CANADIAN NUCLEAR SOCIETY

# Bulletin

DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

MARCH 2016 MARS VOL. 37, NO.1

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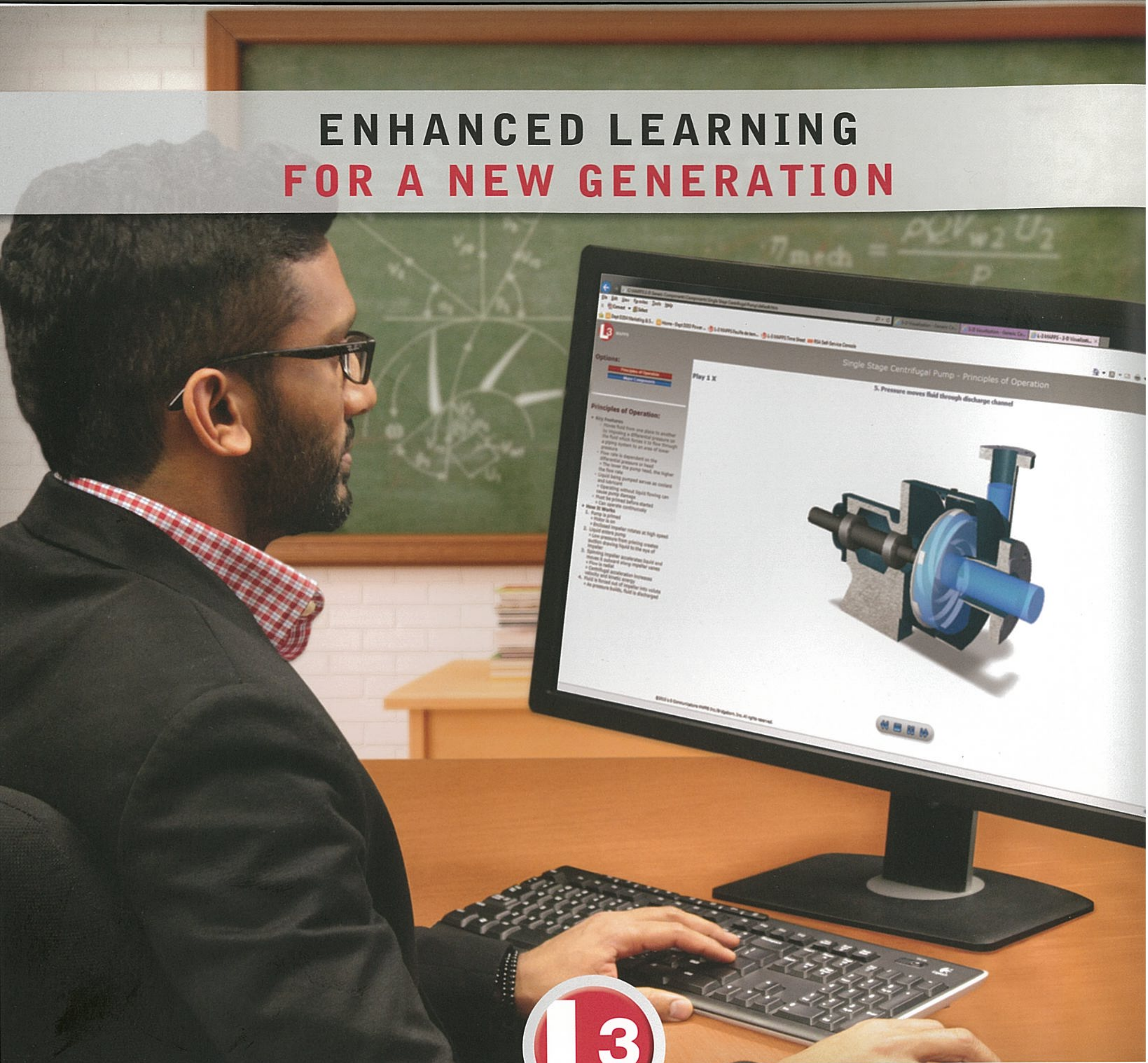
ENHANCED LEARNING
FOR A NEW GENERATION
Single Stage Centrifugal Pump - Principles of Operation
L3

# Carbon Tax: Who's hosing us now?

With falling oil prices around the world we are finally getting some relief at the pumps and on our home heating bills. Most people agree it's about time. So then, for a cash hungry government, what better time is there to introduce a new tax?

Enter the Carbon Tax. With so much concern about global warming people believe that governments need to be taking positive steps to combat climate change. Rightly so. But a "Carbon Tax"? It's a hard sell for politicians because it still uses the word "Tax", a word too easily understood. Hence, the government spin doctors needed to find a more useful (less understood) euphemism for its new tax. Enter instead "Cap-and-Trade". It's a nice enigmatic phrase that safely avoids unwanted thinking. Thus, Ontario's Wynne government is hosing us again in their 2016 budget, entitled "Jobs for Today and Tomorrow". In it, the phrase "Carbon Tax" doesn't even appear!

"Cap-and-Trade" sounds perfectly acceptable. The word 'Cap' implies a necessary limit on carbon emissions, agreeable to voters. The word 'Trade' represents our shared value of commerce and enterprise (necessary for jobs). Cap-and-Trade means that companies are assigned "credits" for how much carbon they can emit. An enterprising company can make money by selling its unused credits at a government-set "market" price. Conversely, polluting companies can buy unused pollution credits and then pollute more. But wait, companies having to pay for pollution credits will have less money to pay its employees (i.e. lost jobs), which you may recall from the budget's title ("Jobs"), would be an obvious contradiction. So, according to the budget big polluting companies are exempt from having to pay to pollute. Great for big business, but for us common folk there is neither a cap-and-trade option nor any exemptions - we the people pay the tax.

Here is how the Wynne government "spins" the Carbon Tax - err, "Cap-and-Trade":

*"Ontario's proposed cap-and-trade program – in addition to reducing emissions – will direct resources and investment to encourage companies to be more innovative and ensure households thrive during the transition to a low-carbon economy."*

Nice spin, but the Carbon Tax is nothing more than a cash grab. What's not nice is that the Carbon Tax will not reduce carbon emissions. Drivers have no choice but to continue to burn gasoline, but they will have to pay more to do so. Households will continue to heat their homes, but will pay more to do so. How does this encourage innovation? How does this ensure households thrive?

Tax payers would accept a Carbon Tax if it was actually used to reduce carbon emissions, but despite the fancy Government spin it's not going to happen. The 2016 Ontario budget claims that the money will be spent on "green projects" but that's just meaningless "spin". Recall that, under the guise of "green energy" wind farms grab high priced Feed-In-Tariffs paid to big business, while burning "back-up" natural gas. The government's "green projects" raised electricity prices and increased carbon emissions.

If the Wynne government were serious about reducing carbon emissions it would put the Carbon Tax toward that purpose instead of shoring up its own ideological boondoggles. It could use the Carbon Tax to develop a hydrogen economy, invest in plug-in vehicles and recharging stations, electrify rail corridors and develop real carbon-free technologies. In fact, a hydrogen economy is achievable and cost effective. Surplus electricity from off-peak Nuclear and Hydro could produce hydrogen, which could be converted back to electricity during peak demand using fuel cells or direct combustion. Hydrogen can also fuel cars and buses, home heating and industrial processes. It can even be integrated into existing infrastructures by manufacturing natural gas ($2H_2 + C = CH_4$) and gasoline ($9H_2 + 8C = C_8H_{18}$). We can indeed move toward a low carbon world without sacrificing the economy to do it! That would be good use of the Carbon Tax! And good for our planet!

## In This Issue

The Canadian Nuclear Association held its annual conference and trade show in Ottawa last February with another high turnout, and some good news was announced. Details are given in the lead article of this *Bulletin*.

The spring of 2016 is also an infamous anniversary of some of the worst accidents in history, such as Fukushima, Chernobyl, Three Mile Island and the British Petroleum oil spill disaster. Disasters often have common causes, and if studied can lead to safer organizations and products - but only if the lessons are put to good use. This Bulletin looks back on some serious accidents and examines what has changed as a result.

As usual there are some technical papers and a collection of news. And Endpoint takes a close look at a technological innovation that is so "low tech" is seems outright "high tech".

Comments and letters are always welcome!

# From The Publisher

The moment came during a panel discussion at the winter conference held by the Canadian Nuclear Association in Ottawa this past February. One short question from one of the panelists, "What does success look like for Canada's nuclear industry?"

To answer it, we need to look at recent changes that have come upon us, particularly those over a very short 10-week period from December last year to the end of January this year. The first event in the new future for nuclear in Canada was the announcement on December 3, 2015 that Bruce Power and the Independent Electricity System Operator (IESO) had come to agreement on the future of the Bruce site.

Under the agreement, Bruce Power will commence the sequential refurbishment of Bruce units 3-8 starting in 2020. The program will involve the investment of approximately $13 billion in upgrades and equipment replacement at the Bruce plant over the course of about a decade. Over that time, an additional workforce of between 1,500 and 2,500 will be on site for the completion of the project. It will inject about $4 billion annually into Ontario's economy, and it will ensure that the world's largest operating nuclear facility will continue to provide about one third of Ontario's electricity into the 2060s. Since most of the goods and services required will come from Ontario, the project will induce the employment of another 18,000.

The second event came in two parts on January 11, 2016. Ontario Energy Minister Bob Chiarelli announced that the province agreed to the full refurbishment of the Darlington nuclear power station. Starting in 2016, each of the four Darlington nuclear power reactors would be refurbished in a program lasting to 2026. During that time, the Minister indicated that the $12.8 billion project would create 30 million man-hours of work and add about $15 billion to Ontario's GDP. Like the Bruce announcement, it meant that the Darlington nuclear power station will continue to produce more than 20 per cent of the province's electricity supply into the 2060s.

The second part of the announcement was that the province would seek permission to extend the operation of the Pickering nuclear power station to 2024, rather than shut down in 2020 as previously planned.

Taken together, these announcements mean that for the next 40 to 50 years, nuclear will remain the source of more than half of Ontario's electricity. They also mean that Ontario's residential and industrial electricity customers have a future of low cost, base load electricity. They mean that the nuclear supply chain in Ontario and in other parts of Canada will have an enormous amount of work over the next decade. They mean that nuclear science and engineering will continue to be a significant part of Ontario's education programs and career opportunities.

Another important development for Ontario's electricity system was the decision by the IESO to change the floor prices for variable generation (wind and solar) on December 2, 2015. The new floor price regime is to take effect in the first quarter of 2016.

The existing floor price regime had ensured that wind and solar would be the first generating sources added to Ontario's electricity grid on a daily basis. The result of this has been the displacement of nuclear and hydraulic generation from the province's supply, either by venting steam or spilling water from dams for the past five years.

No longer. This decision by the IESO, which followed a series of reviews and hearings during the summer of 2015, means that nuclear and hydraulic generation will be subject to far fewer reactor maneuvers and water spills than was previously the case.

Taken all together, the refurbishment decisions and the IESO floor price determination mean the reversal of what has been the province's de facto electricity policy since 1993. With the termination of the hearings into the Ontario Hydro Demand/Supply Plan in 1993, the province's electricity supply policy became one of reliance on renewables and natural gas to provide any new electricity required in Ontario. This supply policy became official with the passage of the Green Energy and Green Economy Act of 2009. That supply policy has now been swept away; Ontario's future is nuclear, according to the government, not one dominated by wind and natural gas.

Beyond that, it has become clear that Canada's nuclear technology will have large opportunities overseas as well. The two CANDU projects in Romania, Cernavoda 3 and 4, and the project in Argentina, Atucha 3, will have a large Canadian component in the construction of these CANDU 6 reactors. The technology agreements last year with China will also mean more Canadian involvement with China's nuclear power program.

So taken all together, the answer to the question of what success looks like for Canada's nuclear industry becomes quite simple. It's where we are right now.

*C.G.H.*

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~ Cover Photo ~

Water samples are collected at Key Lake, Saskatchewan, as part of the environmental management system.

*Photo courtesy of Cameco*

CANADIAN NUCLEAR SOCIETY

**bulletin**

DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

**ISSN 0714-7074**

The *Bulletin of the Canadian Nuclear Society* is published four times a year by:
The Canadian Nuclear Society
c/o AMEC NSS Limited
700 University Avenue, 4th Floor
Toronto, ON M5G 1X6
Telephone (416) 977-7620
e-mail: cns-snc@on.aibn.com

Le Bulletin SNC *est l'organe d'information de la Société Nucléaire Canadienne.*

CNS provides Canadians interested in nuclear energy with a forum for technical discussion. For membership information, contact the CNS office, a member of the Council, or local branch executive. Membership fee for new members is $82.40 per calendar year, $48.41 for retirees, free to qualified students.

*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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Printed by The Vincent Press Ltd., Peterborough, ON

**Canada Post Publication Agreement #1722751**

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# Federal, Ontario Governments Show Renewed Interest in Nuclear: CNA 2016 Winter Conference

By COLIN HUNT

Nuclear energy has a clear and important future under the newly elected Government of Canada. Such was the principal message of Kim Rudd, Parliamentary Secretary to Natural Resources Canada Minister Jim Carr.

Speaking as the keynote speaker at the Canadian Nuclear Association's (CNA) 2016 Conference and Tradeshow in Ottawa on February 25, Ms. Rudd stated that the Minister had made nuclear science and technology his top priority. She left no doubt of her views on nuclear power, describing it as "safe, secure, reliable".

She outlined a view highly supportive of existing and new nuclear technology. Ms. Rudd described the development of small modular reactors as having considerable future promise. And she was unequivocal in her views on nuclear research.

"We are strongly committed to supporting nuclear research including the new investments in (former) AECL facilities," Ms. Rudd said, referring to the plans for redevelopment of the Chalk River Laboratories.

Ms. Rudd indicated that environmental and economic performances are linked.

"We want to see a clean environment and a strong economy go hand in hand."

Ms. Rudd noted that the current government places strong emphasis on aboriginal affairs, desiring more and greater opportunities for First Nations communities. She cited Cameco Corporation as a model to be emulated, noting that 47 per cent of its work force was from First Nations.

Ms. Rudd commented on offshore aspects of Canada's nuclear industry as well. She noted the government's approval of nuclear trade and technology contacts with India. Of particular note was the first shipment of Canadian uranium to India. She noted with approval that a strength of Canada's industry was its regulator, the Canadian Nuclear Safety Commission (CNSC), which she described as strong and reliable in protecting Canadians.

Ms. Rudd's supportive and optimistic views were echoed in the last session of the conference on the morning of Friday, February 26 by two Ontario government ministers, Bob Chiarelli, Minister of Energy and Reza Moridi Minister of Research and Innovation, and of Training, Colleges and Universities.

Reza Moridi, Bob Chiarelli and John Barrett.

Speaking in the conference concluding panel with CNA President John Barrett, Mr. Chiarelli noted that nuclear has been the workhorse of Ontario's electricity system for decades, and that it will remain 50 per cent or more of Ontario's electricity supply for decades to come.

He highlighted the importance of nuclear and the government's decision to agree to the refurbishment of the Darlington and Bruce reactors.

"More than 90 per cent of our electricity in Ontario today is free of emissions of any kind," Mr. Chiarelli said, indicating that the government wanted to maintain such a high environmental and economic performance. He noted that the investigations leading up to the 2013 energy plan indicated that nuclear was the best way to go.

The refurbishment plan is also important for Ontario's industrial economy. Mr. Chiarelli noted that more than 180 companies in Ontario, located in every part of the province, have some involvement in nuclear refurbishment. He added that the right decision was also a popular decision, noting very strong local support for nuclear refurbishment in Ontario's nuclear host communities.

Mr. Moridi referred to the wider importance of nuclear science and technology to Ontario, but noted one significant problem.

"We have the best nuclear technology in the world, but we have not been very good at marketing it," Mr. Moridi said. He noted in particular the absence of the federal government from overt support for nuclear over the past 10 years. He said that the nature of nuclear science and technology is that it needs political support on an ongoing basis.

He noted approvingly of recent measures to expand Canadian nuclear contacts and trade, in particular the recent multiple agreements with Chinese organizations and companies. He indicated that India has large potential for Canadian industry in the years to come.

Optimism about future prospects was also a feature of Preston Swafford, Executive Vice-President and Chief Nuclear Officer of SNC Lavalin. He indicated there were strong prospects for Canadian nuclear business with projects in Romania, to build Cernavoda 3 and 4, and in Argentina, with its intention to build another CANDU at Atucha 3.

One of the great strengths of CANDU was its ability to manage the back end of the nuclear fuel cycle, according to Mr. Swafford. In particular he referred to the ability of CANDU to use the spent fuel from light water-moderated reactors. This specifically is the subject of some of the new nuclear co-operation with China.

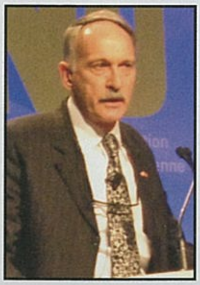
Mr. Swafford noted that SNC Lavalin has invested $20 million in upgrading its facilities at Sheridan Park in Mississauga.

Ontario nuclear refurbishment was the subject of Mr. Jeffrey Lyash, the new President and CEO of Ontario Power Generation Inc (OPG). He opened his remarks with a personal tribute to Bruce Power President and CEO Duncan Hawthorne.

Mr. Lyash said that the project to refurbish the Darlington nuclear power station is of vital importance to OPG. He noted that the station represents one-third of the total value of the company. The scale of the refurbishment project over the next decade is equally significant: 5100 jobs will be created to complete the project.

"We are the low cost providers of electricity in Ontario," Mr. Lyash said. After refurbishment, power from Darlington would cost between seven and eight cents/kWh.

Optimism for the future was also the theme of remarks by Canadian Nuclear Laboratories (CNL) President and CEO Mark Lesinski. He outlined for the



conference CNLs plans stretching out to 2026. These plans included the decommissioning and demolition of 122 buildings on the site of Chalk River Laboratories. Many of these buildings date back to the 1940s and 1950s, and some are now in poor shape. They will be replaced by several much larger new facilities, devoted to CNL's principal research missions.

Mr. Lesinski also indicated that CNL will be undertaking and completing the decommissioning of other facilities as well. By 2024, he said that all decommissioning activity would be complete at Whiteshell Laboratories in Manitoba. And by 2020, the site of the NPD prototype reactor at Rolphton would be cleared as well.

At this time, the scope of CNL's research program has been set at approximately $163 million annually. About half of this revenue will come from federal missions and about half will come from academic and commercial research.

Mr. Lesinski noted the coming shutdown of the NRU in 2018. He indicated that the future loss of NRU would not impact research capabilities at CNL.

Michael Binder, President of the CNSC, opened the conference on February 26. He noted that 2015 had been an extremely busy year for Canada's regulator. Both Bruce and Darlington had gone through operating licence renewals, the joint environmental assessment report of the low and intermediate waste storage facility at Bruce had been completed, and both regulators and licensees had completed post-Fukushima refit plans for reactors in Canada.

There was also extensive international activity. The first shipment of Canadian uranium was delivered to India, and Canada was the host of two international nuclear missions, OSART and IPPAS.

Dr. Binder noted that 45 countries are now considering the introduction of nuclear power into their electricity supply systems.

"It is essential that they have an effective nuclear regulator in place for that to happen," Dr. Binder said.

New nuclear technology was also of growing interest to the CNSC. Dr. Binder indicated that a number of new technologies, primarily in the area of small modular reactors, have emerged in recent years, and he indicated that the CNSC must be ready for them if and when they approach the CNSC for licencing.

The 2016 CNA annual winter conference was strongly attended this year. More than 770 delegates were in attendance, supported by 48 exhibitors and 24 sponsors.

# Scenes from The Conference


*CNS booth at the CNA Winter Conference.*

*Bruce Power President Duncan Hawthorne (L) received memorial gift from Hatch Vice-President Hany Michael on behalf of the CNA.*

# Infamous Anniversaries: Learning from Severe Accidents

By RIC FLUKE

The spring of 2016 is an infamous anniversary of catastrophes that shook the foundation of nuclear power: 30 years ago a reactor exploded at Chernobyl, and just five years ago three reactors melted down at Fukushima. Thirty-seven years ago a reactor nearly melted down at Three Mile Island, and it was 63 ¼ years ago when the research reactor NRX exploded at Chalk River. Nuclear technology is not alone in severe mishaps. The spring of 2016 is the 6th anniversary of the British Petroleum Oil Spill in the Gulf of Mexico.

In each unfortunate event there has been serious investigation and learning, but unlike the Oil Industry, the Nuclear Industry and its Regulation has evolved with good effect. The Nuclear Industry embraces pro-active learning by making real safety improvements, but the Oil Industry has chosen to embrace reactive learning, by fixing bad PR.

In a world seeking safe, reliable and economic sources of energy, and hope for a world threatened by climate change, Nuclear Technology can provide the solution. But along the way the technology has suffered some unfortunate events, disasters actually. Many industries facing similar disasters respond by blaming someone, claiming to have "fixed" the problem, and go on doing what they did before. But the Nuclear Industry is different. There is no blame, just learning and making improvements to prevent a recurrence. By carefully examining accidents and taking corrective actions the nuclear industry has grown to be the safest technology to meet world health and energy needs in a planet-friendly manner.

Here are some key events, in Canada and abroad, that have given us pause. By examining accidents, nuclear and non-nuclear, we find a number of common factors from which we can use to build an industry-wide culture of safety as our paramount priority. It is knowledge we can use, or choose to ignore; that choice is what differentiates the Nuclear Industry.

## December 12, 1952, Canada

On December 12, 1952, an experiment using the NRX research reactor at Chalk River went terribly wrong when a miscommunication, combined with a series of equipment problems, led to a runaway nuclear chain reaction that destroyed the reactor. It was what the industry calls a Reactivity Initiated Accident (RIA). True to the nature of an RIA, it only took a minute for the reactor power to

*NRX Reactor at Chalk River*

runaway from 0.5% power more than 450% of its rated full power, and then only two more minutes to explode. Fortunately there were no injuries.

An RIA can destroy the core *IN A SNAP!* The possibility of an RIA was recognised very early; the experimental reactor in Chicago, "Control Pile 1" (CP1), built in the 1940s under the spectator seats of Stagg Field at the University of Chicago, had a novel safety device. A control control rod was suspended above the reactor core with a rope that was tied to the balcony rail of the stadium, and a man with a very sharp axe stood ready to cut the rope, releasing the control rod into the core should there be a malfunction. He was called the **Safety Control Rod Axe Man**, which became the acronym (some say "*backronym*") now known as SCRAM. In some plants today, the "Big Red Button" is identified by the word "SCRAM".

The 1952 accident at NRX led to the Canadian Licensing requirements for Two Independent and Diverse fast acting shut down systems, independence and diversity in safety design, the concept of Guaranteed Shutdown State and human factors improvements at the human-machine interface.

The NRX accident also influenced US nuclear policy. The US Navy assisted in the NRX cleanup, led by Lieutenant Jimmie Carter, who would later became president of the United States. Carter said his experience at Chalk River led to his decision to cease development of the neutron bomb and to sign the SALT II nuclear arms reduction treaty with the

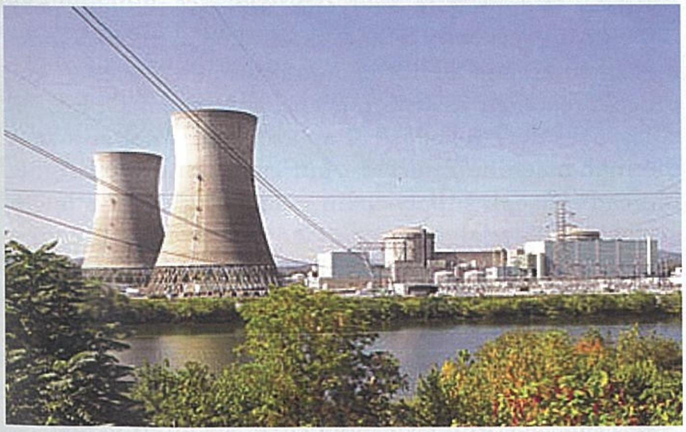
Soviets. Related to his decision was his 1977 cancellation of the Clinch River experimental Fast Breeder Reactor project, a technology that could produce weapons grade plutonium, but more important, could have been used to dispose of accumulating spent fuel from Light Water Reactors by "burning" it instead of burying it. Without the Fast Reactor program, the US decided nuclear waste would be buried in a new waste repository called Yucca Mountain. After utilities spent billions of rate-payer dollars to build Yucca Mountain, anticipating that it would be a permanent solution to the mountains of accumulating waste stored on reactor sites in spent fuel ponds ... well ... you know the rest of that story!

## March 28, 1979, United States

Looking at Three Mile Island from the outside it seemed as though nothing was wrong. The American news rag National Enquirer (known for its alarmist headlines about mutant monster chickens and other nonsense) speculated that the TMI "accident" was a hoax, claiming that it was a Hollywood ruse to promote the just released movie *The China Syndrome*, starring Jane Fonda, Michael Douglas and John Lemmon.

But a hoax it was not. The regulator woke up and imposed new safety rules. The industry woke up and realized that one bad operator can take down the entire industry, inspiring the book by Joseph Rees *Hostages of Each Other*. There was no harmful release of radiation from the station and there were no injuries, but it did wreak a lot fear and showed how seriously flawed emergency response plans had been. The evacuation, ordered by misinformed and fearful politicians, caused the worst traffic chaos in American history.

Prior to Three Mile Island there was a general reluctance in the industry to admit that a severe accident could occur. It was considered too unlikely to happen, even by the US Nuclear Regulatory Commission. The industry, with the regulator's acceptance and encouragement, focused on the worst *hypothetical* accident, assumed to be a large pipe break in the reactor cooling system (Large LOCA). By designing for the largest hypothetical LOCA, the plant could easily cope with a smaller LOCA. This convenient concept was accepted by regulators world-wide. What happened at TMI, of course, was a small LOCA. It was triggered by an error made by maintenance workers on the turbine system. The training programs did not emphasize the possibility that a maintenance error on the "conventional" side could impact on the safety of the nuclear systems. After all, nuclear systems are designed with "backup" systems.



*The Three Mile Island nuclear power plant in Pennsylvania*

Unfortunately the relevant backup system was out of service, due to another maintenance error unknown at the time. Even so, a Small LOCA is not immediately serious and there is ample time for the operator to terminate the event before there is any serious damage, *provided* the operator is trained to "do the right thing". At TMI, they were *not* trained to do the right thing, and in retrospect they were *trained to do the wrong thing*, which they did. It is wrong to say that the operator "did the wrong thing" (turning off the coolant pump when it started to vibrate) when the manual specified what the operator is to do (turn off the pump if it starts to vibrate). It is also unfortunate that the designer, years before the plant was built, did not provide the right control panel indication that would have alerted the operator that *what he thought he had done* had actually *not been done*. When the switch was turned to close the open relief valve, which would have terminated the loss of coolant, the valve position indicator light only acknowledged that a command to close it had been sent, and not whether the valve had actually closed, which it had not! Thus, accidents can happen if the designer, working in head office, errs in a way that an unseen "trap" is set, into which the operator falls.

Failed communication (a common theme in most accidents) was also an important contributing factor to the TMI accident. One year prior to the Three Mile Island accident, an identical failure occurred at the Davis-Besse plant. Its reactor is identical to TMI and built by the same designer (B&W). At Davis-Besse, just as at TMI, the coolant pressurizer relief valve opened and would not close, but the operator at Davis-Besse closed a "block" valve that backs up the relief valve described above. Ironically, the safety bulletin sent to B&W customers describing the Davis-Besse experience, which would have given the TMI operator information to terminate the event before damage could occur, arrived ONE DAY AFTER THE TMI ACCIDENT! A significant learning about this finding is the importance for the nuclear industry to share Operating Experience (known now as OPEX). Although OPEX is an important process promoted by the Institute of Nuclear Power Operators (INPO), such sharing was not immediately forthcoming.

As noted by Joseph Rees (*Hostages of Each Other*) such OPEX gathered by INPO was regarded as proprietary and confidential, and it took some time for the industry to realize the mutual advantage of sharing safety related OPEX; if they don't, then one single "uninformed" organization can taint the entire industry. Today, all nuclear operators (including CANDU owners as well as research reactor operators) exchange OPEX on a weekly basis.

## April 26, 1986, Soviet Union

The No. 4 reactor at Chernobyl exploded and then burned for several days releasing radioactive contamination that spread all the way to Canada. There was loss of life, widespread evacuation and consumption of foodstuffs was banned. In Sweden and Canada, indigenous peoples took the brunt of that one, since their lifestyle is not a "supermarket" mentality; they live on what the land provides.

The accident at Chernobyl was a Reactivity Initiated Accident (RIA), and it happened *IN A SNAP!* An RIA has a sudden onset and terrible consequences. The reactor must be designed to make sure it cannot happen. Redundant and diverse shut down systems must act independent of anything else that may fail, and independent of what an operator might or might not do, either by will or neglect. This has been a Canadian licensing requirement since the 1952 NRX accident.

Contributing to the Chernobyl accident was an overly complacent organization in the former Soviet Union where safety was over-ridden by a "production prerogative", a common causal factor in most accidents. They attempted to conduct a test on an operating commercial power reactor, and there was a limited time frame because of a planned maintenance outage that day. Ironically, it was a safety system test.

The reactor was taken off the grid according to schedule and power was reduced in preparation for the test. Then the grid authority ordered the reactor put back on line because Ukraine needed the power. When attempting to raise power again they couldn't because "xenon poison" was building up. Operators did their best, but with incorrect and poorly documented design and operating manuals prepared by head office, they did not understand the limitations of safe operation, and were not aware of serious instabilities at low power.

Control rods were withdrawn to increase power, and as power rose it "burned" away the xenon poison causing power to over-shoot on the high side. This led to boiling in the channels, creating a void, and because the RBMK design has a positive void reactivity response, power rose even further. The computer control system attempted to shut down the reactor, which would prevent doing the test, so operators disabled it. The number of control rods removed from core exceeded the allowable number, but this was not

*New Safe Confinement under construction to enclose the Chernobyl reactor during cleanup.*

recognized by the operators due to the confusing wa in which the requirement was specified. Called th Operating Reactivity Margin (ORM), it was a comple function of several parameters including how mar days the reactor had been operating. The OMR wa understood at head office, but the operators did no know how to calculate it.

The Number 4 Reactor at Chernobyl exploded se onds after the shift officer pushed the Soviet equi alent of the "Big Red Button", called AZ5. It is no known why he decided to trip the reactor; he die before he could tell anybody. But like in several ser ous accidents, nuclear or non-nuclear, the events i the hours prior to the accident had set the stage fo the accident to happen. They had reached "the poir of no return", a point where nothing could have pr vented the disaster.

The significant learning from the Chernobyl accider is the need for all parts of the organization, includin head office, to embrace a strong safety culture. Th was lacking, not only in the former Soviet Union, bu all over the world. The World Association of Nuclea Operators (WANO), now a global complement to th US-based INPO, defines the attributes of a good safet culture. It applies to everyone, not just the guy wea ing hearing protection and safety boots, but include management and all of the organization's processes an procedures such as training and sharing of OPEX. I recognizes that the cause of an accident is not always a the man-machine interface, but can include a designe in head office, a supply-chain manager who buys nucl ar quality materials and components, the guy in the reg ulatory office who reviews the safety case in the licenc application, and indeed recognises that the cause of a accident can be well remote, in place and time, fror the accident itself. In other words, we are all in thi together, and we are *Hostages of Each Other*!

The Chernobyl accident had human casualties. Ther were some 200 cases of acute radiation sickness; 32 of them died. Those who died were the heroic rescue workers and fire fighters, unprotected from inhaling the contaminated smoke. Off site, widespread contamination resulted in evacuation of 5 million people. Of those there were 15 reported deaths due to thyroid cancer, but there are speculative estimates of a few thousand other cancer deaths out of the 5 million, a number to be used with caution because it is based on the disputed *linear-no-threshold (LNT) theory*. Even more tragic was that fear and mistrust of medical authorities led to elected abortions. In far away Greece, where radiation doses were trivial (normal background levels), some 2500 mothers obtained abortions over fears of radiation from the Chernobyl accident [*Trichopoulos, D. et al, (1987). "The victims of chernobyl in Greece: Induced abortions after the accident". British Medical Journal* ***295*** *(6606): 1100.*]. Loss of life is never acceptable, but when it is a result of unfounded fear based on ignorance rather than medical knowledge, it is appalling.

## March 11, 2011, Japan

The Great East Japan Earthquake, the largest ever recorded in Japan and the 5th largest anywhere since recording began in 1900, was powerful enough to move the Japanese island 2.4 metres closer to America. It was powerful enough to change the earth's orbit permanently. The earth spins faster now, and every day is nearly 2 microseconds shorter. The tectonic plate sprung up from the ocean floor triggering an 800 km/h tsunami that killed almost 20,000 people and inundated the six-unit nuclear power station at Fukushima Dai-ichi.

The world witnessed the events unfold on live TV. Explosions destroyed the reactor buildings one by one, each releasing large amounts of radiation. The world panicked.

Fukushima was the first serious reactor accident that was triggered by an extreme natural disaster. Like most design organizations, historical records were used to determine the likelihood of a natural phenomenon, but recorded history doesn't go back far enough. Other information, such as paleontology and geophysical information must be considered. Around the world organizations conducted "stress tests" to evaluate vulnerabilities to extreme natural phenomena and adopted additional safety features to protect against such disasters.

The Japanese nuclear regulator was aware of paleontology (sand analysis) obtained ten years earlier confirming a very large tsunami had struck the area, and made recommendations for stronger tsunami protection, but their recommendations were voluntary and not imposed. The Japanese utilities did not want to provoke anti-nuclear sentiment by admitting that there was vulnerability. The decisions made in Japan have

Reactor building explosion at Fukushima, seen on Live TV.

proven fatal to nuclear programs, not just in Japan, but in other countries around the world (*Hostages of Each Other*).

Unlike Chernobyl there were no cases of acute radiation sickness at Fukushima. Follow-up studies show no difference in thyroid abnormalities between those near to the contaminated area and elsewhere in Japan, and there were no reports of any elected abortions following the disaster. Some 300,000 nearby residents were evacuated as a precaution, which is attributed to have caused some 1500 or so deaths due to the stress of being displaced, mostly among the elderly. At the time it was considered a safer alternative to evacuate people to avoid the radiation, but in retrospect, the radiation would have done less harm to those people.

## April 20, 2010, Gulf of Mexico

On the evening of April 20, 2010, a gas release and explosion occurred on the Deepwater Horizon oil rig at British Petroleum's Macondo exploration well. Eleven people died, 17 were injured. The fire burned for 36 hours before the rig sank, and 5 million barrels of oil spewed into the Gulf of Mexico for 87 days before the well could be sealed.

The drilling operation had a history of difficulties and by the time of the accident BP was 38 days behind schedule and $58 million over budget. The drilling rig was costing BP $1 million per day and they were eager to cut their losses, seal the well and move on. The plan was to drill deep enough to reach the "pay zone", and then seal the well for future production. The "abandonment" plan involved installing a steel liner, purging the well with a drilling fluid, and then sealing the well with cement. BP's abandonment plan had been reviewed and approved by the US government.

The well was deeper than any before, where the geological formation is at very high temperature and pressure. The purging fluid used for drilling could fracture the formation if it was injected at too high a pressure, or if pressure was too low there was a risk of blowout. This was a difficult balance because the density of the fluid (which affects pressure deep below) needed to be controlled with much precision. Also, typical sealing cement would not

*British Petroleum's drilling rig burns out of control after a blow-out on April 20, 2010.*

perform properly under the extreme conditions and a new cement formula had to be developed and tested.

BP modified the Abandonment Plan five times in the hours before the accident, each time after much debate between the site engineers and the on-shore (Houston) office. BP selected the "Houston" plan which deviated from the plan approved by the regulator. They deviated by installing a production casing in place of the liner, only partially deployed the purging fluid, and went ahead injecting the sealing cement before the cement testing program was completed. Furthermore, interpretation of data measurements in the well was disputed by the various engineering groups, and calculations contained several errors. The events and decisions in the hours prior to the accident had set the stage for the accident to happen. Like Chernobyl, BP had reached "the point of no return"; they committed to the course that led to disaster.

The National Commission reported to the President that the accident could have been prevented, that the series of mistakes - systematic failures in risk management - put in doubt the safety culture of the entire Oil Drilling industry, and that deep water exploration and production involve risks for which neither industry nor government has been adequately prepared. Upon reading BP's version of the incident, the National Commission's Chief Scientific and Engineering Advisor, Richard Sears, commented:

> *"It appeared that for BP, the accident happened at 9:49 p.m. on April 20; whereas in some ways, the blowout began in early 2009 when they initially designed the well."*

Immediately, the President ordered a moratorium on off-shore drilling, but it was quickly lifted after strong lobbying and litigation by the Oil Industry. Lawmakers called for the Oil Industry to adopt a safety culture similar to the Nuclear Industry, by sharing safety related OPEX for example, but the Oil Industry and its lobbyists resisted stating that it would stifle competition. In fact, the Oil Industry continues t lobby senators and politicians for leniency in regul tions, incentivized with lucrative "donations".

## What the Future Holds

When people and politicians do not understand th basis of safety and risk, they will decide on a cours that is most convenient, not knowing that their actior can carry more risk and do more harm. Perhaps th greatest risk to society and the environment sten from a common but unfounded fear of radiatio When mothers elect to terminate their unborn for fe of radiation, which happened after Chernobyl, the are misinformed or do not trust those who hold bett knowledge. Ignorance of radiation can be more harn ful than the radiation itself.

The British Petroleum spill off the coast of Americ caused acute and long-lasting harm to people and th environment, but it would appear that people and pol ticians ***still*** do not understand the real risk of oil expl ration. By opting to abandon nuclear energy in favou of fossil fuels (Japan, Germany, Italy, Switzerlan others), people and politicians do not understand th safety and risk of their choices. They are misinforme deliberately misinformed. Misinformation is spread l those who are either ignorant or purposely deceitfu have a vested interest, or simply subscribe to an ide logical agenda.

# The Public May Fear Nuclear Based on Our Own Words

By MARTYN R. WASH, COMMERCIAL AND TECHNICAL NUCLEAR CONSULTANT, AND CNS MEMBER

All too familiar nuclear terms are used by us all, which can be worrisome or scary when quoted in newspapers or on the car radio. This article is intended to suggest alternative and more media friendly words when describing our increasingly meaningful industry. A case in point:

*On November 9, 1992*[1]*, the following announcement was placed on the bulletin board at Zircatec Precision Industries (now CFM), "Darlington Goes Critical". A number of employees from the office and manufacturing floor quickly asked if they could go home given that the situation at Darlington was critical. These people worked in a nuclear fuel plant and didn't comprehend that going critical was a wonderful event for our industry.*

So our industry is replete with many words that may cause undue concern or fear for those outside our industry. We want to maintain the accuracy of words so they are understood by our peers, and therein lay a potential misunderstanding by others. Here are some examples that have been used in the public domain that may give rise to concern and fear. Alternative words are needed and welcomed.

*Criticality*

The word "critical" used in the nuclear context refers to the "welcome balance" of the nuclear chain reaction. Thus, in the aforementioned notice at Zircatec, the phrase "Darlington Goes Critical" means a good thing, that the reactor has achieved a planned balance of the chain reaction and is operating well. However, in the human health context, it refers to a "serious imbalance" of one's condition. That's why hospitals have "Critical Care Units". The nuclear industry is using a word that is well understood by most of the public (as a bad thing) to mean something entirely opposite (a good thing).

*Burnup*

The term "burnup" is used to describe the depletion of the fuel's usefulness to power a reactor before it must be replaced. To those unfamiliar with this term, it might leave the impression that uranium "burns" like coal. So instead of saying, *"The fuel is replaced when it has reached its target burnup" we could say "The fuel is replaced when it has reached its target depletion of usefulness".*

*Nuclear Waste*

Used CANDU uranium fuel still contains an energy store of fissionable U-235 (approx .2-.5 %) and 97% U-238, which can be recycled in a fast spectrum reactor fuel cycle. So used fuel is not waste, but is an energy store. Using the words 'future energy store' can be used in presentations and social media as a new buzz word whenever 'used fuel' is mentioned.

*Burial Costs*

Even in polite society we don't say 'burial costs' so why do we use it so often in our industry? There will always be a portion of fuel that is waste that will ultimately require sequestration. Carbon capture and sequestration (CCS) is often heard these days so instead of 'burial costs', waste sequestration costs could be used in our industry.

*Reprocessing*

The word 'reprocessing' is often related to the weapons industry and is used to garner fear by anti-nuclear activists such as Dr. Helen Caldicott and others. Rather than use the word reprocessing we could use the word *recycling* as it conjures a more acceptable mindset.

*Fast Breeder Reactors*

As above with the word reprocessing, fast breeder reactors have been used for weapons production and may be linked in the public's mind for the production of plutonium (used in weapons, but also for electricity generation). Some authors have chosen to use the words *fast spectrum* reactors as an accurate description of this style of reactor.

*Poison*

To most people, poison is word used to describe a substance that brings about illness, injury or death. In a nuclear reactor, "poison" is the term used to describe a neutron suppressant introduced to shut down a reactor. Using the word poison probably doesn't engender warmth of any sort with the public. The terms *burnable poison* makes matters even worse. Poison is a hard word to replace with a more friendly word. The words suppressant or absorbent come to mind. *"Reactors can be safely shut down in a controlled fashion using a neutron absorbent".*

Many words mean different things to different people as we speak with politicians, antis and of course our real clients the public. When we consider the possibility of using some of the word changes suggested herein, we may wish to do some surveys to see how these adaptations sell in the public domain. There are several more words than were mentioned here which could fall into the same category.

1 CNS Website
http://www.cns-snc.ca/history/canadian_nuclear_history.html

# DND/CAF Energy Horizons from Historical Data to the Potential Exploitation of Emerging Technologies

by PAUL LABBÉ[1]

*[Ed. Note: The following paper was presented at the 7th International Conference on Modelling and Simulation in Nuclear Science and Engineerin Ottawa Marriott Hotel, Ottawa, Ontario, Canada, October 18-21, 2015]*


## Abstract

This paper reviews the energy portfolio of Department of National Defence (DND) and of the Canadian Armed Forces (CAF) from different perspectives based on recent data analyses of the energy used over several years. Then it shows a projection of the potential impacts on current and future DND/CAF capabilities of selected emerging technologies (nuclear and non-nuclear). When possible, it estimates the potential life-cycle cost savings from the hypothetical adoption of such technologies that minimize operational cost and waste management burden.


**Keywords:** Energy use, capability, emerging technology, efficiency, energy/power density, waste.

## 1. Introduction

This paper first objective is to provide sufficient information to appreciate the energy portfolio diversity and magnitude of the DND/CAF. The second objective is to highlight the particular energy challenges due to the fully burdened cost of energy (FBCE) that DND/CAF face here for off-grid installations, and abroad for deployed forces in operational hostile theaters. The third objective is to report on performance claims of emerging technologies and show the potential impact of these technologies on DND/CAF capabilities. Then an estimated order of magnitude of recurring and non-recurring energy cost savings is provided.

## 2. DND/CAF Total Energy Used

Fuel/energy (~11 PJ[2] per year) used for DND/CAF buildings includes electricity, natural gas, heating fuel oils, propane, kerosene, arctic diesel, cooling water, steam and solar photovoltaic (SPV) [1]. The average over 14 years for heating is around 7.6 PJ with a small downward trend. Electricity for the same period is around 3.4 PJ with a small upward trend. Reference [1] provides details on DND/CAF best estimates of the proportion of energy used by the fleet of each envi-

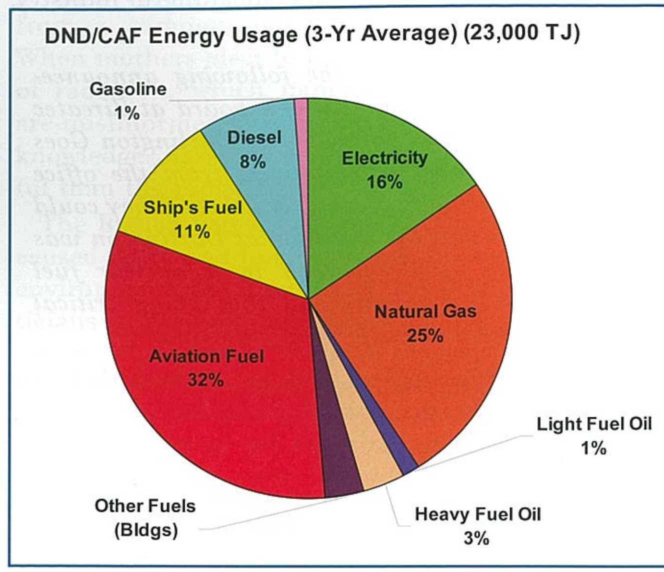



**Figure 1:** Average annual consumption of domestic and expeditionary energy per type.

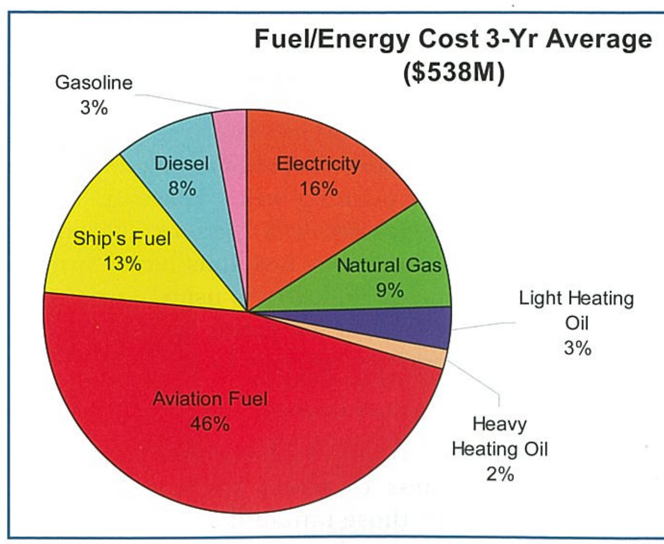



**Figure 2:** Annual domestic and expeditionary energy cost proportion.

ronment (air, maritime and land) out of a total of 1: PJ per year for both domestic and expeditionary oper

1 Defence Research and Development Canada (DRDC), Ottawa, Ontario, Canada, K1A 0K2.

2 34,121 Tons of Coal Equivalent (TCE) is a petajoule (PJ) which equals one quadrillion ($10^{15}$) joules. 14.6 PJ is about 4,111 GWhe net, the 2013 electricity production of Point Lepreau CANDU, New Brunswick, Canada.

ations. Here are the magnitudes of fleet energy used in percentages for the three environments: Canadian Army (CA) 17%, Royal Canadian Navy (RCN) 21% and Royal Canadian Air Force (RCAF) 62%.

For the following charts (Figure 1 and Figure 2), in addition to expeditionary energy used, the total domestic energy includes the fuels used in commercial vehicles and combat equipment (including expeditionary CA energy [1, 2]), the energy used in domestic operations and the total energy used for buildings. Figure 1 includes all DND/CAF energy usage: aggregated total expeditionary and domestic energy averaged over three fiscal years from 08/09 to 10/11 is 23 PJ or 23,000 TJ. About 52% is for the fleets and the remaining 48% for the buildings/commercial vehicles.

Figure 2 shows for the same fiscal years the fuel/energy expenditures for domestic utilities and fleets' fuel expenditures that include invoices coming from international operations. These expenditures of the department correspond closely to the 23 PJ of Figure 1.

From the total cost of $538 million Canadian dollars (CAD), about 70% of the cost is for the fleet and 30% for the buildings. The large difference in percentage between the energy quantities (52%-48%) and costs (70%-30%) is dominantly driven by the low cost of natural gas in Canada. The aviation fuel represents about 66% of the total fleet fuel cost, which is assumed to be the sum of the following: gasoline (3%), diesel (8%), ship's (13%) and aviation (46%), for a total of 70% of the total fleet fuel cost. This RCAF 66% of the fleet fuel cost correlates closely with the 62% of the fleet energy since aviation fuel is relatively more expensive.

## 3. Total DND/CAF Energy Cost Trends and Global Perspective

Figure 3 shows that the total energy expenditures for all buildings (green), then the fleets (blue) and then the total of all DND/CAF energy used (red) over 14 years follow persistent upward trends [1]. If it is assumed that these types of trends continue in the future then the fleet energy price (upward trend in blue) will approximately double in a decade. The total CAF fleet energy spending would have increased from approximately 140 million dollars in fiscal year 1998/99 to 800 million dollars in 2030/31, about six times as much if no significant corrective actions are taken. The total DND/CAF energy cost (538 million in 2010-11) follows a similar trend (upward trend in red) from about 240 million to 1,100 million dollars by 2031, which is about five times as much.

Currently no additional cost is included in these

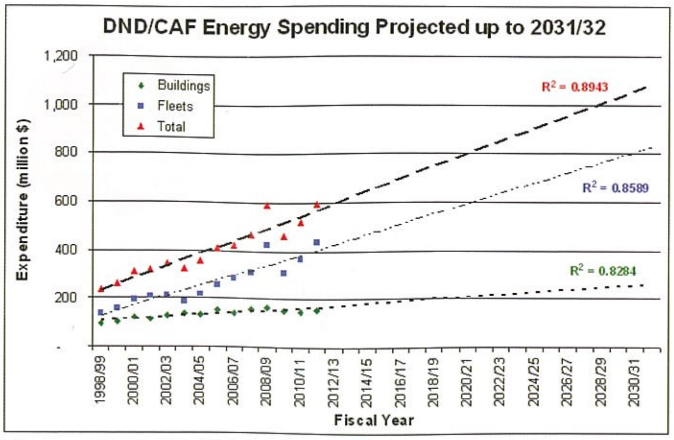



**Figure 3** DND/CAF 14-year energy trends and a 20-year projection based on these trends.

figures for an eventual carbon tax. In the advent that Canada adds a charge or tax for greenhouse gas (GHG) emissions, this total DND/CAF energy cost trend might be more significant in such future.

The estimate of world energy use in 2008 of ~533 EJ[3] [3] allows to appreciate the order of magnitude of the total energy consumption of primary energy used by Canada in 2008, 12,510 PJ[4] [4, p. 7] or ~13 EJ, i.e., about 2.4%. According to Statistics Canada, the total energy used by all of Government of Canada (GoC) is ~60 PJ (2008, 60,134 TJ [5, p. 5]), which is about ~0.5%. Using the ratio of all combined floor areas (buildings and platforms), the gross floor area, we obtain a coarse estimate of ~42% or ~25 PJ for the total energy used by DND/CAF out of the ~60 PJ for the whole of GoC while the remainder for other government departments (OGDs) is ~58% or ~35 PJ. Figure 4 illustrates the magnitudes of these energies used from the world perspective up to the DND/CAF total amount of energy used which is about 0.2% of Canada primary energy used in 2008.

## 4. Increased Electricity Demand to Power New Information Technologies

An important trend to consider is the constant increase in data processing and exchange[5] required in modern operations. If this is compounded with cyber warfare and intelligence over telecommunication and Internet, this may translate in substantial energy cost increases as reported in [1]. So it is reasonable to expect that the energy demand from information technologies used by DND/CAF to more than double over

3 One exajoule (EJ) is equal to one quintillion ($10^{18}$) joules, $10^3$ PJ or $10^6$ terajoule (TJ).

4 http://oee.nrcan.gc.ca/publications/statistics/parliament10-11/chapter1.cfm?attr=0 (Access date: 17 Sept. 2013).

5 Command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) systems must be secure, resilient and deployable.

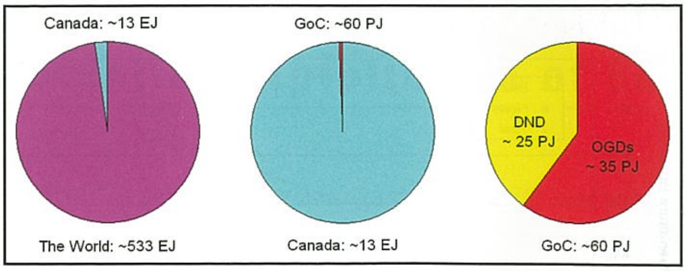



**Figure 4:** Relative energy consumptions: Canada versus World, the total of all government of Canada (GoC) versus Canada and DND/CAF versus OGDs within GoC.

the next decade if remediation actions are not initiated soon. According to the Environmental Protection Agency (EPA) executive summary report [6], essentially the best practices scenarios assumed moving in a new facilities or major upgrades[6] to existing ones. But even the improved operation scenario that assumed no significant capital investment offers electricity cost savings in excess of 20% according to this report.

Natural Resources Canada (NRCan) Office of Energy Efficiency (OEE)[7] reports that a "*data centre is a building space filled with information technology (IT) equipment: servers, storage, networking equipment, but also cooling equipment and power supplies. Data centres consume about 1% of Canada's electricity. One square foot of data centre space can use up to 100 times more electricity than a regular office space. Servers use only around 40% of a data centre's electricity. Another 40% goes to cooling these servers; and another 10% goes to power supplies losses. Conservation measures can dramatically reduce the electricity consumed by data centres.*"

A good example of essential capabilities in future combat theaters is persistent surveillance with sufficient precision for mission effectiveness and force protection. These capabilities would use extended endurance unmanned aerial vehicles (UAVs) as well as underwater, surface and land unmanned versions[8]. Such capabilities could be classified as energy hungry because their power requirements are moderate while their extended time of operation without the need for logistic support is over several days. In some operational theaters, users would like to extend the autonomy period to weeks without re-fueling or recharging the batteries.

### 4.1 Electricity demand for new weapon technologies

A US Navy projected 64 MJ railgun may require 16 MW for 6 MA peak at a shooting pace of 6 shots p minute with a maximum range of 350 km. Such railgu would shoot 10 times further than normal ship mour ed guns (a definite advantage in combat) and save a l of money (improving sustainability) for its operatic per shot compared to current guns+ammunitions ar missiles. Railgun and directed energy weapon (DEV technologies (these include technologies such as: hig energy laser (HEL), radio frequency (RF) DEWs, ar relativistic particle beams (RPBs) and high pow microwave (HPM)) require usually large and hea high power sources although technologies advance made them more deployable. However, such electrici demand still represents a major challenge to accomm date, especially on legacy platforms. Various types DEWs are currently in deployment phases for air, lar and naval platforms with a large variety of electric energy demands. Figure 5 shows that the pulse pow depends on type of targets, use and range.

For an hypothetical HPM, the authors [8] assume a efficiency similar to radar technologies, i.e., 17% of tl input power results in radiating power. They consid that 3.7 GW of input power is required to deliver, a range of 10 km, a power flux of 10 $kW/m^2$ on a 3 mrad spot size of 300 m. References [9, 10] provi information on damage level of DEWs.

These technologies are power hungry while pe sistent surveillance and C4ISR ones are energy hungr

### 4.2 Electricity end use growing faster than fuel direct use

According to Richard G. Newell and Stuart Iler stated in "The Global Energy Outlook" [11, p. 4 "*In terms of end-use energy consumption, electri ty is growing much faster than direct use of fuels* Similarly, future DND/CAF electricity demand fro new technologies, such as C4ISR and weapon system is expected to increase at a faster pace than the dire use of fuel especially for the fleets and off-grid insta lations. This is the most critical point that DND/CA must address to insure sustainable capabilities to fu fill their mandate here and abroad.

## 5. Tools for addressing holistically the DND/CAF energy demand domain challenges

Here are some energy considerations essential ensure energy technologies fitting to DND/CAF cap bilities, especially when they drive operational effe

6 ENERGY STAR® is the mark of high-efficiency products in Canada.

7 http://oee.nrcan.gc.ca/equipment/manufacturers/1875 (Access date: 17 Sept. 2013).

8 For example, Tactically Exploited Reconnaissance Node (TERN) in a DARPA program run jointly with Office of Naval Research (ONR): http://ww darpa.mil/Our_Work/TTO/Programs/Tactically_Exploited_Reconnaissance_Node_(TERN).aspx (Access date: 17 Sept. 2013).

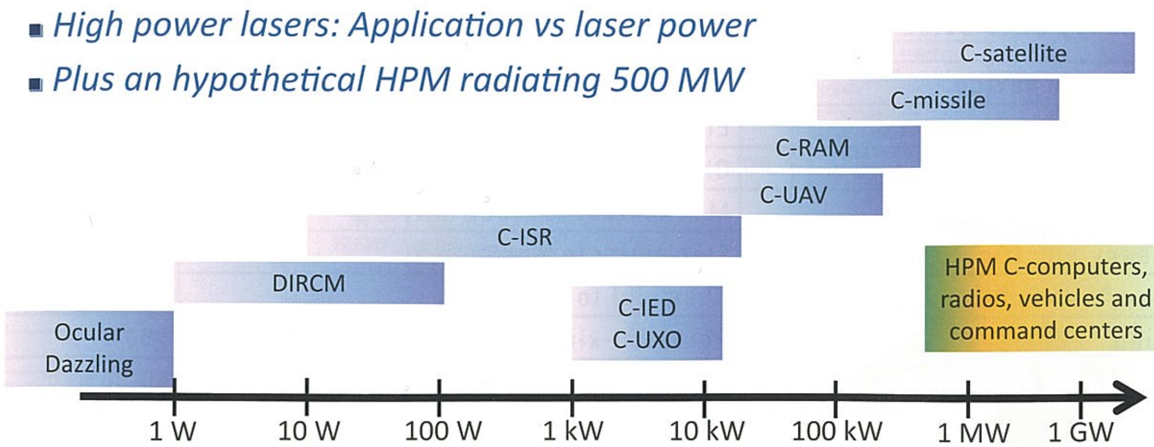
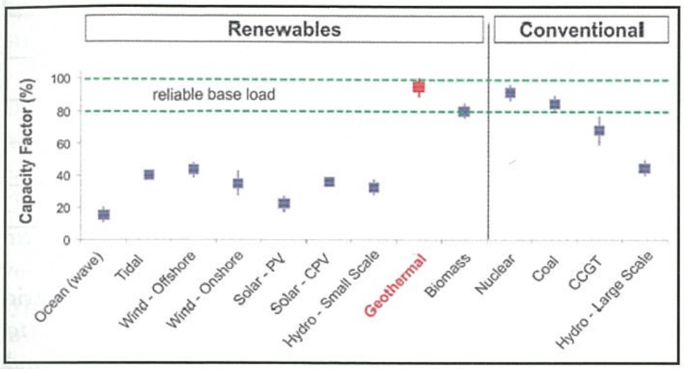



**Figure 5:** Typical radiating power required for specific counter attack [7].




PV = photovoltaics; CPV = concentrated photovoltaics; CCGT = combined-cycle gas turbine.

**Figure 6:** Typical capacity factors of different power generation technologies.

tiveness, provide CAF advantage over opposing forces and reduce risk to our combatants [1]:

1. Capacity factor, i.e., actual energy output over a period of time against generation potential.
2. Energy conversion efficiency, i.e., the ability to convert the maximum amount of source energy toward the desired work, function or amenity.
3. Power density versus energy density (acceleration versus range), i.e., the ability to achieve varying load profiles (demands) over time.
4. Volumetric versus gravimetric energy density or power density (size versus weight), i.e., the ability to meet the physical constraints imposed by the intended application.

## 5.1 Capacity factor

Capacity factor (net) could be defined as the ratio of the net electricity generated, for the time considered, to the energy that could have been generated at continuous full-power operation during the same period[9]. A similar definition can be applied for thermal systems and electrical-thermal systems [12]. Figure 6 shows typical capacity factors used by NRCan [13] to show the advantages of enhanced geothermal technologies for electricity generation and district heating in Canada.

## 5.2 Energy conversion efficiency

Energy conversion efficiency needs to be maximised in order to reduce undesirable loss and expenses while providing energy for a capability or a desired work. Most of the time an energy conversion or transformation is required to accomplish the desired work. Energy conversion efficiency ($\eta$) is the ratio between the useful output of an energy conversion device and the input, in energy terms. The useful output could be electrical, mechanical, or thermal.

$$\eta = \frac{E_{out}}{E_{in}} \qquad (1)$$

Table 1 shows the high efficiency of electric motors and generators compared to internal combustion (IC) engines. Also worth observing is the energy conversion combination ($\eta \approx 63\%$) of fuel cell devices with electric motors and batteries which surpasses the traditional gasoline combustion engine ($\eta \leq 30\%$) or the more energy efficient diesel engine ($\eta \leq 50\%$). However, for off-grid operations the traditional IC engine has the advantage of a transportable and storable fuel. In the case of newer technologies, fuel cell technologies could offer similar advantages, with the addition of being more energy efficient than using IC engines.

9 http://www.nrc.gov/reading-rm/basic-ref/glossary/capacity-factor-net.html (Access date: 17 Sept. 2013).

**Table 1**: Efficiency of selected energy conversion devices.

| Energy conversion device | Energy conversion | Typical efficiency[10] |
|---|---|---|
| Electric heater | Electricity to thermal | ~100%[11] |
| High-efficiency gas furnace | Chemical to thermal | ~98% |
| Large electric generator | Mechanical to electricity | >95% |
| High-efficiency electric motor | Electricity to mechanical | >90% |
| Battery | Chemical to electricity | >90% |
| Water turbine | Potential-kinetic to mechanical | >90% |
| Permanent-magnet alternator | Mechanical to electricity | 60-90% |
| Fuel cell | Chemical to electricity | Up to 85% |
| Large diesel engine generator[12] | Chemical to electricity | ≥60% |
| Diesel engine (car/truck/ship) | Chemical to mechanical | 30-50% |
| Gas turbine, jet engine | Chemical to mechanical | Up to 40%[13] |
| Solar cell | Sun radiation to electricity | 10%, up to 40% |
| Light-emitting diode (LED) | Electricity to light | Up to 35% |
| Thermophotovoltaic (TPV) | Heat-infrared to electricity | 8-30% |
| Firearm (.300 Hawk ammunition) | Potential to kinetic | ~30% |
| Gasoline engine (car/truck) | Thermal to mechanical | 10-30% |
| Fluorescent lamp | Electricity to light | 20% |
| Incandescent lamp | Electricity to light | 5% |

### 5.3 Power Density Versus Energy Density

A Ragone plot helps visualizing the energy-power density of candidate sources for a specific application energy and power demand. Figure 7 compares selected batteries chemistries with other technologies. It shows that most batteries deliver more energy when operating at low power over longer period, while due to their chemistry and heat loss they deliver less energy at high power over shorter period. In addition, Figure 7 shows that energy drives the vehicle range while power drives the acceleration. YASA-750 delivers a power density of 6 kW/kg[14]. Another example is Siemens' unique weight-to-performance ratio of 5 kW/kg for aircraft[15]. Nanotechnologies enhanced conductors and materials can improve these by more than 20%.

### 5.4 Volumetric Versus Gravimetric Energy or Power Density

An important aspect of energy sources is their suitability to an application in terms of volume and weight. Volumet versus gravimetric energy or power density is critical applications such as dismounted combatant systems a air platforms where there are requirements to meet t physical constraints imposed by the intended applicati (size or form factor, and weight). Figure 8, adapted frc [14], shows that an increase in gravimetric power dens could result in a lighter device, while an increase in vo metric power density could result in a smaller device.

## 6. Applying the Selected Energy Considerations to Platform Demands

For example, a fuel cell usually requires using battery-supercapacitor energy storage device in ord to increase its maximum power capacity much abo what it could deliver as shown by Figure 7. Fuel ce provide better energy densities than most energy st

10 Information sources include http://en.wikipedia.org/wiki/Energy_conversion_efficiency (Access date: 17 Sept. 2013).

11 Using a thermopump, this could be increased by a factor of three using a ground-water loop.

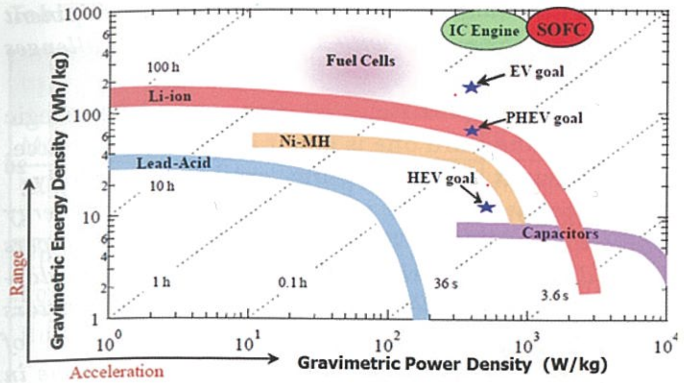
12 http://arpa-e.energy.gov/?q=arpa-e-events/small-scale-distributed-generation-workshop (Access date: 17 Sept. 2013).

13 This needs to be adjusted by the propulsive efficiency $\eta_p$ for specific jet parameters.

14 http://www.yasamotors.com/products/yasa-750/

15 http://www.siemens.com/press/en/feature/2015/corporate/2015-03-electromotor.php?content%5B%5D=Corp

16 This illustration is based on various sources including product data sheets as reported in http://bestar.lbl.gov/venkat/files/batteries-for-vehicles.| (Access date: 17 Sept. 2013) by Dr Venkat Srinivasan of the Lawrence Berkeley National Lab. Then the solid oxide fuel cell (SOFC) was added in the provided by Dr Eric Wachsman (www.energy.umd.edu). Finally it was further updated here for the purpose of this paper with the selected axis labe




Legend: solid oxide fuel cell (SOFC); internal combustion (IC) engine; nickel–metal hydride battery (Ni-MH); hybrid-electric vehicles (HEV); electric vehicles (EV); and plug-in hybrid-electric vehicles (PHEV).

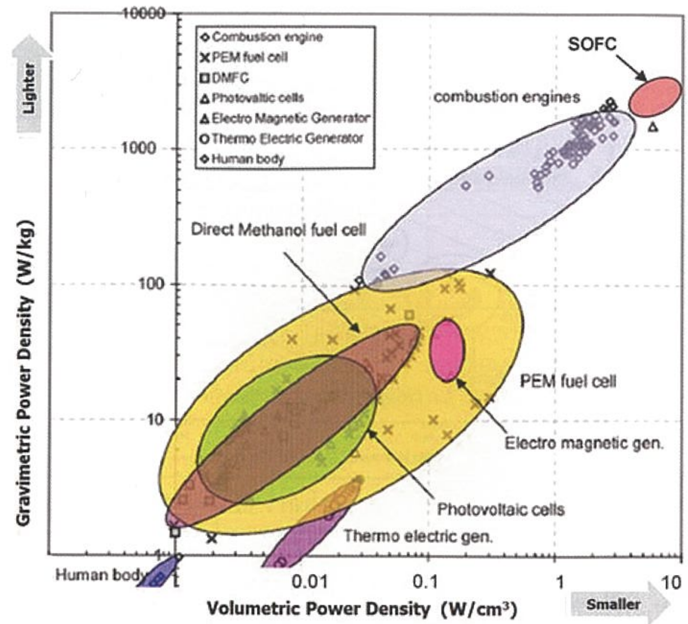
**Figure 7:** Balance between gravimetric energy and power densities (range versus acceleration)[16].

age technologies but offer less power densities than supercapacitor energy storage technologies.

For a more persistent surveillance using low cost UAV platforms one may assume that such UAV will not be equipped with weapons, sophisticated stealth capabilities or electronic countermeasures. For such UAVs the energy requirements will be dictated by the mission profile, distance to the area to conduct surveillance, type of propulsion, period of time required, type of sensor suite required for the desired surveillance and probability of detecting wanted objects or opposing force actions (e.g., identifying hostile activities such as deploying IEDs along a route). The total energy and power will be the sum of the requirements for the sensor suite demand and the propulsion demand for the UAV with its sensor, communication and other payloads such as the navigation system.

## 6.1 Examples of Operational Energy Costs

Another aspect is the fully burden cost of energy in a theatre of operations where opposing forces disrupt fuel supply chain or in a difficult to access location such as CFS Alert. A recent energy audit of CFS Alert reveals that the cost of fuel is about five times as much as the bulk price negotiated across Canada for the CAF. The fuel at CFS Alert needs to be airlifted out of the US Base Thule in Greenland. For operations in the Middle East, fuel delivered by convoys is often disrupted by opposing forces. Here are some DoD examples of FBCE costs:[18] *"The Defense Logistics Agency buys military fuel for $2.82 per gallon. But that same fuel can cost $13 if it's shipped by ground*




Legend: proton exchange membrane (PEM) fuel cell; and solid oxide fuel cell (SOFC).

**Figure 8:** Selected energy sources illustrating size and weight at play[17].

*to a forward-deployed location, during peacetime. If it's transferred in-flight from a refueling airplane to another aircraft, the gas is $42. If troops are in hostile areas, prices can range from $100 to $600 for "in theater" delivery. The Army estimated fuel can cost up to $400 a gallon if the only way to ship it is via helicopters."* For the purpose of this paper, it is assumed that the lower bound multiplying factor due to FBCE during CAF operations in hostile areas is 40 times for land and air platforms. A factor of 4 could be used for naval platforms.

## 7. Technology Wild Cards

A 'wild card' is an unpredictable or unforeseeable factor that occurs outside of the normal rules and expectations. Examples of technology wild cards may include a) progress in technologies to produce new hydrocarbons with less GHG impacts at lower price than $50 a barrel, b) technologies to produce mechanical work and electricity with much less fuel, and c) others with substantial paradigm changes with much higher energy and power density with minimal waste and environmental impacts, such as a new nuclear technology with minimal harmful radiation, no dangerous wastes and little undesirable environmental impact.

In this paper disruptive technologies are defined

17 Figure 8 is based on the material provided by Dr Eric Wachsman (www.energy.umd.edu) and also published in Wachsman and Lee [14]. Authorization to use the material confirmed by email: Wachsman-Labbé 18 July 2013.

18 http://www.nationaldefensemagazine.org/archive/2010/April/Pages/HowMuchforaGallonofGas.aspx (Access date: 7 April 2015).

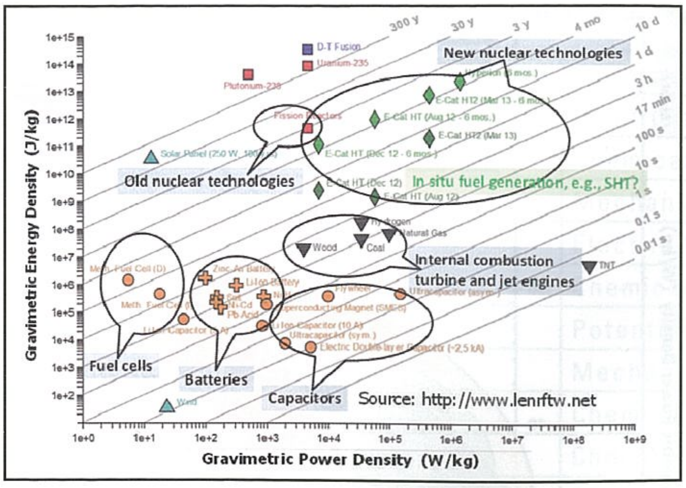



**Figure 9**: Notional Ragone chart modified to show selected categories of energy sources[19].

as follows [15]: "*What makes a technology 'game changing', 'revolutionary', 'disruptive' or a 'killer application' is that it both offers capabilities that were not available – and were in many ways unimaginable – a generation earlier and in so doing provokes deep questions whose answers are not readily available. These kinds ... of questions encompass not only what is possible, but also what is proper, in everything from doctrine and staffing to law and ethics. Such technologies – be they fire, the printing press, gunpowder, the steam engine or the computer – are rare but truly consequential.*"

There are a variety of emerging energy technologies claimed by several organizations and individuals to be able to produce at very low cost, high volume, high energy density and power density above what is currently known with no major environmental negative impacts. Figure 9 positions the level of some of these energy claims under the label of 'new nuclear technologies'.

Such emerging technology is considered disruptive. According to a United Kingdom MOD report, "*Global Strategic Trends - Out to 2040*" [16], not only trends drive the future situation but shocks like: the 2007-8 financial crisis, the 9/11 terrorist attacks and the collapse of the Berlin Wall.

"*Strategic shocks have a cascade effect, leading to multiple, apparently unconnected and unforeseen changes. They transform the strategic context, changing behaviour and activity across the board. For example, the 2007 financial crisis began with US sub-prime debt... the future cannot be predicted in detail or with certainty. However, they will inevitably influence defence and security in some way, providing a strong argument for versatile and adaptable defence institutions, equipme and personnel to deal with the unexpected challen they will present.*"

This MOD report selected five credible strate shocks and the third one is about a new energy sour more efficient than anything available currently "*New Energy Source. A novel, efficient form of ene generation could be developed that rapidly low demand for hydrocarbons. For example, the devel ment of commercially available cold fusion react could result in the rapid economic marginalisation oil-rich states. This loss of status and income undiversified economies could lead to state-failure a provide opportunities for extremist groups to rise influence.*"

DRDC report [1, p. 41] provides a summary energy disruptive technologies that could deliver s eral orders of magnitude greater energy density th current fossil fuels. One of them was given differe names (see Atomic Energy of Canada Limited (AEC report [17]) over the years from the coined la 'cold fusion' then to Low Energy Nuclear Reactio (LENR), Chemically Assisted Nuclear Reactio (CANR), Lattice Assisted Nuclear Reactions (LAN Condensed Matter Nuclear Science (CMNS) a Lattice Enabled Nuclear Reactions. For this paper t term LENR is used. Recently this emerging disrupt technology, LENR, has been identified as one of t technology to be considered by the technology wat of TTCP MAR TP-8 Power and Energy, Materials a Systems. It is included in a recent NATO report [18

The Preface of the 25 February 2015 Current Scien Special Section: Low Energy Nuclear Reactions p vides an overview of the 34 selected papers coveri this subject [19]. These papers cover findings, stud and theories about radioactive nuclear waste remed tion/recycling, transmutation, hydrogen, exothern reactions, experimental systems, etc.

During a 2015 interview [20], Dr. Michael McKu of the Stanford Research Institute (SRI) said that tested, under a DARPA contract, between 12 and LENR technologies for the United States governm [21, 22, 23, 24]. Also McKubre claimed that his te was able to replicate at least five of those technolog so far. Furthermore an advanced LENR device, And Rossi's Energy Catalyzer High Temperature (E-( HT), was evaluated by different groups of experts [2 In 2014 E-Cat HT tests were run and partly fund by the Swedish energy research consortium, Elfo [26]. Based on the Elforsk report, Professor Alexan Parkhomov published in December 2014 a report which he claimed to have replicated Andrea Ross

19 More details about the data and methods used in developing this Ragone chart are available at: http://www.lenrftw.net/comparing_energy_sour html (Access date: 14 May 2014).

20 https://www.gov.uk/government/publications/dcdc-global-strategic-trends-programme-global-strategic-trends-out-to-2040 (Access date: 14 2014).

**Table 2:** Examples of capabilities and related potential multiplication factors.

| Platform | Typical performance | Projected performance based on energy density |
|---|---|---|
| MQ-1 Predator | Range: 740 km Loiter: 14 hours | For air platforms the gravimetric factor should be dominant: x 293. |
| Sikorsky CH-124 Sea King | Range: 1,000 km<br>Maximum flying time: 3h 45 minutes | |
| CP-140 Aurora<br>Long-Range Patrol Aircraft | Range: 9,266 km at 648 km/h<br>Flight time: 14.5 h | |
| Buffalo Mine Protected Vehicle | Range: 480 km<br>Fuel capacity: 322 L | For a land platform, ship and submarine the volumetric factor should be dominant: x 1,000. |
| M1 Abrams | Range: 426 km<br>Fuel capacity: 1,900 L | |
| Halifax-class frigate | Range: 17,600 km<br>Maximum time at 28 km/h: 14 days | |

E-Cat HT technology. Parkhomov's paper detailing his replication was originally published in Russian but several English translation versions can be found on the Internet [27].

Another technology [1, p. 43] that can put DND/CAF capabilities on steroids includes the possibility reported under 'in situ fuel production'. The high rates of hydrogen production as claimed by Solar Hydrogen Trends (SHT) were confirmed by third party measurements (209 kL/h for 415 Wh, that generating hydrogen at an equivalent of 626 kWh, or at 1500 times the input energy used) [28]. The size and weight of tested SHT devices were small although larger than E-Cat HT ones. The E-Cat HT and SHT devices are under the label 'New nuclear technologies' in Figure 9. Once these high-energy density devices are adapted to defence platforms, they will provide enough energy to power adapted defence platforms for extended periods much beyond what is currently possible, including powering emerging DEWs and railguns.

Most recent results from the independent E-Cat HT trials [26] showed exceptional energy densities. When including internal plus external components, the volumetric energy density observed was 36,000 MJ/L and the gravimetric energy density was 13,000 MJ/kg. In comparison, the energy densities of gasoline are 32.4 MJ/L and 44.4 MJ/kg respectively. So the E-Cat HT is 1,111 times more volumetric energy dense and 293 times more gravimetric energy dense than gasoline.

The E-Cat HT fuel weight of the charge was 1 g [26]. According to the Elforsk report, it delivered the following thermal energy density and power density: 1.6 $10^6$ Wh/kg or 5.8 $10^6$ MJ/kg, and 2.1 $10^6$ W/kg. These results place the E-Cat HT beyond any conventional source of energy.

Based on information available so far about high-energy density technologies, one can project their potential impacts on defence and security (D&S) capabilities in terms of advantages and threats to Canada, i.e., advantages in terms of multiplying DND/CAF capabilities and threats if malevolent groups use such advantages against our nation and our allies. This paper only focused on comparing existing platform autonomy using germane energy sources (batteries or fuels and associated energy conversion technologies) with what is possible according to a selected high-energy density technology, the E-Cat HT. The following results are intentionally limited to unclassified sources of military platform specifications.

## 8. Applying the Identified Energy Technologies to Unclassified Military Platform Performance

Using the conservative results for the E-Cat HT, one can project the order of magnitude of the multiplying factors of performance for a variety of military capabilities as follows:

Similar gains in D&S capabilities for defence infrastructure and off-grid installations are expected, e.g., CFS Alert used an average of 1.8 $10^6$ L of JP-8 per year (2007-2010), that is 62 $10^{12}$ J. A 1- MW E-Cat plant generates 32 $10^{12}$ J per year, so two plants could fulfill CFS Alert energy demand.

### 8.1 In Addition to Capability Improvements, What Could be the Recurrent Cost Saving?

If the assumed cost of a 1-MW E-Cat plant[22] is \$1.5 million USD and the Canadian currency conversion is around 0.8, then each plant costs about \$1.875 million

22 http://www.e-catworld.com/2014/12/16/the-impact-of-oil-prices-on-lenr/ (Access date: 16 April 2015).

CAD and delivers 31.6 TJ per year. Heating for all of DND/CAF is 7.6 PJ so it requires 240.8 plants. The investment cost for heating with these plants is $75.3 million so that over 10 years a potential return on investment could be $300 million.

Assuming an energy conversion efficiency of heat to electricity of 30%, as from a thermoacoustic generator, then the DND/CAF electricity demand could be fulfilled by 359 units. The $86 million for electricity cost could be used to amortize the cost of the 359 units required with a potential return on investment of $186 million over 10 years. Note that the operation cost is assumed to be similar to the existing systems. We don't know if the cost for operating the new installations is lesser or higher. Using SHT could be more efficient with a fuel cell but not enough information is available to prepare a similar potential return on investment at the time of writing this paper. However, using SHT could offer an advantageous alternative for the fleets.

CFS Alert used an average of 1.8 ML of JP-8 per year at an average cost of $5.45/L (2007-2010) that is 62 TJ at a cost of $9.81 million per year. Only two 1-MW E-Cat plants are required to fulfil the demand. So the initial cost of the two plants could be paid in the first year with a surplus of $6 million. For the subsequent years the recurring saving for the energy at CFS Alert could exceed $9 million per year.

When such environmentally friendly energy technologies will power most DND/CAF capabilities, decennial savings in excess of several billions dollars would become achievable.

## 9. Conclusion

DND/CAF energy recurring expense represents a substantial portion (4%) of its budget. The $538 million for energy is more than the total department S&T investment. The discussed emerging technologies provide amazing potential improvements to DND/CAF capabilities while at the same time making operations and missions more sustainable.

Eventually, technology like LENR will facilitate the integration and persistent exploitation of new information technologies and weapons such as railguns and DEWs on legacy and future platforms. Such capabilities were either not achievable or sustainable using legacy energy technologies.

It is expected that Canadian multidisciplinary teams with relevant know-how would investigate the plausibility of claims made about LENR while DRDC conducts operational research studies and system analyses to estimate which legacy capabilities would most benefit from such advanced energy technologies. The time has come to investigate the impact of a variety of advanced energy technologies on Canadian Defense and Security, and Canadian Armed Forces capabiliti [29].

In addition, such energy technologies would provi opportunities to produce clean water and better livi conditions to people in places around the world affe ed by climate changes or already under extreme har living conditions. Improved living conditions are like to reduce regional conflicts and wars. The advent of lo cost environment-friendly transportable energy sou es/systems would improve Canada resources exploi tion and transformation thus stimulating its econom

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# Applicability of Simplified Human Reliability Analysis Methods for Severe Accidents

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*[Ed. Note: The following paper was presented at the 7th International Conference on Modelling and Simulation in Nuclear Science and Enginee Ottawa Marriott Hotel, Ottawa, Ontario, Canada, October 18-21, 2015]*


## Abstract

Most contemporary human reliability analysis (HRA) methods were created to analyse design-basis accidents at nuclear power plants. As part of a comprehensive expansion of risk assessments at many plants internationally, HRAs will begin considering severe accident scenarios. Severe accidents, while extremely rare, constitute high consequence events that significantly challenge successful operations and recovery. Challenges during severe accidents include degraded and hazardous operating conditions at the plant, the shift in control from the main control room to the technical support center, the unavailability of plant instrumentation, and the need to use different types of operating procedures. Such shifts in operations may also test key assumptions in existing HRA methods. This paper discusses key differences between design basis and severe accidents, reviews efforts to date to create customized HRA methods suitable for severe accidents, and recommends practices for adapting existing HRA methods that are already being used for HRAs at the plants.


**Keywords:**Severe Accident, Design Basis Accident, Human Reliability Analysis

## 1. Introduction

The Canadian Nuclear Safety Commission (CNSC) [1] defines probabilistic safety assessment (PSA; also internationally often called probabilistic risk assessment or PRA) as "a comprehensive and integrated assessment of the safety of the plant or reactor." Within PSA, human reliability analysis (HRA) can be defined as "a structured approach used to identify potential human failure events and to systematically estimate the probability of those events using data, models, or expert judgment" [2]. HRA also exists as a standalone enterprise within human factors engineering primarily to support design activities [3-4], but the discussion here centers on its application as part of a formal PSA for as-built nuclear power plants. The CNSC [1] also delineates three levels of analysis:

1. *A Level 1 PSA* identifies and quantifies the sequences of events that may lead to the loss of core structural integrity and massive fuel failu
2. *A Level 2 PSA* starts from the Level 1 results, analyses the containment behavior, evaluates radionuclides released from the failed fuel quantifies the releases to the environment; an
3. *A Level 3 PSA* starts from the Level 2 results, analyses the distribution of radionuclides in environment and evaluates the resulting effec public health.

HRA follows these three levels, but instead focu specifically on the human contribution to the eve For HRA, we propose the following extension of PSA level definitions:

1. *A Level 1 HRA* concentrates on the sequence human actions that may contribute to loss of structural integrity;
2. *A Level 2 HRA* concerns human actions that contribute to radioactive release after the los core structural integrity;
3. *A Level 3 HRA* starts from the Level 2 resu and considers human actions that may contri to effects on the environment and public he following the loss of core structural integrity.

Fortunately, Level 2 and 3 events are extremely and are appropriately called *severe* accidents. M HRAs focus on Level 1 analysis, which includes fa at the plant that have the potential to result in damage. In the vast majority of cases, core dan is prevented through safety systems and succes human recovery actions at the plant. As part trend toward a more comprehensive risk assessn internationally within the nuclear industry, PSAs HRAs are now increasingly also modeling Level 2 3 events.

## 2. Differences Between Level 1 and Level 2 HRA

Despite clear definitions of the different level PSA and the importance of HRA for each of t levels, Cooper et al. [5] note (pp. 1686-1687):

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2 Canadian Nuclear Safety Commission, Ottawa, Ontario, Canac

> The main focus of ... HRA method development has been on at-power, internal events, post- initiator, control room operators actions that are taken when following emergency operating procedures and with the support of needed indications (*i.e.*, no failures of alarms or other instrumentation). ... [T]here are still very few HRA applications that have supported [PSA] for hazards beyond internal events or post-core damage accident sequences (*e.g.*, Level 2). Also, there have been few U.S. HRA method developments aimed at supporting such [PSA] studies. Consequently, HRA applications to-date have been performed using the existing HRA methods that were intended for use in supporting at-power, internal events PRA.

Whereas Level 1 HRA will generally be concerned with the evolution of an event from full- power to the point of core damage, the situation for Level 2 and Level 3 is fundamentally different. The plant is no longer at power, it is no longer fully functional, and it may challenge operator experience and training. Cooper et al. [5] identify several key differences in the context being analyzed between Level 1 and Levels 2 or 3, which are paraphrased below:

- Whereas Level 1 incidents make use of emergency operating procedures, Level 2 or 3 require severe accident management guidelines (SAMGs), which do not feature the same level of detail and call for much more open decision-making on behalf of plant personnel.
- Whereas for Level 1 incidents most decision-making happens in the main control room, for Level 2 or 3 incidents the decision-making responsibilities shift to the Technical Support Center (TSC) and may include significant inputs from outside organizations such as community emergency response teams.
- For Level 1 incidents, it may be assumed that there are plentiful indicators and ample information on plant status available in the main control room. With the shift to the TSC and with potentially degraded indicator status and limited accessibility to parts of the plant, there is generally diminished and less accurate information available during Level 2 or 3 incidents.
- Leading up to a Level 1 incident, there are generally successful decision paths to avert or mitigate core damage. After core damage for Level 2 or 3 incidents, the decision-making may require trade-offs among less desirable outcomes.
- For Level 1 incidents, the plant is assumed to be functioning, and it is possible for balance-of-plant activities (outside the control room) to be carried out successfully. For Level 2 or 3 incidents, there may be radiation or other environmental hazards that make these activities dangerous or impossible.
- The plant is staffed and equipped to handle Level 1 incidents. Level 2 or 3 incidents require additional off-site personnel and potentially specialized gear to compensate for equipment damage. The availability of these personnel or that equipment may not be guaranteed, especially if the incident is caused by an event like a natural disaster that has regional consequences beyond the nuclear power plant.

A similar characterization of Level 2 HRA is found in Dang et al. [6]. This recent work in [5] and [6] highlights significant differences from Level 1 HRA. Yet, there has to date been little research to adapt existing HRA methods for Level 2 or 3 analyses. A particular challenge is that the quantitative implications of these differences are not fully understood [7]. For the time being, absent dedicated research on the influence of these factors on human performance, these factors must out of necessity be quantified according to existing Level 1 HRA approaches.

An additional difference that is not specifically called out in [5] or [6] is the addition of new emergency mitigation equipment (also known as the Diverse and Flexible Coping Strategies [FLEX] in the United States, see [8]). This equipment affords new opportunities for recovery but may also require additional staff resources to activate [9-10].

The majority of HRA methods have been developed to support Level 1 analysis. The original and still most widely used HRA method, the Technique for Human Error Rate Prediction (THERP), did not explicitly refer to differences between these levels of analysis [11]. While the THERP method may have predated the advent of Level 1, 2, and 3 discussions in the PSA community, the distinction between levels is also not critical to the integrity of the method. THERP and other HRA methods study human actions and decompose those actions into human behavioral primitives. In the case of THERP, those primitives are found in lookup tables that can, in theory, be applied equally to any level of analysis. In practice, the lookup tables in THERP do not align to many of the types of situations found in Level 2 analysis. To use THERP for Level 2 analysis is quite likely overgeneralizing the method to contexts for which it was not intended.

Newer, simplified HRA methods like the Standardized Plant Analysis Risk-Human Reliability Analysis (SPAR-H) method [12] handle human behavior in terms of performance shaping factors (PSFs), but the basic treatment of these PSFs does not change as the level of analysis changes. The generalizability of the PSFs is a strength of this type of approach, but there is a need to validate the assumptions and quantitative outcomes of SPAR-H for Level 2 applications, since the current standard guidance on the method does not address Level 2 analysis.

HRA methods are not alone in omitting discussion of Level 2 HRA. The standards documents for HRA provide little to no explication of Level 2 considerations. For example, the Systematic Human Action Reliability Procedure (SHARP1) by the Electric Power Research Institute (EPRI) [13] provides an industry-standard framework for integrating HRA into PSA. It does not delineate between levels of HRA. The HRA standard (IEEE-Std-1082) published by the Institute of Electrical and Electronics Engineers (IEEE) [14] does very briefly draw this distinction (p. 2): "An HRA is an integral part of a Level 1 PRA. In higher level PRAs, Levels 2 and 3, the quality of the analysis, *i.e.*, quantification of human error is dependent on the analyst's ability to specify scenarios and the expected human actions." The IEEE standard goes on to suggest that the standard can help the process at higher (*i.e.*, Level 2 or 3) levels of analysis, but no explicit guidance is given to clarify how the levels differ. Newer guidance like NUREG-1792, *Good Practices for Implementing Human Reliability Analysis* [15], only makes cursory mention of Level 1 vs. Level 2 analysis, stating simply that the good practices should apply to Level 1 and, at least to a limited extent, to Level 2 HRA. Other guidance, such as the PSA standard published by the American Society of Mechanical Engineers (ASME) [2] is more cautious about generalization and limits its guidance solely to Level 1 analysis, with the exception of coverage of limited Level 2 as it pertains to large early release frequency accidents. Where discussion briefly branches into Level 2 PSA in the ASME standard, there is no elaboration on special HRA considerations in these sections.

The key challenge comes in generalizing a framework of HRA built around Level 1 analysis to other levels. The analyst is left without standards or specific guidance on applying HRA originally intended for Level 1 to Level 2 or higher. To this end, Fassman [16] captures many of the key definitions and issues pertinent for understanding Level 2 HRA. In Fassman's terminology, there is a continuum of human actions from normal operations to emergency operations to severe accident operations. The latter case includes two particularly important characteristics (p. 1):

> Either there are no procedures for coping with these scenarios, or if there are suitable procedures, they do not rule out operators' performance of additional, objectively inopportune actions from other procedures.
>
> [or]
>
> The scenarios are marked by factors, which can degrade or contribute to a degradation of operators' diagnosing and (or) decision making activities in such a way, that the prerequisites for performing objectively inopportune actions seem be fulfilled and that action performance seems be required in the scenario in question.

In other words, either through the lack of proced or their vagueness for incidents beyond Level 1, operators are forced to make what Fassman calls ad actions. Further, these actions and accompanying d sion-making are complicated by degrading condition the plant, including misleading or missing plant sta information overload (*e.g.*, through alarm flooding), unavailability of certain equipment. Fassman allude Rasmussen's famous skill, rule, and knowledge b decision-making taxonomy [17]. In normal operati the operators can rely on rule-based decision-makin relying on guidance from the procedures or skill-ba decision-making, which is driven by clear indicat from the control boards. In contrast, in severe accid space–often absent procedures and clear indicatio the operators must rely foremost on their knowle of the plant to guide their decision-making. Such d sion-making and actions are largely outside the pur of Level 1 HRAs. Specifically, such scenarios introd new drivers on performance and more significance operator actions to select and guide recovery acti Level 2 HRA also introduces greater opportun for consequential errors of commission–actions operators take that prove erroneous. Much of Lev HRA is concerned with errors of commission–act the operators fail to take but that are required in procedures.

Errors of commission have been a topic of consi able concern within HRA, so much so that coverag them is considered one of the defining characteris of contemporary or second- generation HRA [18]. concern over the lack of treatment of errors of com sion was a genesis of A Technique for Human E Analysis (ATHEANA) [19] as well as the Commis Errors Search and Assessment (CESA) method [ The Nuclear Energy Agency (NEA) organized a sig cant workshop on the topic of errors commission [ These efforts highlight the importance of error commission as a previously underrepresented so of human errors in HRAs. Importantly, howe this research focused on Level 1 HRA. While the a growing awareness of the significance of error commission, the specific research to address error commission for Level 2 HRA remains unrealized. awareness extends to the understanding that error commission likely play a larger role in Level 2 tha Level 1 HRA, but the details are still emerging.

## 3. Current Level 2 HRA Efforts

While there has emerged an extensive literature Level 2 and even Level 3 PSA, the counterpart dis sions in HRA have been rather limited. In this sect

| | Influence factors | Description |
|---|---|---|
| 1 | Time for decision | The time necessary to obtain, check and process information and make a decision about the required action. This influence factor has three modalities "short" "medium" or "long". |
| 2 | Information and measurement means | This IF refers to the quality, reliability and efficiency of all measurements and information available in the control room and means of transmitting them to crisis teams. This influence factor has two modalities "satisfactory" or "unsatisfactory". |
| 3 | Decision difficulty | This IF refers to the difficulty in taking the right decision. This influence factor has three modalities "easy" "medium" or "difficult". |
| 4 | Difficulty for the operator | The difficulty of the action (quality of the procedures, experience and knowledge in the control room or in the plant) is evaluated independently of work conditions. This influence factor has two modalities "easy" or "difficult". |
| 5 | Difficulty induced by environmental conditions | This IF takes into account the on-site conditions in which the actions decided upon, have to be performed (radioactivity, temperature, smoke, gas, exiguity...). This IF has two modalities "normal" or "difficult". |
| 6 | Scenario difficulty | This IF refers to the difficulty of the global context of the current accident scenario in which a decision must be made. This influence factor has two modalities "easy" or "difficult". |
| 7 | Degree of involvement of the crisis organization | Local crisis organization on the plant site or the whole national crisis organization. This influence factor has three modalities "not involved", "local crisis team involved" or "local and national crisis teams involved". |

**Table 1**: The severe accident influence factors in HORAAM (from [26])

we review HRA development efforts focused specifically on Level 2 HRA.

Richner [22] developed a simplified HRA quantification approach to address the incorporation of SAMG operator actions in Level 2 PSA at the Beznau Nuclear Power Plant, a two-unit pressurized water reactor. Richner notes several topics not addressed in traditional HRA as implemented at the plant, including:

- Emergency crews taking control of the plant
- Coordination of multiple emergency crews
- Following SAMGs by emergency crews

This mirrors many of the statements made later by Cooper et al. [5] about the focus in HRA on using emergency operating procedures by main control room reactor operators–two assumptions that may no longer be applicable during severe accidents. Richner goes on to model particular severe accident actions using THERP and the closely related Accident Sequence Evaluation Program (ASEP) method [23], primarily on the basis of task difficulty as a reflection of the time windows to complete those tasks. The approach yields a single table for quantification based on difficulty. The author notes that this approach yields significantly lower accuracy than the Level 1 models used at the plant. In the present authors'interpretation, the approach is comparable to a screening level analysis for severe accident events.

MacLeod et al. [24] developed a simplified HRA approach to account for FLEX gear. This method starts with a base human error probability (HEP) and then uses a series of decision trees to arrive at the HEP for specific situations. These contexts include internal events, internal flooding, high winds, internal fires, external flooding, and seismic events. These situations may occur in concert with severe accidents, but the method is also suitable for use in Level 1 events. The method takes contexts into account, including the availability of staff, the time required to complete tasks, the accessibility of the equipment, personnel protection safety limits, the reliability of communication between groups of dispersed individuals, and the availability of other required equipment.

Électricité de France designed the Méthoded'évaluation de la réalisation des missionsopérateur pour la sûreté (MERMOS) HRA method originally for Level 1 HRA but recently extended it for Level 2 applications [25]. In this approach, conservative estimates are established for human failure events and then modified as needed to derive a precise estimate. In particular, the modified MERMOS approach uses what is called the Emergency Operating System, which includes both plant and emergency and national crisis response teams. It is noted in [25] that the approach, which relies on a team of experts for classification and quantification of the errors, becomes a large effort due to the need to enlist crisis management personnel in developing the HRA.

The only HRA method specifically designed to address Level 2 HRA is the Human and Organizational Reliability Aspects in Accident Management (HORAAM) method [26]. HORAAM is a decision tree method originally designed to address crisis management at French nuclear power plants. Based on observation of crisis exercises such as severe accident training drills, the method centers on seven key influence factors (see Table 1). These influence factors act much like PSFs in the decision tree approach and appear to map well to existing PSF-based methods like SPAR-H [12]. The HORAAM method is particularly helpful due to its application for Level 2 HRAs. However, as a method, its approach does not represent a strong departure from other HRA methods. Where there are already established HRA methods in place at utilities, HORAAM's greatest value may reside in the clarification it can provide in refining definitions of PSFs already in use. It serves as a particularly useful augmentation rather than a replacement for existing HRA methods.

| Special Characteristics of Level 2 PSA in terms of HRA | Description | Corresponding PSFs of SPAR-H method |
|---|---|---|
| Extra Emergency Teams | ✧ extra time for communication between different emergency teams<br>✧ quality of coordination within each emergency team and between different emergency teams | 1 available time<br>3 complexity<br>8 work process |
| SAMG | ✧ clarity and complexity of SAMGs<br>✧ team members' experience in SAMGs | 3 complexity<br>4 experience/training<br>5 procedures |
| New Severe Accident Scenarios | ✧ severity of the accident<br>✧ adverse environment that plant staff may work in (heat, smoke, radioactive release, etc)<br>✧ team members' experience in severe accident scenarios | 1 available time<br>2 stress<br>4 experience/training<br>6 ergonomics<br>7 fitness for duty<br>8 work process |
| Accessible to local places | ✧ During severe accident, some local place may be difficult to access or totally inaccessible. So plant staff's activities may be delayed or not able to perform. | 1 available time<br>* If the local place is inaccessible, HEP = 1. |
| Need to Special Tools | ✧ During severe accident, plant staff may need some necessary special tools to perform their activities. The special tools may be difficult to access or totally inaccessible.<br>✧ The staff's experience in using these special tools will also impact HEPs. | 1 available time<br>3 complexity<br>4 experience/training<br>* If a special tool is inaccessible, HEP = 1. |

**Table 2:** Special considerations in applying SPAR-H to Level 2 HRA (from [23])

## 4. Level 2 Implications for SPAR-H as an Example Existing HRA Method

The custom Level 2 HRA approaches discussed in the previous section may not be ideal for widespread adoption where existing HRA methods are in place. Either these approaches represent significant simplifications of HRA that are actually akin to a screening analyses, or they account for only a portion of the Level 2 context (*e.g.*, only crediting FLEX), or they represent completely new approaches that are unlike existing HRAs used for Level 1 PSA. In other cases, there are potential cultural differences with how operations are handled in severe accidents. In particular, it is noteworthy that neither MERMOS nor HORAAM directly treat SAMGs, one of the major defining characteristics of Level 2 HRA as suggested in [5]. Instead of using these Level 2 HRA methods, it may be preferable for utilities to adapt and extend existing, well understood, and comprehensive HRA approaches to Level 2 applications.

Raganelli and Kirwan [7] note that most attempts to model Level 2 HRA make use of expert elicitation. The difficulty with this approach is that it is virtually impossible to find experts who are qualified to provide frequency information, since severe accidents are such rare occurrences. Further, the rarity is compounded by extreme uncertainties due to the unique nature of the events and the beyond design basis performance of engineered systems. Raganelli Kirwan suggest that more rese needs to focus on the human formance envelope, specifically edge effects where human perform starts to break down due to ext stress and other PSFs. They fu state (p. 11), "...what is needed programme of work that seeks fi understand the limits of PSA mod for L2, and then to understand h behaviour in such scenarios. From understanding, factors can be extr either to guide experts participati or conducting HRAs for [Level 2] or to inform HRA techniques models themselves." Below, we b adopt this approach by seeking to an existing HRA approach to the 2 considerations, thereby provid tool to help analysts understand quantify the nuances of Level 2 H

The SPAR-H method [12] is v used in the U.S. by utilities and b nuclear regulator. This method flexibility for a wide range of ana comprehensive coverage of PSFs to consider i analysis, as well as simplicity in implementatio noted earlier, the SPAR-H method, like most methods, is indifferent to levels of analysis. SPAR-H method is also technology neutral an been successfully applied to boiling water rea pressurized water reactors, and CANDU reacto has also been applied to new builds like the Eur Pressurized Reactor [27].

Wang performed the only publically docum Level 2 HRA for existing plants using SPAR-H This work centered on support of Level 2 PSA m for the Chinese nuclear industry. The SPAR-H m was selected for application in Level 2 HRA be other HRA methods currently used for Level 1 did not generalize well to Level 2 considera Existing methods were found not to generaliz beyond main control room operations. The T method [11] was found, due its very limited f treatment of PSFs, to be unable to characteri complex context of human actions during a accident. As depicted in Table 2, the eight PS SPAR-H were found to provide good coverage PSFs that come into play during a severe acc Severe accidents can invoke all eight SPAR-H although Wang's analysis does not imply that all would be invoked simultaneously. Wang goes provide a case study of the SPAR-H analysis f human failure event for an operator failure to safety injection following core damage due to a loss of coolant accident (LOCA). This analysis makes use of the Stress, Complexity, and Procedure PSFs, which receive elevated weightings for the Diagnosis component of the SPAR-H analysis. For the Action component of the analysis, only Stress is invoked to increase the human error probability.

SPAR-H proved an effective method for Wang's Level 2 HRA application. However, there exists no formal guidance on using SPAR-H for Level 2, and it would be a fruitful exercise to adapt existing guidance for nuclear community use. Additionally, just as SPAR-H has specialized worksheets to reflect the nuances of at-power vs. low power and shutdown applications, there may be sufficient differences compared to conventional Level 1 HRA to warrant a new SPAR-H worksheet that is fine-tuned to the nuances of the PSF level assignments and multipliers for Level 2 HRA. Additional development beyond the scope of this paper would be required to perform and validate such a table. It is recommended that additional development work be conducted to create applicable guidance for Level 2 SPAR-H analysis and refine the method as needed. This process may serve as a template for generalizing other HRA methods designed for Level 1 analysis to Level 2 applications.

## 5. Disclaimer

This project has been supported by the Canadian Nuclear Safety Commission. The opinions expressed in this publication do not necessarily reflect those of the Canadian Nuclear Safety Commission. This project is prepared under an international cooperative agreement for the purpose of exchanging technical information. This study is intended for research purposes only, may be preliminary, and certain procedures described may be untested. The research report is purely for information purposes. The report also includes analysis and views expressed by the research team. The recipients of this material should take their own professional advice before acting on this information.

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# Treatment of Alzheimer Disease with CT Scans – A Case Report†

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*[Ed. Note: The following paper, submitted to the CNS Bulletin by the author, will be published in the journal **Dose-Response**, and will be presented at the 15th Annual International Conference on Dose-Response, 19-20 April 2016, University of Massachusetts, Amherst, MA, USA.]*

## Abstract

Alzheimer disease (AD) primarily affects older adults. This neurodegenerative disorder is the most common cause of dementia and is a leading source of their morbidity and mortality. U.S. patient care costs are about 200 billion dollars and will more than double by 2040. This case report describes the remarkable improvement of an advanced AD patient in hospice, who received five CT scans of the brain, about 40 mGy each, over a period of three months. The mechanism appears to be radiation-induced up-regulation of the patient's adaptive protection systems against AD, which partially restored cognition, memory, speech, movement, and appetite.

**Keywords:** Alzheimer disease, CT scan, adaptive protection systems, ionizing radiation

## Introduction

Alzheimer disease (AD) is a neurodegenerative disorder of uncertain cause and pathogenesis that primarily affects older adults. It accounts for more than 50 percent of the cases of dementia and is one of the leading sources of morbidity and mortality in the aging population. The most essential and often earliest clinical manifestation of AD is selective memory impairment. While treatments are available that can ameliorate some symptoms of the illness, there is no cure or disease-modifying therapy currently available, and the disease inevitably progresses in all patients. The incidence and prevalence of AD increase exponentially with age, essentially doubling in prevalence every 5 years after the age of 65 years.[1] There are rare inherited forms of AD (less than one percent of all cases) that present before 65 years of age.[2]

In the United States in 2012, an estimated 5.2 million people over 65 years of age had AD. This figure is projected to rise to 13.8 million by 2050. In a Medicare survey of 22,896 adults age 65 and older, 15 diseases accounted for 70 percent of all deaths. Dementia was second to heart failure as a cause of mortality, accounting for 19 percent of the deaths.[3] While individuals do not die of AD per se, advanced AD increases vulnerability for other disorders, commonly infections, which ultimately lead to their death.[4] Costs attributable to the care of these people range between 157 and 215 billion dollars and are expected to more than double by 2040.[5]

In patients with the typical form of the illness, deficits in other cognitive domains may appear with or after the development of memory impairment. Executive dysfunction and visuospatial impairment are often present relatively early, while deficits in language and behavioral symptoms often manifest later. These deficits develop and progress insidiously.[1] Dyspraxia, or difficulty performing learned motor tasks, usually occurs later in the disease. It leads to progressive difficulty first with complex, multistep motor activities, then dressing, using utensils to eat, and other self-care tasks. This is a big contributor to dependency in mid to late stages of AD. Other signs and symptoms are decreased sense of smell, sleep disturbances, seizures,[6] and motor signs. There can be a variety of atypical presentations and mixed dementias, i.e., AD coexisting with other processes, including vascular dementia and Parkinson disease.

AD progresses inexorably. An older age onset of AD (>80 years) may be associated with a slower rate of decline compared with younger patients. The survival after diagnosis ranges from 3 to 20 years, with an average life expectancy of 8 to 10 years. The mainstay of management is still symptomatic: treatment of behavioral disturbances, environmental manipulations to support function, and counseling with respect to safety issues.[7] Patients generally succumb to terminal-stage complications, such as dehydration, malnutrition, and infection. Advanced AD patients are admitted to hospice for palliative care as their end of life approaches.[5]

The changes in the brain of AD patients are associated with diffuse and neuritic plaques, marked by amyloid beta deposition and tangles, which are comprised of the accumulation of hyperphosphorylated tau (p-tau) protein. The study of AD is being transformed by the availability of new biomarker technologies to measure such changes. Large clinical trials are evaluating anti-amyloid and other therapies, utilizing imaging or cerebrospinal fluid biomarkers. While the pathogen-

† Dose-Response Journal (in press)
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esis of AD remains unclear, all forms of AD appear associated with overproduction and/or decreased clearance of amyloid beta peptides.[4] Autopsy data suggest that symptomatic AD will not occur in every subject with amyloid in the brain.[1]

The study of AD has focused on three interrelated hypotheses:[4]

- Amyloid plaques are a unique genetic and lifestyle disease due to increased production of amyloid beta 42 in younger, genetically high-risk individuals and to reduced metabolism and removal among older individuals
- Vascular disease is an independent determinant of vascular dementia, but also of increased amyloid deposition and neurodegeneration
- Dementia is due primarily to aging and neurodegeneration, independent of amyloid and vascular disease.

Structural brain imaging with computed tomography (CT) and magnetic resonance imaging (MRI) is indicated in the evaluation of patients with suspected AD. It can suggest potential alternative or additional diagnoses. Findings in AD include both generalized and focal atrophy, as well as white matter lesions. The most characteristic focal finding in AD is reduced hippocampal volume or medial temporal lobe atrophy. Because hippocampal volumes decline in normal aging, age-specific criteria are needed. Functional brain imaging with FDG-PET, functional MRI, perfusion MRI, or SPECT reveals distinct regions of low metabolism (PET) and hypoperfusion in AD. FDG PET and SPECT are the only functional neuroimaging methods that are currently reasonably widely available for clinical use. FDG PET may be most useful in distinguishing AD from other diseases. A 2013 consensus opinion concluded that amyloid imaging is not appropriate in patients who meet the core clinical criteria for probable AD and have a typical age of onset, and such a scan should not be used to determine dementia severity.[1,4,27]

The process of AD begins well before clinical symptoms arise, and this period may be the optimal time to intervene if disease-modifying therapies can be identified. Laboratory and imaging biomarkers are increasingly used in research settings to better define prodromal and preclinical forms of AD and identify candidates for early-intervention clinical trials.

## Case Report: Partial Recovery of a Patient from Advanced AD after CT Scans to the Brain

The patient is 81 years of age. She began to exhibit symptoms of dementia about ten years ago, when her illness was diagnosed as the onset of AD. Her disease had progressed gradually to the final st of advanced AD. The patient had been in ho: care for several months, since April 8, 2015. Ho: care is allowed only if life expectancy is less tha: months. A neuropsychologist examined her on M: and found her to be completely non-responsive. patient would frequently refuse her medications was almost totally non-communicative. She would rarely utter a single word, and that word would n appropriate. She was almost immobile; she hac attempted to rise from her wheelchair in months

Her spouse was aware that low doses of ionizing ation generally stimulate a patient's protection tems against diseases and age-related deteriorat He requested her physician to prescribe a standar scan, to determine any anatomical changes that occurred and to stimulate neuroprotective sys Two scans were carried out on July 23, 2015. Two later, her caregiver, who was unaware of this radi treatment, reported a noticeable improvement. caregiver was quoted as saying: "She is doing sc that it is amazing. I have never seen someone im this much. She wanted to get up and walk. She talking some, with more sense, and she was fe herself again."

On August 6, another CT scan was providec August 11, the following recording on the spc cell phone was made by the daughter of the pat best friend in the memory care unit. "I just w to just tell you how beautiful the last couple of have been when I visited and (she) was so intera Oh my goodness! I don't know what the last few have been, but, and even today, she was like relaxed. I don't know if it was the non-full mo what. Anyway, I just wanted to say how nice it v see your wife doing so good."

On August 12, the patient's spouse received tl lowing email from the patient's caregiver:

"Hi ..., I have noticed that ... has been much talkative lately. She really wasn't talking much She will read words in books, ask questions, as people are. She seems to be much more aware surroundings. At times she tries to push herse from her wheelchair thinking that there is some she needs to be doing. She is eating by hersel eating all of her food. Her mood is very good. not as tired as she had been during the times there."

Another CT scan was administered on Augu and patient's condition continued to improve. I the week of September 14, the following beha were observed:

A sign of old memory return was seen whe called her daughter's old roommate by name an said "roommate."

An improvement in motor function was seen in an exercise group, the patient lifted her leg and did several head turns in phase with the group.

The patient often talked in 3-5 word sentences as well as shorter responses, such as "yes, no, maybe, etc." Whatever her verbal response, it almost always seemed appropriate.

The patient's improvement following these CT scans was being noticed by all of her rotating caregivers, by her two personal caregivers, by all family members, and by visiting friends. Slow but steady improvement continued for about another three and a half weeks.

An additional CT scan was given on October 1. Almost immediately, a significant setback was observed with an estimated loss of about 80 percent of the gain. This was very discouraging initially, but a slow recovery of cognitive ability began again. A neuropsychologist examined the patient on October 28 and indicated that she was able to give some simple verbal responses, which reflected some minimal improvement from the May 21 examination by the same doctor.

The patient's slow progress continued until November 20, when she was judged to be no longer eligible for the hospice care that had begun on April 8. It was to last only 6 months. Withdrawal of hospice care was another indicator of the cognitive and physical improvement. She is judged improved enough to be readmitted to a stimulating, dementia day-care program that she had been discharged from 18 months ago.

To understand the reason for the patient's setback after the last CT scan, the patient's spouse asked the hospital to provide the X-ray doses that had been given during the four visits. The doses, CTDIvol, are doses measured in a plastic patient model and used as a reference for patient dose. They are the doses that were output by the scanner. The values reported are:

| Date (2015) | July 23 | August 06 | August 20 | October 01 |
|---|---|---|---|---|
| Dose (CTDIvol) (mGy) | 82.34 (39.49 + 42.85) | 38.74 | 46.94 | 38.54 |
| Dose (cGy) | 8.2 | 3.9 | 4.7 | 3.9 |

Note that two CT scans were given on July 23 in order to obtain a satisfactory image of the brain. So the patient actually received a total of *five* scans. Each scan delivered a dose of about 40 mGy. The images were not assessed after each CT scan to measure any change in the amount of amyloid plaque present.

Referring to Figure 2 below, the observed positive responses of the patient suggest that the <u>cumulative</u> dose of the first four radiation exposures, a total of 168 mGy, was in the range of increasing radiation-induced beneficial health effects. The fifth exposure brought the cumulative dose beyond the optimum level and caused a significant decrease in the cognitive and mobility benefit. However, as of January 30, 2016, the patient has recovered beyond her late August condition, and she continues to improve.

## Beneficial Effects of Ionizing Radiation

Beneficial effects of ionizing radiation were identified by medical scientists and practitioners very soon after the discoveries of x-rays and radioactivity about 120 years ago. They employed radiation initially to diagnose fractures and other medical conditions, but quickly discovered that large exposures were harmful. However, low exposures produced remarkably positive effects. Murphy and Morton observed in 1915 that a low radiation dose, to the entire bodies of mice, increased the activities of their protective processes against the overproduction of lymphocytes, significantly preventing or impairing tumor growth.[9] Many important applications of radiation, other than curing cancer, were identified in the early 1900s. Many thousands of patients were treated with low radiation with no apparent increases in the incidence of cancer or genetic effects, long after these radiation treatments. The applications include healing of wounds and the cure of a wide variety of infections, such as gas gangrene, carbuncles and boils, sinus infections, inner ear infections, pneumonia, and treatments of arthritis and a multitude of other inflammatory conditions.[10,11,12] A very recent article describes the treatment and cure of bronchial asthma.[13] An assessment of animal model studies on the capacity of long-term, whole-body gamma rays to affect life span concluded that low dose rates enhance longevity; the median life span of a population is usually increased by 10-30%, but not the maximum life span potential.[14] The mechanism for beneficial health effects of radiation is up-regulation of an organism's adaptive protection systems by multiple or chronic low-dose exposures.[15,16]

How much harm does a low radiation dose cause? The *spontaneous* rate of DNA damage is enormous.[17] The average number of endogenous DNA alterations per average cell†, *per day*, is about a *million*. About $10^{-1}$ are double-strand breaks (DSBs). The main cause of this damage is metabolic reactive oxygen species. Surprisingly, the rate of DNA damage caused by a low level of ionizing radiation is relatively negligible. A background radiation level of 1 milligray‡ (mGy) per

† An average cell weighs about $10^{-9}$ grams. Therefore, a person weighing 70 kg has about 70 trillion cells.

‡ The gray (Gy) is the System International unit for absorbed ionizing radiation dose, energy in joules per kilogram of mass. A dose of 1 Gy = 1 J/kg; 1 mGy = 0.001 Gy, and 1 cGy = 0.01 Gy = 1 rad.

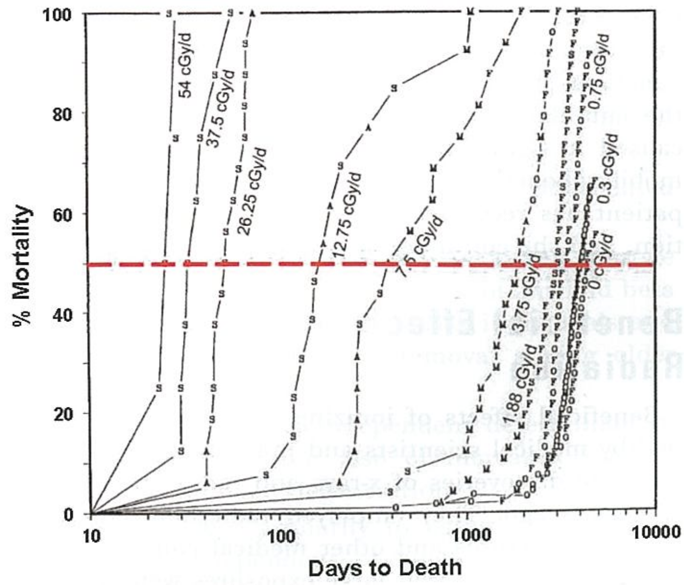


**Figure 1a.** Mortality curves for groups of dogs in different $Co^{60}$ radiation levels[19] Note that the intersection of the red dashed line (at 50% mortality) with each mortality curve defines the median lifespan of the group of dogs in the indicated radiation level.

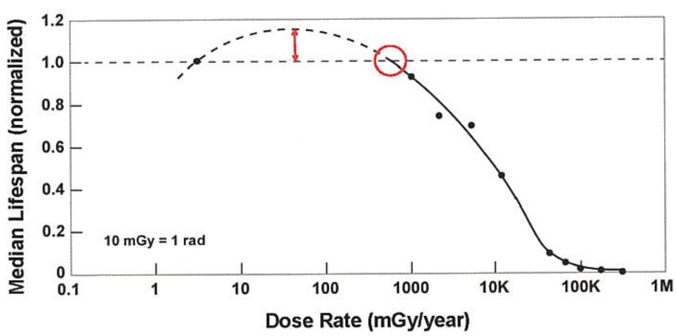


**Figure 1b.** Median lifespan vs. radiation level.[11] Note that the NOAEL for gamma radiation-induced lifespan reduction of dogs is about 700 mGy/year (70 cGy/year).

year induces about $10^{-2}$ DNA alterations per cell, per day. About $10^{-4}$ DNA alterations per cell, per day are DSBs. The endogenous DNA damage rate is about 100 million times the rate from background radiation. The DSB rate is about 1000 times the DSB rate from 1 mGy per year.[18]

The protection systems prevent, repair, remove and replace cell and tissue damage, regardless of whether the damage was caused by endogenous metabolic processes or by toxic damage by all of the *exogenous* causes, including radiation. These systems, which include the immune system, act to restore and maintain all biological functions necessary for survival in good health. All organisms adapt to their environments, so when a small increase in ambient radiation

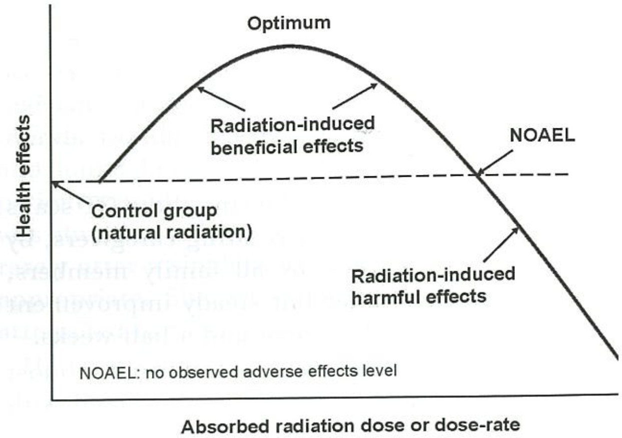


**Figure 2.** Dose-response model for ionizing radiation.

level occurs, the protection systems adjust to additional stress by becoming up-regulated, i.e increasing their levels of activity.

The observed results are net *beneficial* health ef including increased life span,[14,20,10,21] as show Figures 1a and 1b. On the other hand, a very acute exposure causes tissue damage by cell ki as in radiation therapy of tumours. A high dos over a long period of time is harmful because it its the protection systems and may damage Figure 2 illustrates the dose-response behaviour c phenomenon. There is a threshold dose or dose above which a beneficial health effect is obser This observed health effect transitions from b cial to harmful above the no *observed adverse level* (NOAEL). The dose-locations of the thres NOAEL, and the amount of benefit or harm for ticular radiation-induced health effect at a given depend on the patient's genetic characteristics and medical condition. This applies not only to ing radiations but to any physical or chemical str

For a patient's static defences to act, stresses to exceed threshold levels to disturb cell and/or functions. The metabolic or dynamic defences in 1) fast-acting ones that start immediately aft injury occurs (DNA repair alone involves more 150 genes), and 2) delayed defences that ari up-regulation of defense mechanisms leading to the system to repetitive stress for a prolonged of time. Such adaptive protection may follow repeated short-term stresses and serve the int of the system even for life. Adaptive protection stimulated maximally by an acute exposure to 150 mGy.

Low-dose induced adaptive protections may o not only against damage from renewed irradiatio also against damage from toxic impacts from n diation sources.[15,16] Adaptive protections may in reduced damage causation, increased damage and damage removal, for instance by immune responses against cancer cells, bringing a life-long benefit. One may speculate that also damage accumulation of beta amyloid through glial cells may be prevented, interrupted or eliminated following exposure to such low doses at which adaptive protections operate at their best.

## Proposed Treatments of AD Patients with Ionizing Radiation

Bistolfi states that vascular-cerebral amyloidosis is the hallmark of AD.[23] Localized tracheo-bronchial amyloidosis (TBA) has been successfully treated with beams of radiation, 20 Gy in ten fractions of 200 cGy in two weeks. As 20 Gy in two weeks is followed by inflammatory reactions, this high dosage cannot be suggested in the hypothetical treatment of AD. An innovative alternative might be a weekly long-term low-dose, say 50 to 100 cGy, fractionated radiotherapy (RT), matching the very slow response of amyloid to radiation. Before applying it to AD patients, the proposed schedule should be tried in TBA patients to compare the new results of long-term fractionated RT with the results of 20 Gy/2 w. Should long-term fractionated RT prove effective, its application to AD patients might become an effective and safe treatment.[23]

Doss discusses the concerns that have been expressed recently regarding the observed increased DNA damage from activities such as thinking and exercise.[24] Such concerns have arisen from an incomplete accounting of the full effects of the increased oxidative damage. When the effects of the induced adaptive protective responses, such as increased antioxidants and DNA repair enzymes, are taken into consideration, there would be less endogenous DNA damage during the subsequent period of enhanced defenses, resulting in improved health from the thinking and exercise activities. A low dose of radiation, which causes oxidative stress and increased DNA damage, up-regulates adaptive protection systems that decrease diseases. There are ongoing debates regarding the carcinogenicity of low radiation, with two recent advisory committee reports coming to opposite conclusions. Data published since then have overwhelmingly ruled out its carcinogenicity, paving the way to consider its use for disease reduction. Stimulation of adaptive protection with low doses of radiation is a promising approach to control neurodegenerative diseases, for which there are no methods of prevention or cure. A compelling ethics case should be written to pave the way for a clinical study using low doses of radiation to treat AD and other neurodegenerative diseases.[24]

A study in Australia on the use of ultrasound energy removed amyloid-ß (Aß) and restored memory in an AD mouse model.[25] Since mechanical stress is a method of up-regulating adaptive protective systems, it is not surprising that this approach succeeded. The authors used repeated scanning ultrasound (SUS) treatments of the mouse brain, without the need for any additional therapeutic agent such as anti-Aß antibody. Spinning disk confocal microscopy and high-resolution 3-D reconstruction revealed extensive internalization of Aß into the lysosomes of activated microglia in mouse brains, with no concomitant increase observed in the number of microglia. Plaque burden was reduced compared to sham-treated mice. Cleared plaques were observed in 75% of SUS-treated mice. These mice also displayed improved performance on three memory tasks. These findings suggest that repeated SUS could be considered as a potential AD treatment in humans.[25] The significant physical differences between the skull of a human and a mouse would present a major challenge.

On July 17, 2013, an application for a patent was published, titled: *Radiation therapy for treating Alzheimer's disease.*[26] It makes 14 claims for treating human patients by a method, which is based on studies carried out using mice. The method comprises administering a relatively large amount of ionizing radiation to the brain of the patient employing a variety of different radiation sources. The total dose ranges from 300 to 1800 cGy, administered in dose fractions of 50 to 300 cGy per day. The method is claimed to treat AD by reducing the number or size of amyloid plaques in the brain of the patient.[26]

## Discussion

Was it the low doses of ionizing radiation from the CT scans to the brain that produced the beneficial health effects (decrease of AD symptoms) observed in this patient? Improvements in an AD patient's symptoms have occurred without any treatment, but rarely. Generally, advanced AD patients progress inexorably to death. It is very unusual to observe such a strong reversal. Some might argue that this is only an anecdotal case; however, it is a fact that a very significant improvement happened within two days after the first two radiation exposures totalling 82 mGy. And further improvements were observed soon after the third and fourth radiation exposures. As of January 30, 2016, the patient has recovered from her very disappointing setback, following the October 1 exposure, and her condition continues to improve.

Assuming that AD develops because a person's protective systems become less effective with age and fail to prevent, repair, remove and replace all of the endogenously-occurring cell and tissue damage, it is reasonable to expect that *stimulation* of these systems by applying a small amount of stress would prevent, stop or reverse some of this damage. This stress could be administered, either continuously or in a series of dose fractions, to induce these systems to adapt to higher levels of activity. A booster treatment could be given annually, or when signs of increased AD reappear.

Since the process of AD begins well before clinical symptoms arise, it would be wise to start prophylactic treatment as soon as the onset of AD is identified, to increase its latency.

Bistolfi points out that ten 200 cGy radiation treatments for removing plaque are far too intense for treating AD. He suggests the alternative of a weekly long-term low-dose, 50 to 100 cGy.[23] The human evidence of our case report suggests the optimum cumulative dose is about 16 to 18 cGy.. The dose ranges in the patent application,[26] 300 to 1800 cGy, are far above the optimum radiation dose identified in our case report.

## Conclusions

Alzheimer disease is the most common cause of dementia and is one of the leading sources of morbidity and mortality in the aging population. There are no treatments to cure or delay it. The costs to care for the AD patients in the US are very high and are expected to double by 2040.

This case report provides human evidence that low doses of ionizing radiation to the brain, as provided in several normal CT scans, can produce significant improvements in the condition of a patient with advanced AD.

This evidence suggests a need for clinical studies to develop an optimal treatment, based on the stimulation of the adaptive protection systems with low doses of ionizing radiation or other stressors. Up-regulation of these protective systems in aged people would reverse, stop or delay cell and tissue damage, and would prevent or cure AD.

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# Leukemia and Ionizing Radiation Revisited


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*[Ed. Note: The following paper, submitted to the CNS Bulletin by the author, was published in the 2015 journal Leukemia, Volume 3, Issue 4 (p.202).]*



## Abstract

A world-wide radiation health scare was created in the late 1950s to stop the testing of atomic bombs and block the development of nuclear energy. In spite of the large amount of evidence that contradicts the cancer predictions, this fear continues. It impairs the use of low radiation doses in medical diagnostic imaging and radiation therapy. This brief article revisits the second of two key studies, which revolutionized radiation protection, and identifies a serious error that was missed. This error in analyzing the leukemia incidence among the 195,000 survivors, in the combined exposed populations of Hiroshima and Nagasaki, invalidates use of the LNT model for assessing the risk of cancer from ionizing radiation. The threshold acute dose for radiation-induced leukemia, based on about 96,800 humans, is identified to be about 50 rem, or 0.5 Sv. It is reasonable to expect that the thresholds for other cancer types are higher than this level. No predictions or hints of excess cancer risk (or any other health risk) should be made for an acute exposure below this value until there is scientific evidence to support the LNT hypothesis.



**Keywords:** Leukemia, ionizing radiation, LNT model


## Introduction

While trying to better understand the basis for the present conception that *any* ionizing radiation expo-


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**Table 1.** Incidence of leukemia among the combined exposed populations of Hiroshima and Nagasaki, January 1948 - September 1955 (adapted from Lewis, Tables 2 and 3) [2]

| Zone | Distance from hypocentre (m) | Dose (rem or cSv)† | Persons exposed | Number of cases of leukemia | Total cases million |
|---|---|---|---|---|---|
| A | 0 - 999 | 1300 | 1,870 | 18 | 9,626 |
| B | 1000 - 1499 | 500 | 13,730 | 41 | 2,986 |
| C | 1500 - 1999 | 50 | 23,060 | 10 | 434 |
| D | 2000 and over | 5 | 156,400 | 26 | 166 |

**Table 2.** Leukemia incidence for 1950-57 after exposure at Hiroshima (adapted from UNSCEAR-1958, Ar G, Table VII) [8]

| Zone | Distance from hypocentre (m) | Dose (rem or cSv) | Persons exposed | Number of cases of leukemia | Total cases million |
|---|---|---|---|---|---|
| A | 0 - 999 | 1300 | 1,241 | 15 | 12,087 |
| B | 1000 - 1499 | 500 | 8,810 | 33 | 3,746 |
| C | 1500 - 1999 | 50 | 20,113 | 8 | 398 |
| D | 2000 - 2999 | 2 | 33,692 | 3 | 92 |
| E | over 3000 | 0 | 32,963 | 9 | 273 |

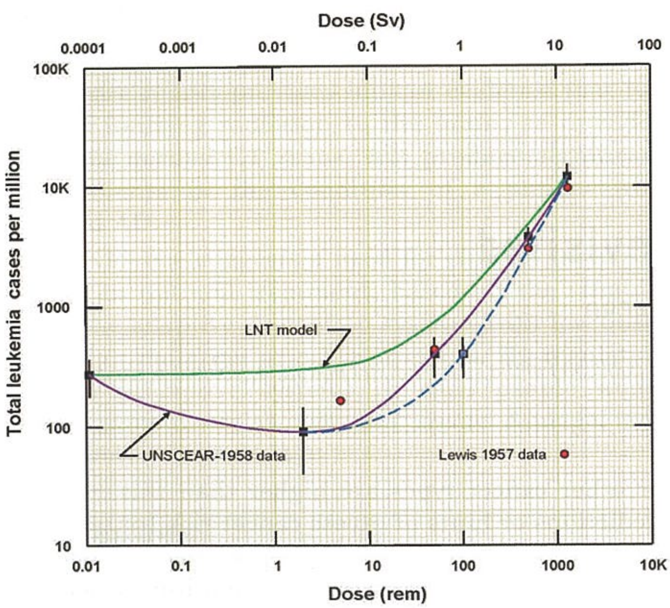


**Figure 1.** Leukemia incidence among the Hiroshima atomic bomb survivors, 1950-57.

sure, no matter how small, is linked to an elevated risk of cancer, the authors re-examined the early articles in *Science* that triggered the regulatory changes and the propagation of this hypothesis. Two articles dating back to the 1950s stand out. The first was the June 29th 1956 paper by the Committee on Genetic Effects of Atomic Radiation of the National Academy of Science (NAS) [1]. It recommended the application of a linear no-threshold (LNT) model for assessing the risk of radiation-induced mutations in germ cells [1]. The second was the 1957 paper by Lewis [2] that recommended the LNT model be used for calculating the excess risk of cancer due to any radiation exp

Recently, several articles have been written ing exactly what led to the 1956 NAS paper a subsequent wide acceptance. It appears ther significant misunderstanding and misinterpre of the scientific data, and one such analysis eve as far as asserting that the promulgation of th model was deliberate scientific misconduct [ UNSCEAR report has stated, "Radiation exposu never been demonstrated to cause hereditary eff human populations" [4]. Hundreds of papers on cal treatments of many thousands of patients wi to moderate radiation doses make no observati excess cancer incidence nor genetic effects [5].

## Evidence of a Threshold Dose fo Excess Risk of Cancer

This brief article revisits the Lewis study [2] on mia and identifies a very serious error in his anal was missed by all the international radiation pro organizations and regulators who accepted the mendation to use the LNT model to evaluate risk following any radiation exposure. In his a of the incidence of leukemia among the popu of Hiroshima and Nagasaki, Lewis did not p account for the incidence of leukemia among th trol populations" (the people who were not signif exposed). His Table 2 gives the number of con cases of leukemia in four zones, and his Table the average dose in each of these zones [2]. Th are summarized and shown in Table 1.

To address the leukemia incidence among th trol population, Lewis stated, "Since the majority of the population in zone D (from 2000 meters on) was beyond 2500 meters, the average dose is under 5 rem and is thus so low that zone D can be treated as if it were a "control" zone." In his Fig 1, the dose is about 10 rem at 2000 metres and about 1 rem at 3000 metres [2]. These are significant amounts of radiation, corresponding to about a hundred plain x-rays or up to ten abdomen/pelvis CT scans. We contend that the people who were in the range from 2000 to 3000 metres should *not* have been combined with the non-exposed people who were located beyond 3000 metres. Scott has pointed out that averaging the data in several low dose intervals is an epidemiological trick [6] or approach [7] that is employed to conceal evidence of a dose threshold, which would contradict and invalidate the LNT model that Lewis recommended for calculating the excess risk of cancer due to radiation.

The 1958 UNSCEAR report [8], Annex G, Table VII provides the leukemia data for the ~ 96,800 Hiroshima survivors, including ~ 33,000 who were in zone E, from 3000 metre and beyond. These human data, are shown in Table 2 and in Figure 1 [9]. (Note that both the vertical and horizontal axes are logarithmic, in order to present the data on one page and avoid congestion in the low-dose, low-incidence ranges.) The footnote for zone C in Table VII states, "almost all cases of leukemia in this zone occurred in patients who had severe radiation complaints, indicating that their doses were greater than 50 rem" [8]. In Figure 1, we added a point at 100 rem or 1 Sv to account for this observation of severe radiation complaints regarding the zone C leukemia patients. The dashed line through this point strengthens the evidence that there is a threshold dose for excess risk of leukemia. The total number of cases per million for the controls, 273 over 8 years, corresponds to an annual incidence of about 3.4 per 100,000.

## Conclusions

The UNSCEAR data and the data that Lewis analyzed contradict his recommendation to use the LNT model to predict the excess risk of leukemia (and cancer in general). These substantial data, on about 96,800 humans, suggest there is an acute radiation threshold at about 50 rem (500 mSv) for excess leukemia incidence. It is reasonable to expect that the radiation thresholds for initiation of other cancer types are higher than the 50 rem or 500 mSv threshold for leukemia.

No predictions or hints of excess cancer risk (or any other health risk) should be made for an acute dose below 50 rem or 500 mSv until there is scientific evidence to support the LNT hypothesis.

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*Selected Abstracts from the 7th International Conference on Modelling and Simulation in Nuclear Science and Engineering, Ottawa Marrio Ottawa, Canada, October 18-21, 2015*

## Application of Classroom Simulators in the Training of Managers at CANDU Plants

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### Abstract

Technical managers of Canada's nuclear power plants are required to have in-depth knowledge of the norm abnormal integrated unit operations typical of the plant at which they work. The Advanced Operations Ov for Managers (AOOM) training program was developed by Ontario Power Generation to fulfil this need fo of its managers. The program makes extensive use of "classroom" simulators that have the same software r as the full-scope training simulators, but use graphical user interface to replicate the control room devic the last several years the AOOM program has been delivered by the University of Ontario Institute of Tech

## Validation of Moderator-Level Reactivity Coefficient Using Station Da

By MOHAMED YOUNIS, IOURI MARTCHOUK, AMEC FOSTER WHEELER and P.D. BUCHAN, OPG
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### Abstract

The reactivity effect due to variations in the moderator level has been recognized as a reactor physics ph non of importance during normal operation and accident analysis. The moderator-level reactivity coefficie important parameter in safety analysis of CANDU reactors, e.g., during Loss of Moderator Heat Sink as we the simulation of Reactor Regulating System action in CANDU reactors that use moderator level for reactiv trol. This paper presents the results of the validation exercise of the reactor-physics toolset using the measur performed in Pickering Unit 4 in 2003. The capability of the code suite of predicting moderator-level re effect was tested by comparing measured and predicted reactor-physics parameters.

## Benchmarking of Fast-Running Software Tools Used to Model Releas During Nuclear Accidents

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### Abstract

Fukushima highlighted the importance of effective nuclear accident response. However, its complexity impacted the ability to provide timely and accurate information to national and international stakeholders recommendations provided by different national and international organizations varied notably. Such diff can partially be attributed to different methods used in the initial assessment of accident progression a amount of radioactivity release. Therefore, a comparison of methodologies was undertaken by the NE and its highlights are presented here. For this project, the prediction tools used by various emergency re organizations for estimating the source terms and public doses were examined. Those organizations that capability to use such tools responded to a questionnaire describing each code's capabilities and main algo Then the project's participants analyzed five accident scenarios to predict the source term, dispersion of and public doses.

# GENERAL news

(Compiled by Colin Hunt from open sources)

## Bruce Power President Duncan Hawthorne Steps Down

Duncan Hawthorne announced on February 1 that he would be stepping down from his position as President and CEO of Bruce Power. Mr. Hawthorne has been the head of Bruce Power for 15 years since the company was formed to operate the Bruce Power site. His formal retirement takes effect on April 30, 2016.

"When Bruce Power was created in 2001 our vision was clear – return the site to its full eight-unit potential and establish a long-term structure where the performance of the facility and its employees dictated its future," said Duncan Hawthorne, President and CEO of Bruce Power.

Mr. Hawthorne is stepping down at a time when these objectives have been achieved.

Bruce Power has begun a search for a new CEO, and Chief Financial Officer Kevin Kelly has assumed the role of acting president.

2015 has been a year of great accomplishments by the company. All eight reactors at the world's largest operating nuclear power station have been returned to service. After successfully refurbishing and restarting Units 1 and 2, starting in 2012, for the first time in two decades, all eight reactors were in service, producing more than 30 per cent of Ontario's total electricity supply.

Also in 2015, Bruce Power applied for and was granted a five year renewal of its operating licence by the Canadian Nuclear Safety Commission (CNSC).

Bruce Power signed an agreement with Nordion Inc. for the long term supply of the radioisotope Cobalt-60.

Bruce Power has also established an enviable workplace safety record. At the end of 2015, employees had worked nearly 13 million hours without an acute lost-time injury.

Bruce Power and the Ontario government agreed in December 2015 to refurbish all six remaining reactors at the site. The agreement will extend the operation of Bruce Power's reactors to 2064. The first refurbishment outage will start in 2020.

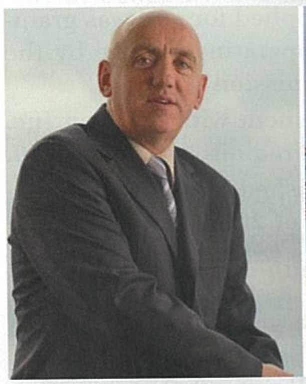
Mr. Hawthorne took control of Bruce Power at a time of considerable uncertainty for the Bruce site. Three of the reactors, Unit 1, 3, and 4 had not been operating since 1998, and one, Unit 2 had been shut down in 1994. At the time, there were no plans to restart any of these reactors.

However, by 2005, Units 3 and 4 had been successfully restarted, and the company commenced planning for the full refurbishment of Units 1 and 2. Throughout the past 15 years, Bruce Power has invested billions of dollars in upgrades to the Bruce reactors, restoring reactor performance and ending restrictions on maximum capacity imposed in the 1990s. Also during this time, Bruce Power has rejuvenated plant staff, attracting hundreds of new skilled workers to the site. It has also established strong relations with neighboring communities and municipalities including host community Kincardine, Ontario.

During this time, there were a number of changes in ownership of Bruce Power as well. The company was originally owned principally by British Energy with some minority partners. After a few years, the British government compelled British Energy to divest all of its overseas holdings, and a new all-Canadian ownership was formed, consisting at the time of Cameco Corporation, Trans-Canada Pipelines, Borealis Corporation, along with the Power Workers Union and the Society of Energy Professionals.

## Former Bruce Power President Duncan Hawthorne Takes Control of Horizon

Duncan Hawthorne, former President and CEO of Bruce Power has been appointed as a Chief Executive of Horizon Nuclear Power in the United Kingdom. Mr. Hawthorne will have responsibility for developing the new nuclear project Horizon has been planning for the Wylfa Newydd site on Anglesey in the United Kingdom.



Wylfa Newydd, along with Oldbury-on-Severn, is one of two sites in the UK in which Horizon is proposing to build new nuclear reactors. Horizon is owned by Hitachi, and the proposed reactors will be BWR type reactors.

## Canadian Simulation Technology Leading in Canada and Around the World

### *L-3 MAPPS to Contribute to Darlington Refurbishment Project*

MONTREAL, March 10, 2016 – L-3 MAPPS announced today that it has signed a contract with Ontario Power Generation (OPG) to provide replacement trip computers for the second shutdown system (SDS2) and display/test computers for both the first shutdown system (SDS1) and SDS2 on the four generating units
Darlington Nuclear Generating Station. The
phase is underway and the final production con
equipment for the four generating units is expec
be delivered by the second quarter of 2019.

"We have always capitalized on common tech
solutions for our Marine Systems and Power S
lines of business," said Rangesh Kasturi, president
MAPPS. "The new project with OPG is an excellent
tunity that allows us to extend the technology and
how that we use in our naval integrated platform m
ment systems and CANDU* plant control compute
apply them to an adjacent plant process at Darling

"For more than four decades, we have worked wit
to develop advanced custom-engineered solutions fo
its nuclear generating stations," added Michael Cl
vice president of marketing & sales for L-3 MAPPS
Systems and Simulation. "We are grateful to OPG
confidence they have placed in us to deliver key
and simulation products that have positively cont
to the strong performance of its plants."

In support of the Darlington refurbishmen
gram and OPG's overall effort to design and de
replacement for SDS2, L-3 MAPPS will carry
hardware design, integration and testing of pr
systems, including qualification testing, follo
the delivery of production units for the SDS2 tr
puters and the SDS1 and SDS2 display/test com

Ontario Power Generation produces about
Ontario's electricity in a reliable, safe and e
mentally sustainable manner. OPG phased o
generation in 2014 – the single largest climate
initiative in North America. OPG relies on hyd
nuclear power, energy sources that are 99.7 perc
of greenhouse gas and smog-causing emissions.
Darlington Nuclear Generating Station, located
Municipality of Clarington in Durham Region,
meters east of Toronto, is a four-unit station wi
output of 3,512 megawatts that began operatin
early 1990s. The refurbishment of Darlington to
the operational life of the station has been in p
for more than six years and will be one of the
infrastructure projects in Canada. Outage execu
the first unit will start in October 2016.

L-3 MAPPS has over 30 years of experience in
ing technological advances in the marine automat
and over 40 years of experience in delivering hig
power plant simulation to leading utilities wo
In addition, the company has more than four
of expertise in supplying plant computer syst
Canadian heavy water reactors. L-3 MAPPS also
targeted controls and simulation solutions to t
sector. To learn more about L-3 MAPPS, please
company's website at www.L-3com.com/MAPPS.

** CANDU is a registered trademark of Atomic Energy of Canada L*
*under license by Candu Energy Inc., a member of the SNC-Lavalin Gro*

# L-3 MAPPS Takes Part in Opening of Upgraded Sizewell B Simulator

L-3 MAPPS announced on February 17, 2016 that it participated in the official opening of EDF Energy's upgraded Sizewell B plant training simulator on January 21, 2016 in Suffolk, U.K. The ceremony was attended by numerous EDF Energy representatives, including Jim Crawford, Sizewell B station director. L-3 MAPPS' team was led by Michael Chatlani, vice president of marketing & sales.

EDF Energy's Jim Crawford said, "Working with L-3 MAPPS, we have been able to embrace new technology to further enhance our nuclear training program here at Sizewell B."

"We have consistently achieved excellent results at Sizewell B, Hartlepool, Heysham 1 and Hinkley Point B, and are so happy to have had this opportunity to upgrade the Sizewell B simulator," said L-3's Michael Chatlani. "Sizewell B has always been a special site to L-3 MAPPS as it gave us our first significant entry into the U.K.'s power generation sector and fueled years of further in-country successes."

"L-3 has been especially fortunate to enjoy an outstanding working relationship with our colleagues at Sizewell B over the last 15 years – the phenomenal teamwork between our two companies has resulted in another

*Upgraded Sizewell B Simulator Opening Ceremony (January 21, 2016). Jim Crawford (Sizewell B Station Director, EDF Energy) (left) accepts plaque from Michael Chatlani (Vice President, Marketing & Sales, L-3 MAPPS) (right).*

world-class simulator solution at Sizewell B," he added.

The previous UNIX operating system-based simulator was replaced with new PC/Windows-based computers running L-3's trailblazing Orchid® simulation environment. The reactor core model was upgraded with Orchid Core Builder to provide the higher-fidelity Comet Plus™ model and improved 2-D and 3-D visualization of the core parameters in runtime. The simulator's containment model was also upgraded

*Upgraded Sizewell B Simulator Opening Ceremony (January 21, 2016). From left to right: Jon Heley, Gavin Lancaster, Julie Greenwood, Kevin Caton, Santosh Sajnani, Andy Hill (EDF Energy), Michael Chatlani (L-3 MAPPS), Nick Alexander, Nigel Bowerman, Stephen Killilea (EDF Energy), Suzanna Guerriero (L-3 MAPPS), Ian Lowe, Simon Goldsmith, Nich Biddiscombe, Mike Parkes (EDF Energy) and Bernard Gagnon (L-3 MAPPS).*

in Orchid Modeling Environment. The enhanced simulator is equipped with new cameras and microphones to record training sessions using Orchid Multimedia Manager, which is fully synchronized with Orchid Instructor Station. The upgraded simulator also includes Orchid Sound System to generate control room sounds depending on the simulator scenario.

L-3 MAPPS additionally provided six Orchid Touch Interface classroom simulators to be used by the plant operators or other plant personnel to become familiar with the plant control room and its operation.

Other deliverables included a 3-D PWR Learning Simulator for training on plant transients, as well as 3-D Learning Modules for fundamentals training with various components, including pumps, valves, heat exchangers, etc. To enhance systems training for plant technicians, L-3 MAPPS also delivered a series of System Knowledge Modules – smaller-scale simulations focused on specific areas of the plant.

EDF Energy is one of the U.K.'s largest energy companies and its largest producer of low-carbon electricity. It is a wholly owned subsidiary of the EDF Group, one of Europe's largest energy groups. EDF Energy generates approximately one-fifth of the U.K.'s electricity and employs around 15,000 people. Sizewell B is currently the only Pressurized Water Reactor in the United Kingdom and is located on the Suffolk coast, northeast of London. Sizewell B went into commercial operation in February 1995 and is expected to be in operation until 2035.

## Darlington Granted a 10-year Licence Renewal

The Canadian Nuclear Safety Commission (CNSC) announced its decision to grant a ten year licence for OPG's Darlington Nuclear Generating Station. The licence will be valid from Jan. 1, 2016 until Nov. 30, 2025.

"This is the longest licence ever granted to a Canadian nuclear power plant," said Glenn Jager, OPG's Nuclear President and Chief Nuclear Officer. "The licence term reflects the strong performance of the Darlington station and the preparations OPG has made for refurbishment."

The Darlington Refurbishment Project will have a significant impact on Ontario's economy. The Conference Board of Canada reviewed the project and determined the refurbishment would generate $14.9 billion in economic benefits to Ontario, and create an average of 8,800 jobs annually between 2010 and 2023. Overall household revenues would increase by $8.5 billion.

"OPG has been preparing for the refurbishment since 2009," said Jager. "Detailed planning is essential for a project of this size and duration. We've planned, practiced and prepared and now we're ready to this important clean power project on time a budget."

Darlington Nuclear is one of the top perf nuclear stations in the world. With a total capa 3,512 MW, it has been producing about 20 per the province's electricity since the early 1990s 99.7 per cent of the power produced free of sm greenhouse gas emissions, OPG is Ontario's l clean energy provider.

## Ontario Agrees to Nuclear Refurbishment at Darlingtor

### *Pickering to Operate to 2024*

Ontario Energy Minister Bob Chiarelli an on January 11, 2016 that the provincial gov has agreed to the plan proposed by Ontari Generation (OPG) to refurbish all four reacto Darlington nuclear power station.

Nuclear refurbishment at Darlington will co $15 billion to Ontario's gross domestic produc throughout the project and create up to 11, annually, according to the Minister. The r ment of all four units is expected to involve million hours of work over 10 years and will Ontario's globally recognized CANDU nuclea chain, with more than 180 companies employi sands of highly skilled workers.

Ontario Power Generation (OPG) is on track to begin refurbishment of the first unit at Darlington in October 2016. To best protect Ontario ratepayers and ensure OPG delivers refurbishment on-time and on-budget, the government has established off-ramps that require OPG to obtain government approval prior to proceeding with each of the remaining unit refurbishments. The budget for the project is $12.8 billion, about $1.2 billion less than originally projected by OPG, and all four units are scheduled for completion by 2026.

The Province has also approved OPG's plan to pursue continued operation of the Pickering Generating Station beyond 2020 up to 2024, which would protect 4,500 jobs across the Durham region, avoid 8 million tonnes of greenhouse gas emissions, and save Ontario electricity consumers up to $600 million. OPG will engage with the Canadian Nuclear Safety Commission and the Ontario Energy Board to seek approvals required for the continued operation of Pickering Generating Station.

Securing clean, reliable power for decades to come is part of the government's plan to build Ontario up. The four-part plan includes investing in people's talents and skills, making the largest investment in public infrastructure in Ontario's history, creating a dynamic, innovative environment where business thrives and building a secure retirement savings plan.

## Kevin Kelly Named Acting President of Bruce Power

Kevin Kelly has taken over as acting president of Bruce Power with the impending retirement of President and Chief Executive Officer Dun can Hawthorne.

The nuclear power operator announced on Tuesday that Hawthorne will retire at the end of April, but will continue to advise and support Bruce Power during a leadership transition.

Kelly, who is Bruce Power's chief financial officer, assumed the role of acting president, effective March 8, while Bruce Power undertakes the process of recruiting a new CEO, which is now underway.

Kelly has been with Bruce Power since the company was formed in 2001. Previously he had worked with British Energy and served on the due diligence and transition team focusing on the deal that saw a long-term lease signed between Bruce Power and Ontario Power Generation for the company to operate the nuclear power plant in Bruce County. He has also worked at BDO's Toronto office.

Hawthorne, who announced to employees on February 1 that he would be retiring this year, has also been with the company since it formed in 2001.

Hawthorne has roughly30 years in the power generation business, holding senior posi tions in power companies in the U.K., U.S. and Canada. Before joining Bruce Power, he was a long-time executive at British Energy.

## Terrestrial Energy Awarded $5.7 Million Grant From Canadian Federal Government

Terrestrial Energy, a vendor of next-generation nuclear power plants has been awarded a CAD$5.7 million grant from the Sustainable Development Technology Canada's (SDTC) SD Tech Fund(TM). SDTC is a foundation funded by the Government of Canada.

Grants funds will be used to support Terrestrial Energy's pre-commercial activities, which conclude with the construction of an electrically-heated non-nuclear mock-up within 30 months. The mock-up will test and demonstrate many aspects of IMSR (Integral Molten Salt Reactor) operation, and will include the data collection over a wide range of operating scenarios of the performance of the IMSR's passive cooling systems; this will validate Terrestrial Energy's safety analysis computer codes, a common industry requirement. The results will support Terrestrial Energy's regulatory engagement and key aspects of the IMSR's Safety Case, one built on simple, natural and passive cooling mechanisms.

On February 16, 2016, the CNSC agreed to conduct a phase 1 vendor design review for the Terrestrial Energy integral molten salt reactor design concept. The review duration is estimated to take 18 months as determined by Terrestrial Energy's schedule for submissions. At the end of the review, an executive summary of the project report will be posted on the CNSC website.

## Cameco Named on Top 100 List for Most Sustainable Corporations in the World

For the first time Cameco has been named one of the world's most sustainable corporations in a global analysis organized by Corporate Knights, a Canadian-based media and research company.

The companies who make the Global 100 ranking are the top overall sustainability performers in their respected industry sectors and are selected from 4,353 companies listed companies with a market capitalization greater than $2 billion (USD).

Companies are judged on 12 key indicators. This includes scoring criteria such as total revenue divided by a company's greenhouse gas emissions, safety performance, and percentage of tax paid.

"This recognition shows Cameco is seen as a global leader in transparency, environmental stewardship and corporate responsibility," said Sean Willy, Cameco's director of corporate responsibility. "It proves the work we are doing at a site level around water and waste management and our commitment to safety is being acknowledged at a world level."

## Study Warns of Worsening UK Electricity Supply Gap

The UK government's policy to close all coal-fired power plants by 2025, combined with the retirement of the majority of the country's ageing nuclear fleet and growing electricity demand, will leave the UK facing a 40-55% electricity supply gap, according to a new report published January 26,2016 by the Institution of Mechanical Engineers.

The report's authors make three recommendations. Firstly, that the UK's National Infrastructure Commission should assess the necessary incentives for industry and the public "to reduce the demand on the electricity system through engineering efficiencies into processes and equipment, awareness raising and advocacy".

Secondly, that the commission "must urgently implement changes necessary across the industry and supply chain" to deliver security of electricity supply with no coal-fired generation. These include investment in research and development activities for renewables, energy storage, combined heat and power and innovation in power station design and build.

Finally, the government and industry should "review the capacity in the supply chains to deliver the construction of the 'most likely' new power infrastructure". This includes identifying timeframes and milestones for conventional and unconventional power generation build - fossil fuel, nuclear, energy storage, combined heat and power and off-grid options - along with growth in skills and knowledge within the UK to meet the potential increase in demand.

## First Vessel Installed in China's HTR-PM unit

The first of two reactor pressure vessels has been installed at the demonstration HTR-PM high-temperature gas-cooled reactor unit under construction at Shidaowan in China's Shandong province. The twin-reactor unit is scheduled to start up next year.

The vessel - about 25 meters in height and weighing about 700 tonnes - was manufactured by Shanghai Electric Nuclear Power Equipment. It successfully completed factory acceptance on 29 February and was dispatched from the manufacturing plant on 2 March. The pressure vessel arrived at the Shidaowan site on 10 March, plant owner China Huaneng Group announced the following day.

Plant constructor China Nuclear Engineering Corporation (CNEC) announced yesterday that the reactor pressure vessel had now been installed wi the unit's containment building. The operation to the vessel over the reactor building and lower it its support ring took seven hours to complete, it s

## No Fuel Damage at Kakrapar

Fuel bundles removed from a leaking coolant c nel at Kakrapar unit 1 are intact and undama Nuclear Power Corporation of India Ltd (NPCIL) s

In its second public statement since a leak of h water coolant prompted the automatic shutdow the 220 MWe pressurized heavy water reactor o March, the company said that the affected cha had been isolated and defueled. Cooling is being m tained in all the remaining channels and the rea remains in a safe shutdown state.

On 16 March, India's Atomic Energy Regula Board (AERB) announced that the coolant cha responsible for the leak had been identified, altho at that time some leakage of coolant was still occur NPCIL said that the leak has now been "arrested".

Kakrapar 1's core contains 306 coolant chan made of zirconium-niobium alloy, each holding bundles of uranium fuel. The fuel is cooled by a flo heavy water under high pressure - the primary coolant - which generates steam in a secondary circuit to drive the electricity-generating turbines.

"The investigation will now be carried out to find the cause of the failure," NPCIL said. It intends to restart the unit after completion of the investigation, inspection of relevant components and implementation of corrective actions, which will require clearance from the AERB. It said that lessons and recommendations emerging from the investigation would be "suitably incorporated".

No increase in radioactivity or radiation levels has been observed in the plant or in the surrounding area since the incident occurred, NPCIL said.

## Nuclear Growth Revealed in China's New Five-Year Plan

China's operating nuclear generating capacity will double over the next five years under the country's latest Five-Year Plan. The plan also calls for the preparation for construction of inland nuclear power plants and work on a reprocessing plant to start by 2020.

The ruling Communist Party of China's National People's Congress endorsed the draft of 13th Five-Year Plan at its annual session earlier this month. The plan will be officially implemented in the next few months. A summary of the plan lists several targets in the field of nuclear energy.

China will complete construction of the four AP1000 units currently under construction at Sanmen in Zhejiang province and at Haiyang in Shandong province. Sanmen unit 1 is expected to be the first AP1000 to begin operating, in September, while Haiyang 1 is expected to start up by the end of the year. Containment tests have already been successfully conducted at both units. All four Chinese AP1000s are scheduled to be in operation by the end of 2017.

The plan also calls for construction of demonstration Hualong One projects at China National Nuclear Corporation's Fuqing plant in Fujian province and China General Nuclear's Fangchenggang plant in Guangxi to be completed by 2020. First concrete for Fuqing 5 was poured last May, while construction on unit 6 began in December. Fuqing 5 and 6 are scheduled to be completed in 2019 and 2020, respectively. Construction of Fangchenggang 3 also began in December, while construction of unit 4 is scheduled to begin later this year. Those two units are also expected to start up in completed in 2019 and 2020, respectively.

## Canadian cyclotron turns 40

Canada has marked the fortieth anniversary of operations at the world's largest cyclotron accelerator, the 520 MeV Main Cyclotron at the Triumf national laboratory for particle physics. Celebrations were attended by science minister Kirsty Duncan.

The cyclotron was officially commissioned on 9 February 1976 by the country's prime minister at the time, Pierre Trudeau. Its controls and electronics have been continually upgraded, and the facility - which accelerates protons up to three quarters of the speed of light - has remained the "workhorse" at the centre of Triumf's operations.

Duncan said that Triumf was a "mecca" for researchers in the fields of particle and nuclear physics, molecular and materials science, and nuclear materials. "Thanks to Triumf's ambitious international partnerships, Canadian researchers have been at the centre of some of the most important global research projects," she said.

As well as being home to Canada's only proton therapy cancer treatment centre, Triumf recently set a new record for the production of medical radioisotopes using a cyclotron as an alternative to production in a research reactor. Technetium-99m, used in around 80% of all medical radioisotope procedures, can be produced directly in a cyclotron by bombarding a molybdenum-100 target with a proton beam. The Canadian government has invested in projects, including Triumf, to bring non-reactor-based radioisotope technologies to market through its ITAP (Isotope Technology Acceleration Program) initiative.

A new advanced electron linear accelerator facility that will also be able to produce medical isotopes, Ariel (Advanced Rare IsotopE Laboratory), is currently under construction at Triumf.

Located on the University of British Columbia's campus near Vancouver, Triumf is owned and operated by a consortium of Canadian universities with funding from the National Research Council of Canada.

*VIPs including federal science minister Kirsty Duncan, parliamentary secretary for science Terry Beech and director of Triumf Jonathan Bagger at the celebrations. (Image: K Stallknecht/Triumf)*

# CNS news

## News from Branches

### CHALK RIVER Branch

On **Wednesday February 24th,** the Chalk River Branch of the CNS hosted its annual **CNS President's Dinner at the Bear's Den in Deep River.** Despite a late February snow storm, a total of 47 enthusiastic CNS members and non-members attended the dinner/talk. The event included a buffet dinner and a very interesting talk by CNS President, Paul Thompson. Paul gave a detailed presentation on the Pt. Lepreau refurbishment project highlighting lessons learned, successes, and challenges faced.

Other upcoming events that the CNS Chalk River Branch is participating in include the **Renfrew County Science Fair, April 9th,** and the **Renfrew County Science Olympics in May 2016** (exact date to be determined).


*CNS President Paul Thompson poses with the CNS CRB Executive. From left to right: Bryan White, Bruce Wilkin, Paul Thompson, Laura Blomeley, Ruxandra Dranga, Aidan Leach, and Andrew Morreale.*

*Event attendees listening to Paul's presentation.*

### GOLDEN HORSESHOE Branch

On **December 8th,** the CNS Golden Horseshoe branch co-hosted **Dr. Robert Walker** with the Engineering Faculty at McMaster Universit Cafe-X event. **Dr. Walker** discussed his **"Th on the Science-Policy Interface in a Co World"**. About 60 people were in attendance fr University, Hamilton and the Golden Horsesho

The Golden Horseshoe Branch has updated i site and plans to update it further on a regular

### NEW BRUNSWICK Branch

On **February 9, 2016, Mr. Derek Mullin, of the New Brunswick Branch,** delivered a tation in Saint John, NB, entitled ***"Point L Generating Station Tsunami Hazard Assess*** to NB Branch members and guests. The prese provided an overview of the methodology, m and results of a state-of-the-art probabilistic t hazard assessment that was performed for th Lepreau region in response to the Canadian I Safety Commission Integrated Fukushima Plan. The presentation was well attended by members and guests, which prompted tho questions and discussion by attendees.

The New Brunswick branch will be soon reach to local CNS members in good standing to a the branch executive committee. As branch affa activity is being increased, we are hopeful that th be a renewed interest in CNS activities and our to promote the exchange of information on all of nuclear science and technology and its applic

### OTTAWA Branch

On **Monday 1st February,** the Ottawa Branch meeting with special guest **Mr. Richard Wiens, D of Strategic Supply at Nordion Inc.** Mr. Wie a very well received presentation entitled **"A Curies and Counting 50 years of Canadian r innovation in healthcare".** Nordion, located in Ontario, has been a leader in the production of isotopes, most notably Cobalt-60 and Molybedr used for diagnosis, prevention and treatment of since the inception of the technology in the early

These products have become critical comp of healthcare, impacting the daily lives of r of people around the world. A continuously ing isotope production landscape and reg environment and the ever-increasing complex the global isotope market have necessitated ongoing innovation in the technology and processes used to produce, refine, package and transport these isotopes.

The presentation provided an overview of current technologies, highlighted present challenges, and provided examples of innovative solutions in the medical isotope world.

A lively question & answer session followed. At the conclusion of the session, Ottawa branch chair Ken Kirkhope thanked Richard for a most interesting and well received presentation. A copy of Richard's presentation can be found at the Ottawa branch web page.

On **March 16,** the Ottawa Branch hosted a presentation by **Paul Thompson of NB Power,** and current **President of the Canadian Nuclear Society.** Mr. Thompson gave a presentation entitled **"Lessons Learned from the Point Lepreau Generating Station Refurbishment"**. The branch executive is lining up other events for the spring session.

## SHERIDAN PARK Branch

The Sheridan Park Branch organized a presentation by **Dr. Ben Rouben** on **March 23, 2016.**

His presentation **"The Origins and 'Why' of the CANDU Reactor Design"** took place in the Darlington Room in the office of Candu Energy Inc. He described the CANDU nuclear-reactor design as a unique Canadian homegrown nuclear technology. Its roots go back to Canada's research in nuclear fission in WWII. In 1987, the CANDU reactor was named "One of Canada's top ten engineering achievements of the past century". The origins of the CANDU, the rationale for its particular characteristics, and the effect and importance of the decisions made were discussed.

## UOIT Branch

- New member recruitment on **January 14, 2016** at the UOIT Clubs and Societies Fair
- First UOIT executive meeting of the year also on **January 14th, 2016**
- A movie screening of Pandora's Promise was done February 3rd, followed by an informal discussion on the future of nuclear. The event had a decent turnout, with half of attendees being first year students.
  - ◊ Several of those first years have attended a leadership workshop to prepare them for getting more involved with the CNS next year
- Potential upcoming events:
  - ◊ A tour of the Mechatronics and Robotic Systems lab at UOIT to introduce students to robotics projects designed for use in the nuclear industry, especially Cameco
  - ◊ Tours to General Electric, Cameco, and other local sites throughout the semester
  - ◊ Trip to the McMaster Nuclear Reactor during the summer
  - ◊ Inviting speakers from General Electric to talk about the nuclear fuel cycle and PRISM reactor (tentative)
  - ◊ Joining efforts with the Health Physics Association for a trip to Canberra

## WESTERN Branch

### General

The Branch is working to develop initiatives and objectives to further its strategic planning process based on the priorities that the Branch executive has established of:

- Doing more as a Branch for our membership;
- Speaking out more as to our communities; and
- Developing resources that support Branch activities and public engagement.

### Branch Activities

**Jason Donev** organized a chapter meeting of the Branch at the University of Calgary on 12 February. The topics of discussion were employment opportunities in the nuclear field as well as a brainstorming session on how to attract more student members. Twenty-four people attended.

The Executive has reached out to faculty at the University of Regina about the possibility of increasing the profile of the CNS in Regina.

### Outreach Activities

**Duane Bratt** was on CBC1's *Alberta at Noon* to discuss the role that nuclear could play in meeting Alberta's low-carbon energy needs December 1.

**Neil Alexander, Esam Hussein** and **Matthew Dalzell** co-authored an op-ed (attached) on the role nuclear energy can have for addressing greenhouse gas emissions targets. It ran in the December 28 edition of the *Regina Leader-Post.*

**Jason Donev** gave colloquia on January 5 and 6 at the University of Saskatchewan and University of Regina on the importance of energy to modern society and nuclear power's role in reducing carbon dioxide emissions. Both talks were well attended and well received.

**Duane Pendergast, Shaun Ward** and **Laurence Hoye** were part of a delegation from the Energy Collegium in Lethbridge making a presentation, related to electricity and Alberta's climate change plans, to the Southern Alberta Municipalities Association on January 15.

**Neil Alexander** and **Matthew Dalzell** authored a commentary on the role that Canada's nuclear sector could play in clean energy and sustainability in Canada and abroad that was published in *The Hill Times* on 2 March.

# MANAGING OUR FOOTPRINT:

**Effective solutions for nuclear waste management, decommissioning, and environmental restoration require a collaborative approach at the technical, social, political, and economic levels. The Canadian Nuclear Society invites you to join this discussion.**

"Collaborative Solutions for Current and Future Needs"

**3rd Canadian Conference on Nuclear Waste Management, Decommissioning and Environmental Restoration**

**Sept. 11-14, 2016 Ottawa**

Canadian Nuclear Society®
Société Nucléaire Canadienne

## "Collaborative Solutions for Current and Future Needs"

## Ottawa Marriott Hotel, Ottawa, Ontario

## Sept. 11-14, 2016

## TOPICS INCLUDE:

- Government Policies, Programs & Oversight
- Stakeholder Engagement
- Aboriginal Participation in the Nuclear Industry
- Uranium Mining & Milling Waste Management
- Low Level, Intermediate Level & Mixed Waste Management
- Waste Characterization, Processing, Packaging & Minimization
- Waste Transportation
- Used Nuclear Fuel & High Level Waste (HLW) Management
- Environmental Remediation
- Decommissioning Strategies & Projects

**For registration and other info, visit our website:**

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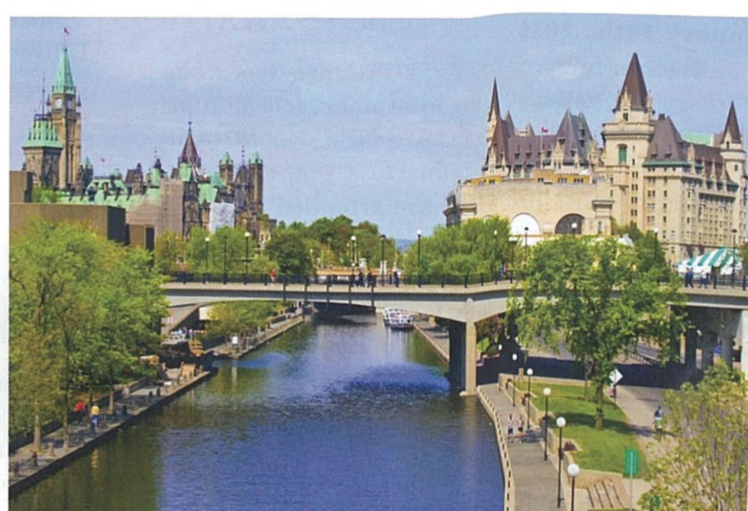

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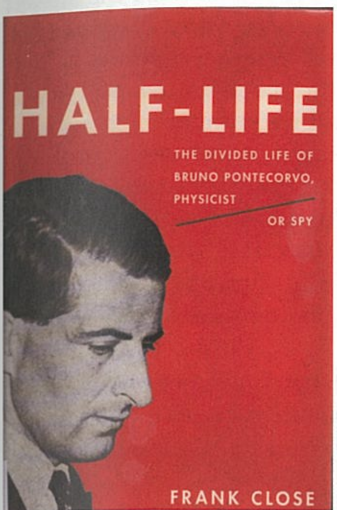
**Early bird registration ends July 31, 2016**

**Book Review** Reviewed by Michael Attas, CNS Manitoba Branch

# *Half-Life* By FRANK CLOSE (Basic Books, 2015)




The subtitle of this book, *The Divided Life of Bruno Pontecorvo, Physicist or Spy*, got me excited. Pontecorvo was one of the scientists who had worked at Chalk River during World War 2 and afterwards, but he had disappeared mysteriously in 1950. Perhaps Frank Close would solve the mystery?

The preface and prologue hinted that indeed the book would explain what happened, and why. Close mentions seeing new documents, formerly secret or lost, providing additional evidence that British and American security agencies suspected Pontecorvo of being a spy. That enticed me to read further. I also hoped to learn more about early nuclear research in Canada, and the origins of the Chalk River Laboratory. I was not disappointed.

The book, like Pontecorvo's life, is divided into two major parts: up to 1950, and beyond that date. In fact the events of 1950 are described in great detail, and could almost be considered a middle part, as that section is called Half Time. All along his narrative, Close takes pains to explain physics terminology such as slow neutrons and critical mass. He also does a good job unveiling the complex relationships between the British MI5 and the American FBI security & intelligence agencies, as well as activities of the Soviet spies controlled by the KGB and the GRU.

The pre-war and wartime events in Bruno Pontecorvo's life echo those of many other European scientists caught up in the rise of fascism. In the early 1930s he joined Enrico Fermi's dynamic nuclear physics group at the University of Rome, studying artificial radioactivity induced by neutron irradiation. The team puzzled over the erratic results until they realized that the fast neutrons from their radium-beryllium source became much more reactive after passing through wood, paraffin, or water. Close repeats the famous story of the team using a goldfish pond as the neutron moderator, but then casts doubt on its veracity. As he says (p. 21), "The story of Corbino's pond is so delightful that I hope it really happened."

As fascism grew in Italy, life for Jews became more difficult, even for non-practicing ones such as the Pontecorvo family. Bruno moved to Paris to work with Nobel-Prize-winners Irène and Frédéric Joliot-Curie. There he met his Swedish wife-to-be Marianne Nordblom, as well as the scientists Lew Kowarski and Hans von Halban, who were to join him in Canada. His engagement with intellectual Communism intensified at that time, though it was not always openly displayed. On the scientific side, he did research on nuclear isomers, and in 1939 on nuclear fission. But by 1940 he and his family had fled to the USA, where Pontecorvo was one of the first to develop neutron-based well-logging techniques and instrumentation for an oil-prospecting company.

Pontecorvo's neutron expertise and instrumentation background made him attractive to the nascent wartime Anglo-Canadian nuclear research program, set up in Montreal and later moved to Chalk River. He was recruited to Montreal early in 1943, following a lengthy process of security clearance. Close details the Montreal Project's ups and downs: alternating good and poor collaboration with the Americans, poor management (especially from Halban), and limited access to materials. By 1944 Pontecorvo had used his neutron methods for uranium prospecting in northern Canada, and by 1945 he was heavily involved in Kowarski's project to build ZEEP, Canada's first nuclear reactor. Close points out that ZEEP "was the brainchild of Alan Nunn May," the colleague who, after returning to Britain, was arrested and convicted in 1946 of spying for the USSR while in Canada.

Pontecorvo remained at Chalk River during the early postwar years, working on the NRX reactor design, but also expanding his talents in nuclear theory. He made significant contributions to the understanding of neutrinos (which had not yet been detected), muons, pions, and the weak nuclear force, as well as developing neutron detectors and the proportional beta counter. Close claims his theoretical advances were worthy of a Nobel Prize, but that was not to be.

The new British nuclear research centre at Harwell had courted Pontecorvo since 1945, but he and his family moved there only in early 1949. But his Communist sentiments were drawing the attention of the security agencies, and suspicion intensified dramatically after the physicist Klaus Fuchs was arrested at Harwell in February of 1950. Fuchs confessed to having passed secrets to the Soviets before, during, and after his time with the US Manhattan Project during the war. Pontecorvo was forced to leave Harwell and on July 24 he accepted a professorship in Liverpool, to begin a few months later.

The family's planned summer driving vacation to Italy began the next day, and Bruno seemed calm and happy well into August. But then, as Close reports, "events became strange," plans changed suddenly, and the family booked airplane tickets to Stockholm. They arrived on September 1, and then flew to Helsinki the next day. From there they were bundled into two cars–Bruno in the trunk!–and driven to St. Petersburg (then called Leningrad). No one outside the USSR heard anything from them for five more years, or even knew where they were.

In the second half of his book, Close recounts Pontecorvo's scientific and family life in the USSR. Sources for this period are less reliable, but doubtless the knowledge in Pontecorvo's head was very valuable to Soviet reactor development. Also clear is the isolation the family felt living at the mosquito-infested Dubna research site in the Russian woods, that contributed to Marianne's eventual mental breakdown. Bruno continued to follow trends in elementary-particle physics, and to conduct neutron experiments, but he was not allowed to publish or attend conferences. This isolation changed suddenly in 1955 with an article in the newspaper *Isvestia* and a press conference. Bruno explained that his desire for peace drove him to support the USSR, and that none of his research had military applications. His reappearance caused a media sensation, and one result was that his British citizenship was revoked. However, he continued to make seminal contributions to neutrino research, and was eventually allowed to travel within Europe. He died in 1993, of Parkinson's disease.

Frank Close has certainly illuminated many aspects of Bruno Pontecorvo's complex life. But on the essential question, whether he was a spy for the Soviets, the answer is still not definitive. Close seems convinced that he was, but admits there is no actual evidence. He notes that *someone* transmitted plans for the NRX reactor to the Soviet Union, and that it could not have been Nunn May. In any case, Close concludes, the knowledge Pontecorvo took with him to the USSR far outweighed any information he may have earlier sent on. And by fleeing to the East, he also suffered more than any "atomic spy" who had been arrested in the West. The physicist Freeman Dyson explored this last point in more detail in his article in the *New York Review of Books* (http://www.nybooks.com/articles/2015/03/05/scientist-spy-genius-bruno-pontecorvo/).

## IAEA Publication

### Ageing Management of Concrete Structures in Nuclear Power Plants

**IAEA Nuclear Energy Series No. NP-T-3.5**

This publication is one in a series of reports on the assessment and management of ageing of major nuclear power plant components. Current practices for assessment of safety margins (fitness for service) and inspection, monitoring and mitigation of ageing related degradation of selected concrete structures related to NPPs are documented. Implications for and differences in new reactor designs are discussed. This information is intended to help all involved directly and indirectly in ensuring the safe operation of NPPs, and also to provide a common technical basis for dialogue between plant operators and regulators when dealing with age related licensing issues.

STI/PUB/1654, 355 pp.; 211 figs.; 2016; ISBN: 978-92-0-102914-0, English, 55.00 Euro

Electronic version can be found: http://www-pub.iaea.org/books/IAEABooks/10659/Ageing-Management-of-Concrete-Structures-in-Nuclear-Power-Plants

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For information on CNS activities and other links – Pour toutes informations sur les activités de la SNC

**http://www.cns-snc.ca**

# Calendar

## 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

# Obituary

## Paul Philip Koenderman

The Canadian Nuclear Society (CNS) was saddened by the news of the death of Paul Philip Koenderman on Wednesday, January 27, 2016. He was killed as a consequence of an accident on Highway 400, when his vehicle was struck by a wheel that flew off a truck.

Paul was the Chairman of the Canadian Nuclear Association (CNA) 1990-91 at a time when the Canadian Nuclear Society (CNS) was the scientific and technical division of the CNA. Paul had served more than 10 years as President and CEO of the industrial business unit of Aecon Group Inc. in Burlington, Ontario. Prior to that, Paul had been the President and CEO (1987-2002) of Babcock & Wilcox Canada Inc. in Cambridge, Ontario throughout the 1990s. During his time at the head of B&W, the Cambridge plant was transformed into the principal facility in North America for the manufacture of steam generators.

During his time as Chairman of the CNA, Paul was noted for his leadership in the formation of the first national public information program by the CNA. He was the recipient of the Ian McRae Award of Merit in 2003.

# What a Canoe Teaches Us

by JEREMY WHITLOCK

Some wag once said that canoes are the closest humans have come to creating a perfect machine. Whether or not this notion holds water, the craft's historical consequence – without it, there would be no Canada (at least as we know it) – is without question. Less appreciated is the canoe's legacy to engineering design: it is a birch bark cornucopia of best practices, evolved from centuries of in-field, and largely indigenous, application.

Consider the following lessons in "good technology design", taught to us by our venerable deckless, keelless *bateau*:

1. **Minimization of moving parts:** The canoe has none. Or more correctly, it has one – the human driving it. The human is, after all, very much part of the machine: it is the motive force, the adjustable ballast, most of the mass, the steering mechanism, the guidance and stability feedback system, and the integral fuel tank. The canoe typically can go five km on one granola bar.
2. **Minimization of environmental footprint:** The craft itself leaves behind no impression of itself, adding nothing to the water or air, and only a mark in the sand that disappears with the next rain storm. It is silent, emission free, low in profile, and thus invites the operator to become an integral part of the world he or she is observing.
3. **Leveraging simplicity:** A paragon of efficiency, the canoe can transport many times its own weight while drawing inches of water (the leader in this category is the 7-metre *canot de maitre* of the Voyageurs – supporting 5 tonnes of men and cargo while weighing 140 kg empty.) Sturdy enough to carry people and freight by water, but light enough to be carried between waterways – the perfect craft for the Canadian Shield country.
4. **Incorporating cultural wisdom:** The European explorers and fur traders quickly dispensed with any technology they brought with them for travelling the waterways of the New World – and adopted the technology of the indigenous peoples. Learn from those that have walked the path before, listen to elders, park egos.
5. **Passive safety:** More of a contemporary design modification, canoes today typically include built-in bow and stern flotation that, while doing nothing to prevent ejection of occupants in the middle of a set of rapids, will raise the probability that the canoe (and the ultimate transportation out of the bush) makes it to the end of the rapids in one piece, even filled with water.
6. **Operational flexibility:** There is no correct way to paddle a canoe, only preferences. There is also neither a front nor back of the craft; its profile is symmetric. Solo paddlers typically face the opposite end that a pair of paddlers face, for reasons of optimal weight distribution. When needed, the canoe can serve as shelter – keeping the rain off during a portage, or even to sleep under (a common practice for Voyageurs).
7. **Available supply chain:** Whether cedar, birch bark or dugout, traditional canoes were manufactured from the materials found along the routes they were paddled, enabling speedy repair. Modern paddlers tend to substitute duct tape and fiberglass kits for spruce gum and roots – a little less elegant but somewhat more reliable.
8. **Ergonomic interface:** A canoe can be operated using a variety of body positions and paddle strokes, allowing not only adjustment to changing wind and water conditions, but periodic relief of muscles. If needed one can even stretch out and catch a nap. (As the late Pierre Berton pointed out, a true Canadian is capable of more than that, should the right partner come along.)
9. **Synthesis of needs:** The most abstract, and arguably most seductive, of the canoe's qualities: in one structure the craft combines the aggressive, exploratory, risk-taking, notionally masculine trait of the adventurer thrusting into the unknown, with the nurturing, protective, emotive, notionally feminine trait of the provider living sustainably with nature. The keen paddler, however incognizant of this metaphysical connection, likely senses its allure every time he or she crosses the gunwales.

Technologies come and go – yet despite vast improvements in materials and manufacturing (not to mention transportation alternatives), the canoe has thrived with essentially the same form and function for thousands of years.

Co-opting this technology from indigenous teachers was a wise choice for early colonials. Systematically disenfranchising the technology's inventors for centuries to follow, however, was a colossal failure of techno-social progress – only now beginning to be recognized. This is the final and perhaps most important lesson of the canoe.