Engineering at UoS and in 1935 became a member of the Honorary Advisory Council of the National Research Council (NRC). In 1939 he became temporary head of the NRC [Thistle, 1975; Herzberg, 1985].

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The Women Scientists of the Montreal Laboratory

Introduction

In their paper 'A Select Few: Women and the National Research Council of Canada, 1916-1991', Marianne Gosztonyi Ainley and Catherine Millar asserts that 'the Atomic Energy Project, although it had thirty physicists, did not employ them (i.e. women). As far as we know, the only women at Chalk River worked in the biology/health radiation and chemistry branches.'

In the same vein, the official plaque at Montreal University unveiled by the Duke of Edinburgh in 1962 in honour of the nuclear research effort during the war, gives only the names of men.

This is not true. Several women worked as scientists in the Montreal Laboratory between 1942 and 1946 on the 'Tube Alloys' project, the British pendant of the Manhattan project. They all had degrees from Canadian universities. It is more than time to name these women and unveil, when known, their scientific contribution.

This article briefly presents the results of my research on the lives of these women. A lot remains unknown. The order of presentation goes from their alma mater, from the west to the east coasts.

Four of them were graduates from the University of British Columbia (UBC) in Vancouver. They worked with or studied under George Volkoff, a prominent member of the Montreal Laboratory that was on leave from his professorship at UBC. These women are:

1. Muriel Wales
2. Anne Barbara Underhill (1920-2003)
3. Lillian May Butler Grassie (1922-2015)
4. Joyce Kathleen Morris Laird (1919-2002)
5. M. E. Kennedy
6. Jeanne LeCaine Agnew (1917-2000)
7. Ethel Lillian Kerr Steljes
8. Dorette Desbarres Bate (1902-1989)

1. Muriel Wales

Muriel Wales was born in British Columbia. Her father was George Frederick Wales and her mother Alice Girvan, from Scottish and Irish origins. She attended the Laura Secord elementary school in Vancouver. She graduated (Bachelor of Arts) from UBC in 1934. Her major was in mathematics and her minor in physics.

In 1937, she won her M. Sc. Degree from UBC in mathematics. Her thesis was 'On the Determination of Bases for Certain Quartic Number Fields'. She moved to the University of Toronto and was awarded her Ph.D. in mathematics in 1940 under the directorship of Samuel Beatty. The title of her thesis was: 'Theory of Algebraic Functions Based on the Use of Cycles'.

She joined the Montreal Laboratory in 1944 and worked as a professional mathematician in the theoretical physics branch, under George Placzek. She is one of two women who authored MT (Montreal Technical) reports:

- MT-242, 'Fast Fission in Tubes: A Numerical Supplement to MT-199', by M. Goldstein, M. Wales and A.S. Lodge, May 1946.

In Montreal, she lived in an apartment on Sherbrooke street west. This is approximately midway between Montreal University where the laboratory was located and downtown. She transferred to Chalk River in 1945 and worked in the theoretical physics branch under George Volkoff and Hank Clayton until 1949. She knew Volkoff well, as she graduated in the same class at UBC.

After she left Chalk River, almost nothing is known of what happened to her. Her father died in 1959 aged 72 and her mother in 1979 aged 90, both in Vancouver. Muriel Wales eventually moved back to Vancouver in her parents' house where she was residing when her mother deceased.

2. Anne Barbara Underhill (1920-2003)

Anne Underhill was born in Vancouver in 1920. She was the daughter of Frederic Clare Underhill, a civil engineer, and of Irene Anna Creery. She had a twin brother and three younger brothers. She went to the Prince of Wales high school where she won the Lieutenant Governor's medal as one of the top students in British Columbia. Her mother died when she was 18. While undertaking her undergraduate studies, she helped raised her younger brothers.

She obtained her bachelor's degree at the University of British Columbia in Chemistry in 1942 and her Master's degree in Physics and Mathematics in 1944, also from UBC, on the Stark effect of helium in some B type stars. Her interest in astronomy would endure for her whole life.

In 1944 she was hired to work in the Montreal Laboratory. It is not known on what research she was involved while in Montreal. He twin brother was killed in Italy during WWII (1944), a loss that she felt deeply.

In 1946, she started studying at the University of Toronto, then moved to the University of Chicago, where she obtained her Ph.D. in 1948 under the direction of Subramanyan Chandrasekhar, an authority in the field of black holes, who would receive the Nobel Prize in Physics in 1983. Her thesis was the first model to compute a multi-layered stellar atmosphere. In 1948 she performed postdoctoral work at the Copenhagen Observatory in Denmark.

She came back to British Columbia and worked at the Dominion Astronomical Observatory in Victoria from 1948 to 1960. In 1962 she became a Professor of stellar astrophysics at Utrecht University in the Netherlands until 1969. In 1966, she wrote 'The Early Type Stars', a book that quickly became a standard reference.

In 1970 she joined the NASA Goddard Flight Space Center in Greenbelt, Maryland, as director of the new optical astronomy laboratory. It is under her direction that NASA sent in space the International Ultraviolet Explorer that pioneered technology that would later be used on the Hubble Space Telescope. She worked for NASA until her semi-retirement in 1985. She then returned to Canada as Professor Emeritus at UBC. She died in 2003 aged 83 years old.

She published over 200 scientific papers, mostly on Wolf-Rayet stars. She received numerous awards during her scientific career and was elected member of the Royal Society of Canada in 1985.

3. Lillian May Butler Grassie (1922-2015)

Lillian May Butler and Vernon Grassie.

Lillian May Butler was born in 1922 in Arden Manitoba, the daughter of Albert and L.M. Butler. She attended the University of British Columbia were she received her B.A. in Chemistry in 1943. In 1942, she married Vernon Grassie, who also studied Chemistry at UBC where he earned his B.A. and Master degrees.

May Grassie in an unidentified lab.

In 1945, they moved to Montreal where Vernon Grassie did his Ph.D. at McGill. Lillian May was hired at the Montreal Laboratory, where she said later to her children that 'she was only taking measurements with Geiger counters, not knowing what the project was about'. While in Montreal, she gave birth to her first child, Louise Margaret Grassie in 1946.

The family moved to Delaware at the end of the '40s where Vernon Grassie was employed by the Hercules Powder Company, a chemical and munitions manufacturing company. In Wilmington Delaware, they had five more children, one girl and four boys, between 1948 and 1958. Vernon Grassie died prematurely in 1969.

May remarried to another chemist, William Hatchard in 1970. They lived a happy family life until 2009 when William passed away aged 90 years old. Lillian May was an avid swimmer, hiker and skier who enjoyed outdoors year-round.

Later in life, May became active in the Peace Movement, even embarking on the "Great Peace March for Global Nuclear Disarmament" held in 1986, a walk of approximately 6000 km from Los Angeles to Washington D.C., advocating for complete and verifiable elimination of all nuclear weapons. She died in the summer of 2015, aged 93.

4.Joyce Kathleen Morris Laird (1919-2002)

Joyce Morris receiving the Governor's General Gold Medal in 1941.

Joyce Kathleen Morris was born in March 1919 in Penticton, BC, to William Morris and Edith Bryning. She went to UBC where she had outstanding results, winning the Governor's General Gold Medal for the class of 1941. She held her Bachelor of Arts in Physics and Mathematics. In the summer of 1941 she married Alan D.K. Laird, a 1940 UBC graduate student in Science.

During the war, Alan Laird was hired by the Canadian Defence Industries in Montreal where he worked on various military projects. Joyce Laird was hired by the Montreal Laboratory where she worked from 1943 to 1945 as a computing assistant in the theoretical physics department. At the end of the war, they returned to British Columbia where Alan worked as an engineer for one year.

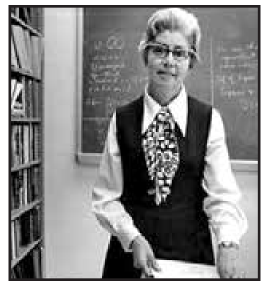
Alan Laird was offered a teaching assistantship in Berkeley, California, in 1946. They established themselves in Lafayette, California, where they lived for the rest of their lives. They had three children, two sons and a daughter.

When her husband retired from Berkeley in 1980, they travelled together extensively in Africa, the Far East, Europe and most of North America. Alan Laird passed away in 1996, while Joyce Morris Laird, died aged 83 years old in 2002.

5. M.E. Kennedy

Miss M.E. Kennedy is mentioned as one of the Canadian staff working at the Montreal Laboratory in the 13th August 1945 press release by the Government of Canada. She graduated from the University of Saskatchewan.

6. Jeanne LeCaine Agnew (1917-2000)



Dr LeCaine Agnew in the classroom, 1972.

Jeanne LeCaine was born in Thunder Bay (formerly known as Port Arthur), Ontario in May 1917. Her parents were Hubert LeCaine and Susan Smith. She attended high school in the Port Arthur Collegiate Institute and received her Bachelor's degree in 1937 at Queen's University in Kingston, with a major in mathematics and a minor in economics. She also received her M.A. degree from Queen's in 1938.

From 1939 to 1941 she did her Ph.D. in mathematics at Harvard University in Massachusetts (officially she was enrolled at Radcliffe College because Harvard was 'all-male', but all her courses and professors were at Harvard). Her advisor was G. Birkhoff, a leading American mathematician. She wrote most of her dissertation from her family cottage at Thunder Bay.

It is while at Radcliffe that she met her future husband, a young history student called Theodore Agnew. After she earned her Ph.D. she became an instructor in mathematics at Smith College, a private women liberal arts college located in Northampton, Massachusetts. Jeanne LeCaine and Theodore Agnew were married on Christmas Day 1942, and a few days later, he was sent on duty to Hawaii, where he would stay for more than 2 years.

Jeanne LeCaine Agnew then decided to do her share in the war, and decided to go back to Canada, the country that she was proud of being a citizen. She was hired by the National Research Council in Ottawa and was rapidly sent to Montreal to work on the Tube Alloys project.

She shared an office with Carson Mark, a Canadian mathematician who was working on the neutron transport theory. He allowed Jeanne to share his family which was an important association for her.

Dr LeCaine is the other woman author of MT reports, producing no less than 5:

- MT-12, 'Elementary approximations in the theory of neutron diffusion', by. P.R. Wallace and J. LeCaine, August 1943.
- MT-29, 'Critical radius of a strongly multiplying sphere surrounded by a non-multiplying infinite medium', by J. LeCaine, April 1944.
- MT-30, 'Application of "synthetic" kernels to the study of critical conditions in a multiplying sphere

with an infinite reflector', by G.M. Volkoff and J. LeCaine, April 1944.
- MT-119, 'Milne's problem with capture, II', by J. LeCaine, April 1945.
- MT-131, 'A table of integrals involving the functions En(x)', by J. LeCaine, March 1945.

After the war, her husband completed his Ph.D. at Harvard. They were both offered positions at the Oklahoma State University, Theodore in 1948 and Jeanne in 1953, were she taught undergraduate and advanced courses in mathematics until she retired in 1984. In 1948, she gave birth to a boy who would die 'aged eleven hours'. The couple had five more children between 1950 and 1960. One of their sons, Hugh LeCaine Agnew born in 1953, would become a history professor at George Washington University. Their younger daughter, Marion Jeanne Agnew, is an editor and writer who lives near Thunder Bay, her mother's home town. As a professor, Jeanne LeCaine Agnew received many awards including the Outstanding Teacher Award in 1964 and 1978. She was named Professor Emeritus upon her retirement. She continued her involvement with the university, working on several committees and supervising independent study courses. She died on May 8, 2000, aged 83 years old.

7. Ethel Lillian Kerr Steljes

Ethel Kerr (inaccurately identified as 'Miss P. Kerr' in the 13th August 1945 press release by the Government of Canada and in the reminiscences by G. Laurence) graduated from McGill University with a B.Sc. in chemistry in 1944. She was hired by the NRC in Ottawa and was transferred to Montreal in June 1945. She probably worked in the chemistry department.

In Montreal she met John F. Steljes who was developing ion chambers of various kinds to detect neutrons and other atomic particles. They both moved to Chalk River and were married in 1947.

In 1948, she published a paper with J.A. McCarter in the Canadian Journal of Research, titled 'Methods for the Determination of the Distribution of Radioactive Phosphorus among the Phosphorus-Containing Constituents of Tissues'.

Ethel and John had four children. In 1975 the whole family traveled to Europe. Their daughter Cynthia Steljes, an oboist with Quartetto Gelato, died of a rare form of cancer in 2006 aged 46.

John Steljes died in 2013, aged 95 years old.

8. Dorette Desbarres Bate

Mt. Allison University Archives – Ref. 2007.07/1282

Dorette Desbarres was born in 1902 in a wealthy family. Her parents are Frederick W.W. Desbarres and Nita Churchill. Her father graduated from Mount Allison University in New Brunswick and was ordained into the Methodist Church in 1893. From 1909 to 1936 he was Professor at Mount Allison and Chief Librarian. Her maternal grandfather, George W. Churchill made a fortune in the shipbuilding and shipping industries in the 1800's. Her mother was a student at Mount Allison Ladies' College in the last years of the 19th century.

Dorette attended Mount Allison and graduated (B.A.) in 1924. She was member of the 1924 women basketball team as shown here (last row, third from the left). She had two older sisters, Marie and Nita.

Dorette Desbarres married William Barrett Bate in 1940. William Bate was a lawyer living in Ottawa. He enlisted in the Royal Canadian artillery in 1940 and was later transferred to the judge-advocate branch of the army. He served in Northwestern Europe and in Italy during WWII.

It is not known under which circumstances Dorette Desbarres Bate was hired by the NRC to work in the Montreal Laboratory. She also worked for the NRC in Ottawa and Halifax.

After the war, her husband came back to practice law and they lived together in Ottawa. He died after a brief illness in 1950.

Dorette Bate lived in Ottawa for the rest of her life. She died in 1989.

Conclusion

Although it is not well known, 8 women scientists participated in the Montreal Laboratory of the NRC and three of them contributed significantly to the theoretical physics section. They formed 15% of that section. This is comparable or higher than the percentage of scientist women working in Los Alamos, as described in the book 'Their Day in the Sun: Women of the Manhattan Project' by Ruth H. Howes and Caroline C. Herzenberg.

Many more women participated in the Tube Alloys project as secretaries, nurses or in other capacities. Their story has yet to be told.

If readers have more information on the lives of these women and what was their role in the Montreal Laboratory, I would be really glad to get in contact.

Gilles Sabourin, Montreal

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- 'Anne Barbara Underhill (1920-2003)', biography on the website http://astro-canada.ca/_en/a2209.php; consulted November 2015.
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GENERAL news

(Compiled by Colin Hunt from open sources)

TransCanada Announces Bruce Power Life Extension Agreement

TransCanada Corporation announced on Thursday, December 3, 2015 that Bruce Power had entered into an agreement with the Ontario Independent Electricity System Operator (IESO) to extend the operating life of the Bruce Power facility to 2064. Under the agreement, full refurbishment will be carried out on six Bruce nuclear power reactors, Units 3-8.

The total cost of the program will be approximately $13 billion: $5 billion in a range of life extension activities 2016-2053, and $8 billion in the main component replacement program. Bruce Power will bear the risk of delivering these projects with better than expected performance being shared with the IESO.

Bruce Power will continue to provide about 2,400 MW as flexible generation, allowing the province to balance system needs in a post-coal electricity environment.

The agreement takes effect January 1, 2016. The agreement provides for near-term life extension (Asset Management program) commencing immediately, which will allow major component replacement beginning in 2020. Bruce Power will receive a uniform price for the electricity from all units starting at $65.73/MWh. Over time, the price will be adjusted for the return on capital invested, which will be approximately $110 million per year over the life of the facility.

Since 2001, Bruce Power has returned the site to its full operational capacity, commencing with the restart of Bruce Units 3 and 4 in 2003-4. Bruce Power entered into agreement with the Ontario government in 2005 for the refurbishment and return to service of Units 1 and 2, which re-entered service in 2012. Total capital investment to date has been approximately $10 billion. The announcement on December 3 extends that agreement to the remaining six reactors.

Bruce refurbishment will commence with Unit 6 starting in 2020, followed by Unit 3 (2022), Unit 4 (2025), Unit 5 (2026), Unit 7 (2028) and Unit 8 (2030).

In 2014, an economic impact study showed that the refurbishment program will produce:

- 18,000 jobs directly and indirectly and $4 billion in annual economic benefit in Ontario through spending on operational equipment, supplies, materials and labour income;
- an additional 3,000-5,000 jobs annually from the investment program to 2036;
- over 90 per cent of Bruce Power's capital spending will take place in Ontario.

The study was carried out by the Provincial Building and Trades Council of Ontario, Southwest Economic Alliance, Canadian Manufacturers and Exporters, The Society of Energy Professionals, the Power Workers Union, and Bruce Power.

Bruce Power currently has two different partnership structures for Bruce A and B. As a result of this agreement, there will be a single partnership structure for the site. Under the single structure, TransCanada and Borealis Infrastructure Management will each have a 48.5% ownership share, with the remainder divided between the Power Workers Union, The Society of Energy Professionals and Bruce Power employees.

BWXT Canada and Bruce Power sign agreement for new steam generators

BWXT Canada (formerly Babcock & Wilcox) and Bruce Power signed an agreement on Friday, December 4, 2015 for the supply of new steam generators for Bruce Power. Each of the four units at the Bruce B nuclear power station will require eight replacement steam generators, starting with Unit 6 in 2020.

The cost of the program is expected to total between $400 million and $500 million for the supply of the 32 steam generators.

The Cambridge, Ontario facility has built all of the original steam generators at the Bruce site since the station went on line in 1977. BWXT has supplied over 300 CANDU and PWR steam generators worldwide.

Premier Marks Saskatchewan's First Uranium Shipment to India

India has a dynamic and growing nuclear energy industry, and uranium from Saskatchewan is now officially part of the electricity generation mix for that country.

"India has just received its first shipment of Saskatchewan uranium under the Canada-India Nuclear Cooperation Agreement, and today we mark an economic milestone for our uranium mining industry and our province," Premier Brad Wall said. "All of Saskatchewan benefits from having this major new customer for our resource, but this export news is particularly welcome for uranium workers, nearly half of whom are First Nations and Métis."

"Opening new markets for Saskatchewan uranium in rapidly growing countries like India and China was a priority for the former federal government," Wall said. "We are thankful for those efforts."

OPG Statement on Deep Geologic Repository

The Minister of the Environment and Climate Change announced there will be a decision on OPG's proposed Deep Geologic Repository (DGR) on March 1, 2016.

OPG has spent more than a decade studying the feasibility of a DGR at its Bruce site in Kincardine, Ontario and has conducted considerable public consultations. The federal environmental assessment DGR included more than 12,500 pages of peer reviewed data.

The proposed DGR, which would be located at the Bruce nuclear facility in Kincardine, will safely store more than 200,000 cubic metres of low and intermediate level waste from 40 years of operating Ontario's nuclear stations.

Used fuel would not be stored in the DGR. Buried 680 metres in stable rock formations that are over 450 million years old, the proposed DGR would permanently isolate and contain the waste deep underground and protect the water and surrounding environment.

New Agreement Seeks to Secure Critical Long-Term Isotope Supply

Two of Ontario's innovative nuclear sector companies are once again building on their strong partnership and respective strengths to create a new, long-term supply of an important cancer-treating isotope, Cobalt-60, that will benefit health care patients in Canada and around the world.

Nordion, a standalone business within Sterigenics International, and Bruce Power announced today they have executed a Memorandum of Understanding (MOU) for the supply of High Specific Activity ('HSA') Cobalt-60, also referred to as medical-grade Cobalt. This type of Cobalt-60 is produced in a limited number of nuclear reactors globally and used in radiation-based treatment of cancer and other diseases in Canada and around the world.

"With limited supply available for the market, Nordion is acutely aware of how important it is, for our customers and for patients globally, that we secure a new long-term supply of medical-grade Cobalt," said Scott McIntosh, President, Gamma Technologies & Corporate Services, Nordion.

"Securing a new supply is a key milestone for both companies. We're using promising new technology in Bruce Power's reactors, adding to the contribution they will make through Ontario's Long-Term Energy Plan (LTEP)."

The LTEP, announced in December 2013, has identified a role for nuclear power in Ontario as part of a balanced, modern and clean electricity system. The role of nuclear power also includes medical applications. For over six decades, Nordion's supply of medical-grade Cobalt has come primarily from the National Research Universal (NRU) reactor at Chalk River, ON. Recognizing that in a few years the NRU reactor will reach end of life, this MOU will lead to the development of a novel approach to create a new source of supply from Bruce Power building on existing technology and practices.

Prestigious International Review of Bruce Power Begins

A group of international nuclear experts, led by the International Atomic Energy Agency (IAEA), arrived at Bruce Power today for an Operational Safety Review Team (OSART) Mission, which runs until Dec. 17.

Bruce Power was put forward for this review in 2014 by the Canadian Nuclear Safety Commission (CNSC), Canada's independent nuclear regulator and an active participant in the international nuclear community.

"We are honoured to have been chosen to participate in this prestigious international review where we will outline the progress we've made since 2001 while continuing to do what nuclear operators do best – focus on sharing best practices and continuously improving," said James Scongack, Bruce Power's Vice President, Corporate Affairs.

The OSART Program has been in place since 1982, providing member states the opportunity to share best practices and also to support continuous improvements to their operations. Best practices identified through these reviews are shared through the IAEA to other nuclear operators. The review will focus on Bruce B, which is recognized internationally for its strong safety and operational performance and was awarded the Institute of Nuclear Power Operators (INPO) award of excellence in recognition of its world-class performance in November 2014.

Japanese Regulator Approves Full Reactor Licences

Three Japanese reactors have approval given on

November 20, 2015 to operate for their full licence periods of 40 years after decisions by the Nuclear Regulation Authority (NRA). One of the units - Sendai 2 - is already in operation, the other two - Takahama 3 and 4 - are soon to restart.

Under Japanese regulations nuclear power plant operators receive a licence that lasts for 40 years, subject to a review at 30 years in which the NRA checks the operator's maintenance plan for the unit. Success at this 30-year check was announced on 18 November by Kansai Electric Power Company's Takahama 3 and 4 as well as Kyushu Electric Power Company's Sendai 2.

Sendai 2 was the second unit to restart under the new regulations, reconnecting to the grid and supplying electricity from 21 October. It is now licensed to operate until 2025.

Takahama 3 and 4 are likely to be the next units to restart, in December and early 2016 respectively. They are also now expected to operate until 2025.

Japanese units can also apply to the NRA for a licence for operation up to the age of 60 years but none have yet done so.

Convention Signed on Extending Lives of Doel Units

Engie - parent of Belgium's Electrabel - signed an agreement on December 1, 2015 with the Belgian government that revises the tax contribution paid by the country's nuclear operators. It also allows for a ten-year life extension for units 1 and 2 of the Doel nuclear power plant.

Under the convention signed yesterday, Electrabel must pay an annual fee of €20 million ($21 million) between 2016 and 2025 for the continued operation of Doel 1 and 2. The fee is to be paid into the country's energy transition fund which was created by the law of 28 June.

UK Sets Aside Funds for 'Ambitious' Nuclear Research and Development Program

The UK will invest at least £250 million ($377 million) over the next five years in an "ambitious" nuclear research and development program, according to the Conservative Party-led government's Spending Review and Autumn Statement published yesterday. British Chancellor George Osborne's 'Comprehensive Spending Review' says this program will "revive the UK's nuclear expertise" and position the country as "a global leader in innovative nuclear technologies".

To help back science-based and innovative companies in the north of England, the government is providing the £250 million for SMR development and wider nuclear R&D, creating opportunities for the North's centres of nuclear excellence in Sheffield City Region, Greater Manchester and Cumbria, as well as the nuclear research base across the UK. This builds on £25 million ($38 million) of UK funding for a Joint Research and Innovation Centre with China, to be based in the North West, which was announced by the Chancellor on his recent visit to Beijing and which the National Nuclear Laboratory (NNL) will lead for the UK.

This is on top of a total of more than £375 million ($566 million) over this Parliament - 2015-2020 - for dedicated science and innovation facilities in the North, according to the Review.

Argentina Inaugurates Enrichment Plant

Argentine president Cristina Fernández de Kirchner led the official opening ceremony of the Pilcaniyeu uranium enrichment plant on 30 November.

Plans to recommission the Pilcaniyeu gaseous diffusion uranium enrichment plant, which operated from 1983 to 1989, were announced in 2006 and formed part of Argentina's ambition to build a self-sufficient nuclear fuel cycle. The original Pilcaniyeu plant had a modest enrichment capacity of 20,000 SWU per year, although plans call for the upgraded plant ultimately to reach a capacity of some 3 million SWU.

The reinstatement of the Pilcaniyeu plant secures Argentina's spot among the countries that can carry out the enrichment process, which is needed to increase the level of fissile uranium-235 for use in nuclear fuel. Unlike Argentina, other countries involved in building new enrichment capacity are focusing on the gas centrifuge process, which is far more energy-efficient. However, Argentina has also been experimenting with laser uranium enrichment technology.

Letters to The Editor

Dear Sir:

The editorial in the latest [September 2015] CNS Bulletin is a typical denier-based mixture of half-truths and irrelevant distractions. By including a few selective instances of real warming effects, the uninformed reader gets the impression of a balanced view. It is anything but. Yes, the Arctic has been warming with severe reduction in summer ice cover; but, no, the Antarctic is not immune, experiencing an alarmingly rapid rise in temperatures around the Antarctic Peninsula, which may already have set the West Antarctic Ice Sheet toward irrevocable dissolution. By careful choice of the period, the claim of no change in the last 17 (not 18 actually) years, the reference is to an anomalously warm year of peak El Niño effect. The rate of rise has slowed since 2000 but the reasons are now well understood as variations in the oceans' heat uptake, which varies with their large-scale circulation patterns. And 2015 is well on its way to being the warmest ever, globally.

The models do account for variation in Sun activity (and many other factors such as volcanic activity) but not the Earth's orbit (because that is an extremely long-term factor) or the Moon's tidal effects (very short-term). It is also incorrect to claim that the oceans are not observed since the definitive view of temperatures worldwide since 1977 has been from orbiting satellites. Cloud influence is not entirely satisfactorily represented, but not for the reason stated but because the effects of clouds are extremely complex–in some cases causing cooling, in some warming. Speaking as an experienced modeler of chemical plants, I am aware that models are never completely accurate but the editorial writer implies that only a perfect model can be valid. Like any convincing model, the IPCC's are both mechanistic and tuned against observation over as long periods as measurements, direct and indirect, can provide. Not perfectly predictive, as the IPCC's ranges of uncertainty show, but invariably indicative of warming that has the potential to become globally catastrophic unless the release of greenhouse gases is curtailed to around 20% of current levels within a few decades.

While I assume that the editorial's author has been sucked in rather than himself creating the misinformation, I'm appalled that the CNS Bulletin presents such a half-baked, misleading rant. The editorial's slur on the impartiality of the IPCC's scientific contributors is totally egregious.

Alistair I. Miller

Dear Sir

I mean not to flatter, but I want to say that I liked what you [Colin] wrote in the September issue about global warming/nuclear energy/and the lead-up to the recent federal election. It was smart, pithy, and well-written. Thanks!

As a matter of fact, together with your own article, I also found Ric Fluke's Editorial crisp and good, and Jeremy Whitlock's "Seventy Years...." historical reflection was excellent.

In sum, I thought the September edition was of a very high calibre and a credit to the 'Society.

Ronald Thomas

Publications

The IAEA is pleased to announce the publication of:

Nuclear Forensics in Support of Investigations
IAEA Nuclear Security Series No. 2-G (Rev. 1)

This publication is a revision of IAEA Nuclear Security Series No. 2, Nuclear Forensics Support, which was published in 2006. Since then, there has been substantive expansion and confidence in the application of nuclear forensics globally to effectively counter the threat of nuclear and other radioactive materials out of regulatory control. Most significantly, nuclear forensics has been applied in response to a number of incidents involving the illicit trafficking of highly enriched uranium and plutonium. The essential lessons learned from these experiences are incorporated in the revised publication to update the procedures and methods used in the conduct of a nuclear forensic examination as well as stress the importance of international cooperation.

STI/PUB/1687, 80 pp., 2 figs; 2015; ISBN: 978-92-0-102115-1, English, 38.00 Euro.

Electronic version can be found:
http://www-pub.iaea.org/books/IAEABooks/10797/Nuclear-Forensics-in-Support-of-Investigations

CNS news

CNS Member John Luxat Leads New Nuclear Technology Facility at McMaster University

A small team of engineering professors led by nuclear safety expert John Luxat is creating an advanced nuclear research capability at McMaster University called the Centre for Advanced Nuclear Systems (CANS). It's taken six years of planning and $24.5 million from the Canada Foundation for Innovation, the Ontario Ministry of Research and Innovation and private donations to open a network of five facilities dedicated to the study of nuclear systems, expected to open in early 2016.

According to Luxat, the goal is to better understand the lifespan of components in nuclear reactors when subjected to intense neutron irradiation, essentially how materials change and degrade over time. The facility network will also provide lab support to the nuclear sector, particularly Ontario's three nuclear power plants: Bruce, Pickering and Darlington.

"If we understand these processes better we can extend operational life between expensive refurbishments," says Luxat. His research focuses on nuclear safety analysis and risk analysis, particularly severe accidents such as those in Fukushima; looking at ways to reuse and reprocess spent nuclear fuel to reduce nuclear waste; and thermal-mechanical behavior of nuclear components and structures under extreme events.

Luxat, a CNS member and former CNS President, serves as NSERC/UNENE Senior Industrial Research Chair in Nuclear Systems and spent 32 years working in the Canadian nuclear industry including managing Ontario Power Generation's Nuclear Safety Technology Department. He serves as director for the Centre for Advanced Nuclear Systems.

For more, including a video, visit: http://dailynews.mcmaster.ca/article/new-facility-will-test-how-long-nuclear-reactor-components-last/#sthash.o5Gs6Xo3.dpuf

News from Branches

BRUCE Branch

On **Monday November 16, 2015**, the Canadian Nuclear Society, Bruce Branch hosted a dinner meeting and presentation from **Scott Berry, Manager Corporate Relations, OPG** on the **Deep Geologic Repository**. It was an excellent presentation! We certainly found it to be of great value and helped us understand the science and process being used for this important proposal. The discussion that the presentation generated lasted for some time into the evening. All in all a very worthwhile event!

In support of the initiative to increase CNS membership I invited several guests including new nuclear workers and recent nuclear retirees to this meeting. Based on the feedback from these guests we most probably will have some new members in the near future!

Art McDonald explains the mysteries of the universe.

CHALK RIVER Branch

On **October 16th**, the Chalk River Branch of the CNS was honoured to partner with Canadian Nuclear Laboratories (CNL) to offer a public lecture by **Canada's newest Nobel Laureate, Dr. Arthur McDonald**. Dr. McDonald spoke to a packed house at the Child's Auditorium about **his research, its connection to Chalk River and what the groups at SNOLabs are doing next.**

CRB Executive – Bryan White, Aidan Leach, Tracy Laping, Ruxandra Dranga, Laura Blomeley, Andrew Morreale, Dan McArthur - Bruce, Samy El-Jaby.

On **November 4th**, the Chalk River Branch held its annual general meeting, electing a new executive. After the AGM activities, a seminar was given by **Dan McArthur**, who spoke on **some testing that Bruce power has completed on technological advancements in public alerting**.

GOLDEN HORSESHOE Branch (GHB)

As of right now, we report the following planned Seminar.

The GHS branch will be co-hosting a Cafe-X seminar at McMaster University hosting Dr. Robert Walker, former CEO of AECL/CNL on December 8th titled: "Thoughts on the Science-Policy Interface in a Complex World". An expected 60 people will attend from interested McMaster students and faculty, and CNS members.

NEW BRUNSWICK Branch

The New Brunswick Branch held one meeting during the reporting period.

On **November 12, 2015, Mr. Sean Granville** delivered a presentation in Saint John, NB, entitled ***"Navigating for Excellence"*** to NB Branch members and guests. The presentation provided an overview of the challenges that Point Lepreau Generating Station was facing following plant refurbishment, how a solution was developed in terms of business planning to turn around plant performance and was documented in the Navigating for Excellence plan. The focus of the plan was to develop a vision and path forward communicate the plan in a way that could be made "real" for the line organization. The presentation prompted a great deal of thoughtful questions and discussion by attendees. Branch Chair Derek Mullin thanked Sean for an excellent presentation and provided a commemorative gift to Mr. Granville.

Following the **November 12, 2015**, lecture, Branch Chair Derek Mullin encouraged attendees to consider nominations for the **2016 Canadian Nuclear Achievement Awards**, jointly sponsored by the Canadian Nuclear Society (CNS) and the Canadian Nuclear Association (CNA), and that these Awards represent an opportunity to recognize individuals who have made significant contributions, technical and non-technical, to various aspects of nuclear science and technology in Canada.

CNS Geiger Kits Status

As reported in the last branch affairs report, the NB Branch has reached out to 31 New Brunswick high schools to determine the fate of the CNS Geiger Kits. Thus far 4 schools have replied to the initial email. Next month we will reach out via telephone in an effort to garner further feedback.

OTTAWA Branch

On **Wednesday 18th November**, the Ottawa Branch held a meeting with special guest **Mr. Frank Saunders, Vice President** of **Nuclear Oversight and Regulatory Affairs at Bruce Power**. Mr. Saunders gave a very interesting and well received presentation entitled "The Bruce Site 2001 – 2015" where he described the many challenges and accomplishments of Bruce Power in redeveloping the 8 unit Bruce station since taking it over in 2001.

Frank has been at the station since that time, during which Bruce Power has refurbished all four units at its Bruce A station, returning 3,000 megawatts of low-cost, reliable electricity to Ontario consumers. Combined with its Bruce B units, it is currently the world's largest operating nuclear site with eight units that have the ability to produce 6,300 megawatts – about a third of Ontario's energy.

The meeting was co-hosted by Mike Taylor and Ron Thomas, and was well attended. A very lively question & answer session followed. At the conclusion of the session, Ron Thomas thanked Frank for a most interesting presentation. A copy of Frank's presentation can be found at the Ottawa branch web page.

The branch executive is lining up other events for the new year. Branch executive member Laurence Robitaille has updated our branch web page and restored our Facebook /Twitter accounts.

WESTERN Branch

General

The Western Branch has had a busy fall period, which has included a number of outreach engagements as well as reflection on the branch's future direction.

Branch Activities

Aaron Hinman has volunteered to serve as the branch's Outreach and Education Coordinator. Aaron has been extensively involved in outreach on behalf of the Western Branch and the Alberta Branch before it. The executive has also begun a strategic planning exercise to assist in determining the direction of the branch. The first step was soliciting responses from the executive to a series of questions:

- Why are you a member of the CNS?
- What do you think the branch does well right now?
- What are three things the branch should do more?
- How can the branch attract new members and attract back old members?

The responses and subsequent discussion will be used to formulate next steps.

Outreach Activities

Jason Donev coordinated the organization of Nuclear Science Week activities nationally. Within the Western Branch, NSW events took place in Calgary (organized by Jason), Saskatoon (organized by **Matthew Dalzell** and the Fedoruk Centre assisted by **Sara Ho** and **Cody Crewson,** featuring a panel with **Duane Bratt** and **Neil Alexander**) and Regina (organized by Canadian Institute of Nuclear Physics members Garth Huber and Zisis Papandreou).

Jason Donev also represented the CNS at **an energy conference organized by the Colleges and Institutes of Canada in Medicine Hat November 6 and 7.**

Neil Alexander participated in a panel discussion with representatives of the CNSC on the opportunities and regulatory issues for small modular reactors organized by the Johnson-Shoyama Graduate School of Public Policy at the University of Saskatchewan and University of Regina on November 24.

Canadian Nuclear Society
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4th Floor, 700 University Ave, Toronto, ON M5G 1X6
Tel: (416) 977-7620 E-mail/Courriel: cns-snc@on.aibn.com

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 2016: 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 currently 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 student's 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 **March 1, 2016**.

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4th Floor, 700 University Ave, Toronto, ON M5G 1X6
Tel: (416) 977-7620 E-mail/Courriel: cns-snc@on.aibn.com

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 2016: 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 **1er mars 2016**.

CNS 2016 SNC
Toronto
June 19-22 juin 2016

36th Annual CNS Conference
40th CNS/CNA Student Conference

Nuclear in the 21st Century: Global Directions and Canada's Role

Toronto, ON June 19 - 22, 2016
Toronto Marriott Downtown Eaton Centre Hotel

Call for Papers

Nuclear science and technology currently provides clean, safe energy, and benefits the health and security of the global community. Building on this strong foundation, nuclear science and technology will become of even greater importance well into the 21st century. Further advancement of the current state of the art would enhance public confidence and acceptance of nuclear science and technology.

The Canadian Nuclear Society (CNS) will host its 36th Annual Conference at the Toronto Marriott Downtown Eaton Centre Hotel in Toronto, Ontario, Canada, 2016 June 19-22. This conference provides a forum for exchanging views, ideas and information relating to the application and advancement of nuclear science and technology, and for discussing energy-related issues in general. Technical topics of interest are listed on the following page. The CNS 36th Annual Conference will feature:

- Plenary sessions with invited speakers to address broad industrial, commercial and research-related developments in nuclear science and technology.
- Technical sessions with subject-matter experts from utilities, suppliers, the regulator, academia, federal laboratories and agencies to present the latest advancements in nuclear science and technology.
- Exhibits with industrial leaders showcasing their latest nuclear products and technology.
- Social events (such as reception, lunches, coffee breaks and conference banquet) to facilitate in-depth discussions on common interests.

To facilitate interaction between experts and the future generation of nuclear scientists, engineers, and specialists, the 40th Annual CNS/CNA Student Conference will be held in parallel at the same venue. The Student Conference will feature a poster session with university students to showcase their latest research findings and advancement relevant to nuclear science and technology. A Call for Students' Extended Abstracts will be issued separately.

Important Dates:

(Extended) Abstract submission: 2015 December 31

(Extended) Draft paper submission: 2016 January 31

Full paper submission: 2016 April 15

Submission Guidelines:

- The abstract should be <150 words in length (technical topics of interest are listed on the following page).
- The full paper should present facts that are new and significant or represent a state-of-the-art review, and should include sufficient information for a clear presentation of the topic. The required format of submission is electronic (Word or pdf).
- Templates for abstract and full paper are available from the Conference website www.cns2016conference.org.
- Submission should be made via: www.softconf.com/h/CNS2016Technical
- Notes: At least one of the authors must register for the Conference by the "early" registration date (2016 April 15) for the paper to be included in the Conference Proceeding.

General Enquiry:

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http://www.cns-snc.ca

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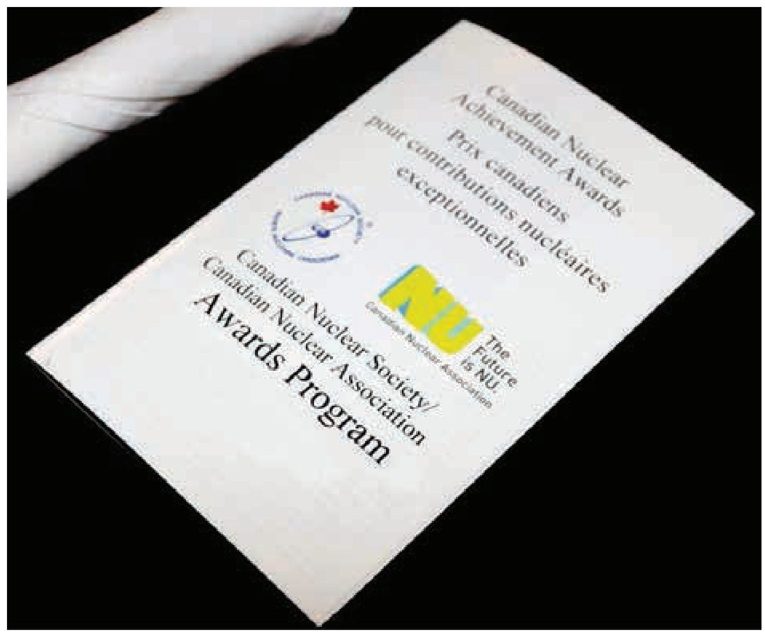
2016 Canadian Nuclear Achievement Awards
Call for Nominations

We are announcing the Call for Nominations for the 2016 Canadian Nuclear Achievement Awards, jointly sponsored by the Canadian Nuclear Society (CNS) and the Canadian Nuclear Association (CNA). These Awards represent an opportunity to recognize individuals who have made significant contributions, technical and non-technical, to various aspects of nuclear science and technology in Canada.



Nominations may be submitted for any of the following Awards:

- W. B. Lewis Medal
- Ian McRae Award
- Harold A. Smith Outstanding Contribution Award
- Innovative Achievement Award
- John S. Hewitt Team Achievement Award
- Education and Communication Award
- George C. Laurence Award for Nuclear Safety
- Fellow of the Canadian Nuclear Society
- R. E. Jervis Award

The deadline to submit nominations is **January 16, 2016.** The Awards will be officially presented during the CNS Annual Conference held June 19 - 22, 2016 in Toronto, Ontario.

For detailed information on the nomination package, Awards criteria, and how to submit the nomination, please visit: http://cns-snc.ca/cns/awards.

If you have any questions, please contact Ruxandra Dranga, Chair – CNS/CNA Honours and Awards Committee by email at awards@cns-snc.ca, or by phone at (613) 717 – 2338.

2016

March 14-16 **CNS CANDU Reactor Technology & Safety Course**
Courtyard by Marriott
Downtown Toronto
cns-snc@on.aibn.com

April 5-9 **20th Pacific Basin Nuclear Conference (PBNC-20)**
Beijing, China
cns-snc@on.aibn.com

April 17-22 **11th International Conference on Tritium Science and Technology**
Charleston Marriott Hotel
Charleston, SC
robert.addis@srnl.doe.gov

June 19-22 **36th Annual CNS Conference**
40th CNS/CNA Student Conference
Marriott Toronto Eaton Centre Hotel
cns-snc@on.aibn.com

July 31-Aug. 3 **ANS International Meeting on Decommission & Remote Systems**
Pittsburgh, PA, USA
cns-snc@on.aibn.com

August 15-18 **13th International Conference on CANDU Fuel**
Holiday Inn Waterfront Hotel
Kingston, Ontario
cns-snc@on.aibn.com

Sept. 11-14 **3rd Canadian Conference on Nuclear Waste Management, Decommissioning and Environmental Restoration**
Marriott Hotel
Ottawa, ON
cns-snc@on.aibn.com

October 9-13 **NUTHOS-11**
Gyeongju, South Korea
cns-snc@on.aibn.com

2017

May **CANDU Maintenance and Nuclear Component Conference (CMNCC-2017)**
Toronto, Ontario
cns-snc@on.aibn.com

June 4-7 **37th CNS Annual Conference**
& 41st CNS/CNA Student Conference
Niagara Falls, ON
cns-snc@on.aibn.com

July 31-Aug. 4 **13th International Topical Meeting on Nuclear Applications of Accelerators (AccAPP17)**
Quebec City, QC
cns-snc@on.aibn.com

Sept. 24-27 **2nd International Meeting on Fire Safety and Emergency Preparedness for the Nuclear Industry (FSEP 2017)**
Toronto, ON
cns-snc@on.aibn.com

"Badge-Draw" Winners at the 2015 October 5-6 CNS CANDU Fuel Course

At the end of the CNS CANDU Fuel Course, on October 6, 2015, 4 prizes were awarded by random draw from among badges returned by Course attendees.

The winners:

- Glenn Kuntz, of Bruce Power, and Syed Bukhari, of Canadian Nuclear Laboratories, each won a copy of the book "Bluebells and Nuclear Energy", by Albert B. Reynolds.
- Na Yeon Kim, of Kepco Nuclear Fuels, and Aaron Barry, of Canadian Nuclear Laboratories, each won a CNS membership valid to 2016 December 31.

Congratulations to all the winners!

Gagnants de prix au tirage des porte-insignes au cours de la SNC sur le combustible CANDU (5-6 octobre 2015)

À la fin du cours sur le combustible CANDU, le 6 octobre 2015, 4 prix ont été tirés au sort parmi les porte-insignes retournés par les participants du cours.

Voici les gagnants :

- Glenn Kuntz, de Bruce Power, et Syed Bukhari, des Laboratoires Nucléaires Canadiens, ont chacun gagné une copie du livre "Bluebells and Nuclear Energy", par Albert B. Reynolds adhésion gratuite d'un an à la SNC.
- Na Yeon Kim, de Kepco Nuclear Fuels, et Aaron Barry, des Laboratoires Nucléaires Canadiens, ont chacun gagné une adhésion gratuite à la SNC, bonne jusqu'au 31 décembre 2016.

Félicitations à tous les gagnants!

Nobel for Old Men

by JEREMY WHITLOCK

"I know you."

The words leave my lips before I realize I've spoken. I don't actually know this man. I know "of" him.

Perhaps it's the casual way he holds his drink. The tired, wise eyes that seem to see a different world than those around him.

"And I know why you're here."

He turns to me, nods, and takes another drink.

"This is kind of exciting," I hear myself continuing, "A Nobel prize in physics! We don't get too many of those in Canada."

"This makes four", the man concedes, staring into his half empty glass.

"Well let's see," I say, counting on my fingers like a child, "the last was Boyle in 2009, for inventing the charged-couple device. Then Brockhouse in 1994, for neutron scattering. Then Taylor in 1990, for inelastic electron scattering. And now McDonald, 2015, for neutrino mass. Yup, four."

"Unless you count Rutherford in 1908, for radioactivity," the man adds, "and you Canadians really should count him you know. He wasn't Canadian but he did the work here."

"Ah yes," I smile, "the one that started it all. Except he had to settle for that prize being in chemistry!"

He still hasn't looked my way, after that first perfunctory nod. I shift a little closer.

"Say, what was it like?" I ask, "All that brilliant science... I've heard stories, of the old days."

A pause, and then he turns.

"It's true," he says, "all of it."

Against my better judgement I emit an incredulous chuckle. The man ever so slightly straightens.

"I mean, all of it?" I ask, "It seemed so easy then to uncover earth-shattering discoveries. One might say even to earn a Nobel prize. Einstein, Rutherford, Fermi, all the greats – they could each have earned two or three."

Another pause.

"Science was fertile", the man finally offers with a nod, gazing past me at whatever ghosts he alone is privy to. "There was much to learn, and much fortitude to learn it."

"Ah but surely life was simpler then," I wonder, "the big questions were there for the answering... particles to be discovered... science was smaller, faster, more personal. Look at Rutherford's benchtop apparatus, and compare to McDonald's SNO laboratory. Look at the infrastructure, the sheer number of people involved."

This time a long reflection: upon my words presumably, but he seems to be plumbing greater depths.

Finally, nodding: "Life was simpler."

We take a drink.

"Learning was simpler," the man adds, more quietly. I lean closer to hear.

"Knowledge was king. Business, finance, politics, medicine, even the occasional war – it was all important and consuming. But above all, knowledge was king. We didn't lose sight of the need... the basic human need... to push back our horizons. Governments knew this. Corporations knew this."

I detect longing, almost as for a lost child.

"What do the youth see in science today? Predefined, scheduled, project managed, fitting within an envelope, cost-recovered, risk mitigated, planned, budgeted, gap-assessed, addressing policy outcomes..."

I sigh, then shrug.

"Maybe," I whisper, hesitatingly, "maybe it wasn't so different back then. Only..."

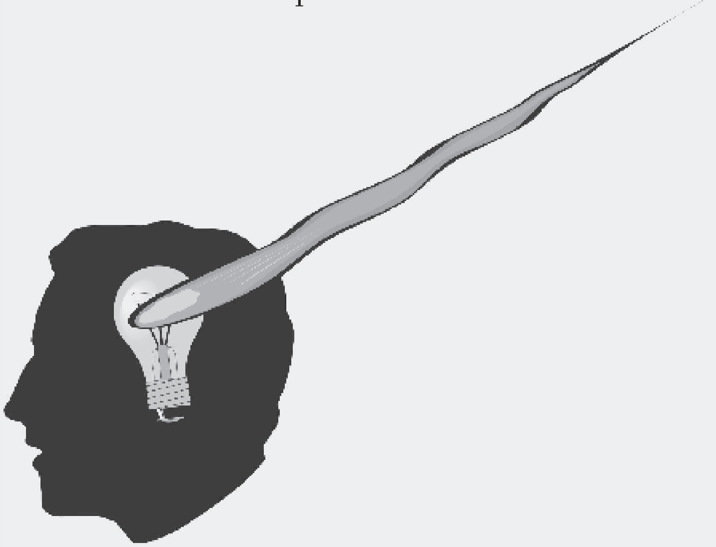
".... only policy outcomes included learning," he finishes.

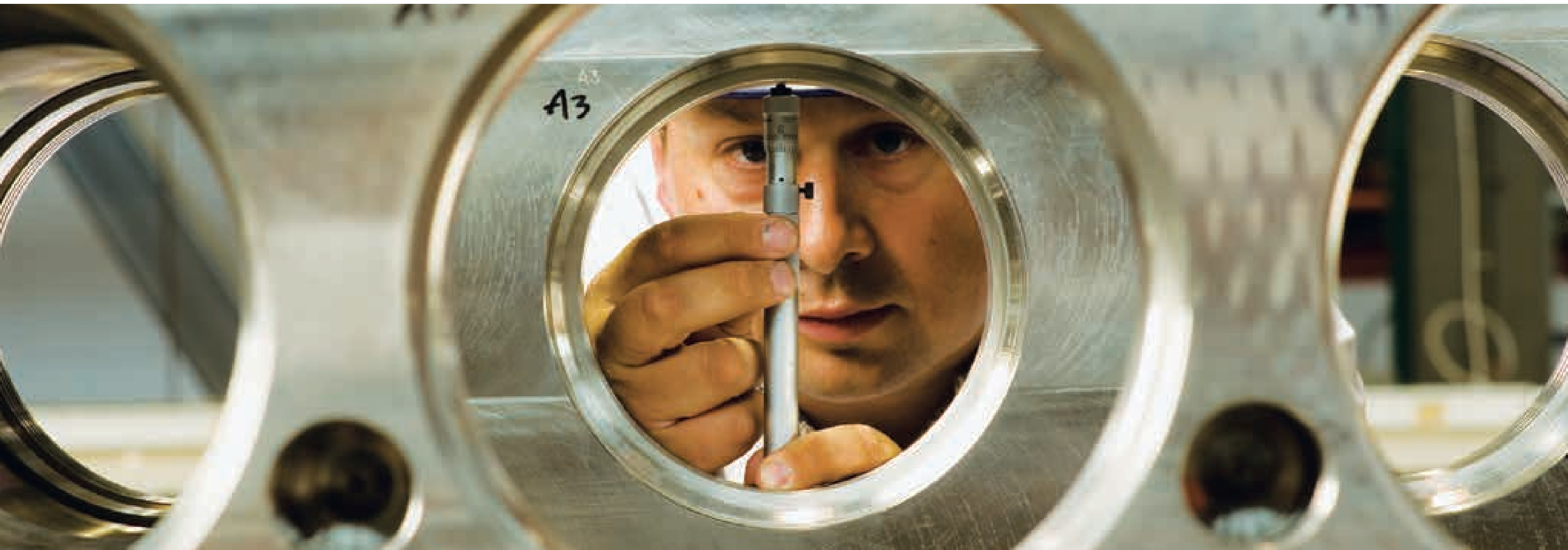
The ensuing silence is shattered by his stool scraping backwards. The man rises with his coat, turns, picks up his glass with its lingering mouthful.

"To neutrinos," he says, and I barely sense a smile as he drinks.

I raise my glass. "To neutrinos."

In a moment he is gone, and I'm left with the ghosts I cannot see. I do hope I see more of him in the future.

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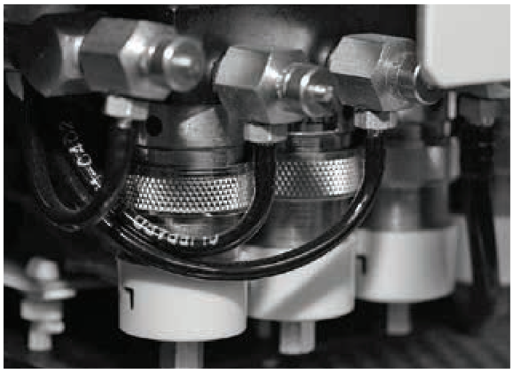

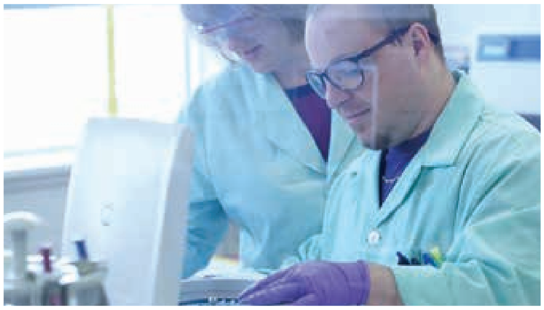

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