The "Hail Mary" Strategy
for reactor safety at the Pickering Nuclear Station

why the Pickering Station should not be allowed to continue to operate beyond 2018

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The “Hail Mary” Strategy for CANDU Nuclear Safety

The CANDU reactor is quite different in design than other power reactors around the world.

For example, American “light-water” reactors have a large, thick-walled, pressurized reactor vessel in which all the fuel assemblies are installed vertically. By contrast, the CANDU core has hundreds of individually pressurized fuel channels running horizontally through a relatively thin-walled unpressurized vessel called a “calandria”.

Each fuel channel has a horizontal "pressure tube” containing uranium fuel bundles, surrounded by a concentric horizontal “calandria tube”. A gas fills the “gap” between the inner pressure tube and the outer calandria tube. Superheated (300 degrees C) coolant rushes through the pressure tubes, transferring heat from the uranium fuel to several huge boilers (“steam generators”) outside the core of the reactor. The boilers produce steam, the steam turns a turbine, and electricity is produced.

Each of the hundreds of fuel channels (about 400) is connected at both ends to “feeder pipes” that direct the hot coolant to the boilers and back again. Counting the pressure tubes, calandria tubes and feeders, there are more than 1500 items, all of which become radioactive and degraded over time. Altogether there are about seven kilometres of small-diameter piping in each CANDU reactor.

Technically, any break in a pressure tube or feeder pipe causes a Loss Of Coolant Accident (LOCA). Such an accident is a serious concern in any reactor. Even if the reactor is shut off, there is enough heat generated by the intense radioactivity of the irradiated fuel that a meltdown can occur. In fact, the TMI and the three Fukushima meltdowns all occurred after the reactors were completely shut off.

To make matters worse, when a CANDU suffers a LOCA, there is an immediate power surge, which — if not terminated within two seconds — will cause severe core damage, leading to a core disassembly. For this reason modern CANDUs have not just one, but two fast shutdown systems.

To prevent LOCAs in older CANDUs, designers specified a limit on how long a CANDU reactor can run before it is shut down permanently or “retubed”. That engineering limit is 210,000 effective full-power hours. In ordinary English, that’s about 30 years if the plant is running at 80 percent capacity.

Originally, retubing meant replacing fuel channels (pressure tubes and calandria tubes). They become embrittled by neutron exposure and they develop hydrogen blisters, making them prone to shatter under stress. But retubing has now been extended to include feeder pipes. Feeders are weakened by corrosion, but that’s not all. The wall thickness of a feeder pipe can be reduced by up to 60 %.

Ontario Power Generation (OPG) wants to run six (out of 8) Pickering reactors, located right on the doorstep of Metropolitan Toronto, for several years beyond the original limit of 210,000 hours.

Four of these reactors (the so-called Pickering B reactors) have never been retubed, nor does OPG have any plans to retube them. But — they don’t want to shut them down either! OPG had so much trouble retubing and then restarting 2 of the 4 Pickering A reactors, at a cost of over $2 billion, that they just decided to scrap the other two Pickering A reactors without bothering to retube them. Same with the 4 Pickering B reactors, except for one thing — OPG wants to run them anyway, without shutting them down or retubing them!

It’s a “Hail Mary” strategy. Run the reactors, and pray for protection.

Oh, and one other thing worth noting. The 2 remaining Pickering A reactors — unlike all other CANDUs, including Pickering B — do not have a second independent fast shutdown system.

Another “Hail Mary”?

Maybe not. Perhaps it’s an “Our Father” to accompany the previous “Hail Mary”.

Gordon Edwards, May 12, 2018. See also: www.ccnr.org/CCNR_CNSC_Pickering_2018.pdf

Canadian Coalition for Nuclear Responsibility | Regroupement pour la surveillance du nucléaire

To:	The Canadian Nuclear Safety Commission
From:	The Canadian Coalition for Nuclear Responsibility
Date:	May 7, 2018
Re:	Licence application for Pickering NGS

The Canadian Coalition for Nuclear Responsibility (CCNR) was founded in 1975. It was federally incorporated as a not-for-profit corporation in 1978. Since that time it has intervened in licensing hearings, participated in environmental assessments, and testified before committees, inquiries, and courts of law, in an attempt to ensure that the general population is adequately informed about the risks as well as the benefits of nuclear energy – from uranium mining to reactor operations, and from the proliferation of nuclear weapons to the management of radioactive wastes.

When, in the year 2000, the Atomic Energy Control Board (AECB) was replaced by the Canadian Nuclear Safety Commission (CNSC), we at CCNR rejoiced that, under the provisions of the Canadian Nuclear Safety and Control Act, the CNSC is to operate as a truly independent regulatory agency, able to make courageous decisions in the public interest without being swayed by economic or political considerations. We were thrilled to see that the CNSC is not only empowered but obligated "to disseminate objective scientific and technical information" relevant to its primary objective, which is to protect the health and safety of Canadian citizens and the Canadian environment.

Unfortunately, on the one notable occasion when the CNSC took a courageous and principled stand having to do with a licence violation associated with the operation of the NRU nuclear reactor at Chalk River, the President of the CNSC, Linda Keen, was publically shamed and discharged in 2008 by the Government of the day. At issue was the licensee's failure, for approximately two years, to fulfil its solemn undertaking to install a seismically qualified backup electricity supply unit in order to mitigate the effects of earthquake damage that might otherwise cause a total station blackout leading to severe core damage accompanied by large offsite releases of radioactivity. Ironically, it was just that same combination of seismic activity, total station blackout, and failure of all backup electricity supply systems that led to the triple meltdown at Fukushima just three years later.

Today the CNSC Commissioners are once again faced with an important decision affecting the public interest, and are called upon to show the courage that is required to set aside economic and political interests and act as a truly independent body whose sole duty is to protect the health and safety of the public and the environment. The Pickering reactors are too dangerous to keep operating. CCNR calls upon the CNSC Commissioners to withhold their approval of this licence extension request from Ontario Power Generation (OPG).

The Darlington and Bruce reactors are being "refurbished" at the cost of many billions of dollars. Why? It is for safety reasons. The pressure tubes, calandria tubes and feeder pipes are subject to multiple degradation mechanisms – embrittlement of pressure tubes caused by hydriding, longitudinal and diametric geometry changes of fuel channels induced by neutron bombardment, and pronounced wall-thinning of feeder pipes caused by flow-accelerated corrosion, to mention some of the most important factors.

Because of the high radiation fields in the core area of the reactor and the close proximity of feeder pipes just outside the core area, it is not possible to examine all the tubes all the time. Even a small loss of coolant accident can cause flow stagnation and fuel overheating in one or more channels, possibly leading to much more serious consequences in the core of the reactor, up to and including severe core damage. This is all the more likely when the tubes are embrittled and corroded, and the walls are unusually thin. The retubing of CANDU reactors is carried out in order to replace all these degraded components with brand new components in an attempt to remove all doubt about where the "weakest link" might be located.

However, OPG decided two decades ago NOT to refurbish the Pickering B reactors. Evidently, OPG made the same decision with regard to each of the Pickering B reactors that Hydro Quebec made in 2012 with regard to the Gentilly-2 reactor at Bécancour – to shut down the reactor rather than to refurbish it.

So these four reactors at Pickering B carry with them all the degraded internals that are being fastidiously replaced in other reactors that aren't even as old as these ones are. As the CEO of Hydro Quebec, Thierry Vandal, told the Quebec National Assembly in sworn testimony in 2013, regarding the Gentilly-2 nuclear power reactor:

> *[translation – see original in appendix] "While it is true that we have an operating license from the CNSC valid until 2016, it is not true, unfortunately, that we can operate this power plant until 2016. The permit that we received for continued operation included an important condition, I think, No. 16, that there be a mandatory stop at the end of 2012, after which we would do one of two things: either we would shut down the plant, which is what we have done, or we would begin the refurbishment.*
>
> *"We asked ourselves what should we do, because we really wanted to have a close look before proceeding. Well OK, that is what is the permit says, but would it be possible to do something different? Would it be possible to rework things so that we could continue to operate a little longer?*

"And then we looked at this question in the context of what, for us, is the ultimate date -- what I would call the extreme limit of operation -- the 210 000 hours, which is the design value for this power plant. When we shut down the plant [on December 29 2012], we were almost there, within a few hours, having run the plant for 198,000 hours since the very beginning. These are the hours of operation at full power. It is a measure of aging, if you will, of the plant components.

"So, for how many hours could we continue to operate from a safety point of view? You've talked a lot about safety issues, but I can tell you that Hydro-Québec's management in no way would have considered to go beyond 210,000 hours even if it was made possible by the design. I would no more operate Gentilly-2 beyond 210,000 hours than I would climb onto an airplane that does not have its permits and that does not meet the standards. So, it is out of question for us to put anyone, i.e. us, the workers, the public, and the company, in a situation of risk in the nuclear domain."

The Pickering B reactors have already operated beyond the time when retubing, or refurbishing, or else permanent shutdown, would have been mandated. Granting OPG's licence request would mean continuing to run these reactors even longer beyond their engineered design life, knowing that the full extent of degradation of fuel channels and feeder pipes cannot possibly be determined by OPG or by CNSC staff. It is compromising the safety of the population living close to Pickering NGS. That is something that CNSC has sworn never to do, and by law is forbidden to do.

By deciding not to refurbish the Pickering B reactors, OPG has committed itself to shutting them down. OPG cannot come back now and pretend that that decision was not already made. If CNSC is to be a credible agency it must deny this licence. The laws of physics are inexorable, the forces involved are powerful, the damage done is irreversible. Retubing is the only approach that would justify relicensing, unless CNSC wants to relax its commitment to "never compromise safety".

The two Pickering A reactors still in operation are among the oldest in the world. They have only one fast shutoff system each. All other CANDUs – including the four reactors of Pickering B – have two independent shutoff systems for safety reasons. American light water reactors do not require more than one fast shutdown system because they do not have a "positive void coefficient of reactivity".

Due to the pressure tube design of reactors such as those at Pickering and Chernobyl, there is a "positive void coefficient of reactivity". This means that if a loss of coolant occurs (e.g. due to a burst pressure tube or a pipe break) and voids form in the coolant, there is an automatic power surge due to an increase in the neutron flux. Unless this power surge is terminated very rapidly, in less than two seconds, there can be severe core damage and large releases of radioactivity from the core. In short, a catastrophic nuclear accident: a loss of coolant and a loss of regulation rolled into one.

Such devastating accidents have occurred in a number of pressure-tube reactors. The first was in the NRX reactor at Chalk River in 1952, due to a failure of the shut-off rods to perform their function. A series of hydrogen gas explosions occurred, hurling a four-tonne gasholder dome four feet through the air where it lodged in the superstructure. A million litres of highly radioactive water collecting in the basement of the plant was piped into shallow trenches offsite and allowed to sink into the soil. The core of the reactor was destroyed during this partial meltdown.

In 1969 a gas-cooled pressure tube reactor suffered a loss of coolant in Lucens, Switzerland, leading to the total destruction of the reactor. And then of course there is the devastating accident at Chernobyl in 1986, releasing about 80,000 terabecquerels of cesium-137 along with many other fission products, activation products and actinides into the environment.

The shocking example of the NRX partial meltdown and the realization that a total destruction of the core of a CANDU reactor can result from a failure to shutdown immediately following a loss-of-coolant accident (LOCA) convinced the CANDU establishment to require two independent fast shutdown systems. Even the Pickering A reactors had two shutdown systems: shut-off rods and moderator dump. (By dumping the moderator into a tank below the calandria, the nuclear chain reaction would come to a halt due to a lack of moderator.) However, it was later discovered that the moderator dump took far too long, requiring almost ten seconds before it was effective in stopping all fission. This was much too slow to stop a power surge and prevent core disassemby following a LOCA.

In 1993, Ontario Hydro was told by the Atomic Energy Control Board (AECB) to install a second fast shutdown system in each of the Pickering A reactors by 1997. But OPG did not want to comply and argued for a much cheaper solution – simply adding more shutoff rods. AECB eventually deferred to the licensee and allowed the cheaper solution to proceed, while recognizing that the Pickering A reactors still did not have two fully independent fast shutoff systems as required for other CANDUs. Knowing what we know now, these reactors should no longer be allowed to operate without two fully independent shutoff systems.

During the 1986 Chernobyl disaster in the Ukraine, only five per cent of the radioactive waste material inside the nuclear plant was released. Yet offsite radioactive contamination was so great that the region within a thirty kilometre radius of the crippled plant is still uninhabitable today – more than three decades later. It is sobering to realize that there are presently over two million people living within thirty kilometres of Pickering NGS. The prospect of such a highly populated region becoming uninhabitable is certainly daunting. Pickering NGS is without doubt one of the worst sited nuclear plants in the world. A nuclear disaster there could cripple Ontario's capital while ruining millions of lives.

Acknowledging that an accident can happen at any time at Ontario's nuclear plants, including those at Darlington and Pickering, the CNSC has issued a report entitled

“Study of Consequences of a Hypothetical Severe Nuclear Accident and Effectiveness of Mitigation Measures”. The report postulates a release of 100 terabecquerels of cesium-137 in such an event. The postulated release is 800 times less than the amount actually released from Chernobyl.

We at CCNR believe the CNSC postulated release is unrealistically low. In fact we regard the report itself as a misuse of scientific language, completely out of keeping with the CNSC’s legal obligation to disseminate “objective scientific information”. By severely underestimating the cesium release, and hence the degree of offsite contamination, the CNSC report provides dangerously misleading information. Such misinformation may seriously hamper proper emergency planning. More realistic assumptions might lead planners to envisage the evacuation of millions of people for extended periods of time, possibly several years.

CNSC’s assumed release is 100 terabecquerels of cesium-137. The CNSC report classifies this as a “large release”, but admits that it is the lowest amount of radioactive cesium-137 that could possibly fall into that category. In fact, 100 terabecquerels of cesium-137 represents the cesium-137 content of just nine irradiated fuel bundles out of the total inventory of more than 4500 bundles in each Pickering reactor core.

The CNSC report also asserts that no large release of cesium-137 can occur without “severe core damage”, described in CANDU literature as a “collapse of the core” or a “core disassembly” at temperatures near 1300ºC. Since radioactivity cannot be shut off, heat continues to be generated even after fission is arrested. Overheating derives from a failure to remove radioactive decay heat fast enough. In the CANDU literature, this is thought to cause progressive collapse of many fuel channels, leaving damaged fuel bundles in a heap near the bottom of the calandria.

At these elevated temperatures the “rupture discs” at the top of the calandria will burst to relieve the steam pressure, creating a pathway for other gases and vapours to exit the core, and expelling moderator water as well.. A large fraction (perhaps 20 to 40 percent) of the 50,000 terabecquerels of cesium-137 stored in the irradiated fuel bundles in the core will vaporize and escape out through the top of the reactor vessel (through the hole created by the destruction of the rupture disc).

Apparently, judging from the CNSC report, both CNSC and OPG believe that engineered systems will be able to prevent all but 100 terabecquerels of that 10 to 20 thousand terabecquerels of air-borne cesium-137 from reaching the environment. So we are to believe that tens of thousands of terabecquerels of cesium-137 will escape from the core of the reactor but never see the light of day? Despite severe core damage and a clear pathway into the reactor building atmosphere? The detailed calculations required to justify this controversial belief , if they exist, have so far not been made public by CNSC or by OPG.

Meanwhile, Pickering's irradiated fuel pools house 400 000 used fuel bundles at the present time. We will assume that the average "age" of these bundles is 10 years.

Average cesium-137 content of a new discharged fuel bundle is 10 to 15 terabecquerels.
Average cesium-137 content of a 10-year old used fuel bundle is 8 to 12 terabecquerels.
A conservative estimate (i.e. an underestimate) is to assume average bundle age is 10 years.

Collectively, the pools contain AT LEAST 3.2 to 4.8 million terabecquerels of cesium-137 – that's 40 to 60 times greater than the amount of cesium-137 released from Chernobyl.

If a Pickering irradiated fuel pool were deprived of cooling water for an extended period, or if the fuel bundles in the pool were physically crushed, or if the pool experienced a blazing zirconium fire, large releases of cesium-137 could occur. In the absence of structural damage to the buildings, these radioactive releases would go up the stack where activated charcoal filters are able to remove 99.9 percent of the cesium before it has a chance of reaching the outside air. However, structural damage could lead to a breach of containment and provide alternate pathways for the escape of cesium-137. Think of a plane crash for example.

Even without structural damage, if ONE QUARTER of the cesium-137 were released from damaged fuel in the pool, AND if 99.9 percent of that was removed by the stack filters, the amount making its way into the atmosphere would still be over 800 terabecquerels – more than 8 times greater than the "large radioactive release" assumed by the CNSC staff in its analysis of a "severe core damage" accident in a Pickering reactor.

Recently, the City of Toronto Health Committee held public hearings to reaffirm the City's status as a Nuclear-Weapons-Free Zone. I was asked to submit a short paper on the effects of nuclear weapons. In that submission I pointed out the following:

> *"According to the Nuclear Waste Management Organization (NWMO), there are over 400,000 irradiated fuel bundles in the spent fuel pools at Pickering NGS. Unlike the cores of the six operating rectors, each containing less than 2600 irradiated fuel bundles, these pools are not protected by heavily reinforced concrete structures. The blast and the incredible heat from the fireball of a nearby nuclear explosion would vaporize the water in the pools and ignite the zirconium cladding of the fuel bundles, creating a blazing inferno in the fuel pools of unprecedented proportions. Such a "fuel pool fire" has no containment structure to limit radioactive releases. Such a fire would release far more radioactivity into the environment than has been released hitherto by all 2000 test nuclear explosions conducted to date, as well as all previous nuclear core meltdowns, such as at Chernobyl and Fukushima Dai-ichi, thereby leaving a legacy of contaminated land that would remain totally uninhabitable for centuries.*

"Because there was relatively little local radioactive fallout from the Hiroshima explosion, the City could be rebuilt and is now a thriving metropolis. If there had been very heavy contamination of the City premises with long-lived emitters of intense gamma radiation such as cesium-137, reconstruction would have been difficult or impossible.

"If a nuclear weapon were to be targeted on or near Pickering NGS, it is likely that a large percentage of the irradiated nuclear fuel bundles in the spent fuel bays at Pickering NGS would be melted and or vaporized, liberating all the cesium-137 along with hundreds of other radionuclides contained in the spent fuel as gases, vapours or aerosols. According to data published by the Nuclear Waste Management Organization, the irradiated fuel bundles in the Pickering spent fuel pool contain an average of 10 trillion becquerels (10 terabecquerels) of cesium-137 per bundle. That amounts to 4 million terabecquerels of cesium-137 altogether, which is 50 times greater than the 80,000 terabecquerels of cesium-137 released by the Chernobyl nuclear disaster. Can anyone imagine the long-term consequences of fifty Chernobyl disasters happening simultaneously within 35 or 40 kilometres of downtown Toronto? I must confess, I cannot."

The sooner Pickering is shut down, the sooner the irradiated fuel in the pools can be put into dry storage – hopefully, in a "hardened" configuration away from the Lake.

The Pickering Nuclear Generating Station has outlived its usefulness and is becoming ever more dangerous due to aging tubes and pipes, failure to upgrade, increasing population density, and a more violent world than hitherto.

Commissioners, do not compromise safety.

Do not extend the licence of this plant.

Gordon Edwards, PhD, President,
Canadian Coalition for Nuclear Responsibility.
www.ccnr.org

The following is a verbatim excerpt from the Canadian Senate's Interim Report on CANDU Safety

"CANADA'S NUCLEAR REACTORS: HOW MUCH SAFETY IS ENOUGH?"

Upgrade of Fast Shutdown System

The most contentious of the planned improvements is the upgrade to the emergency shutdown system. As noted earlier, the removal from service of the four Pickering A reactors was, at least in part, due to Ontario Hydro's inability to meet a licence condition and deadline imposed by the AECB in 1993. The condition in question was the installation of an enhanced fast shutdown system by the end of December 1997.

The AECB began discussions with Ontario Hydro on upgrading the Pickering A reactors' fast shutdown system following the 1986 Chernobyl accident. The Pickering A units were built with only one fast shutdown system, in which control rods can be dropped into the reactor core to stop the chain reaction in the case of an emergency, within two seconds. A second shutdown system that stops the reaction by dumping the heavy water that moderates it, is also available, but takes more than ten seconds to be fully effective and so is said to be slow acting.

From 1986 until 1993, the AECB and Ontario Hydro were involved a closed-door discussion in which they "negotiated what the upgrade would be." The process was criticized by some observers who saw it as an example of an inappropriately close relationship between the regulator and the industry it regulates.

Four upgrade options were finally accepted by the AECB. They ranged from installation of a second, fully independent fast shutdown system to the much simpler addition of a small number of control rods to the existing 21 rods, division of the rods into two banks, and the addition of a separate set of sensors and trip mechanisms for each bank. Either bank of rods, operating alone would be able to shut the reactor down. In fact, as few as five control rods inserted into the core are capable of shutting down the reactor. Finally, in 1993, OPG decided on the latter option, and AECB gave its approval.

The Committee heard testimony questioning the rationale for accepting this particular upgrade, which, the AECB admits does not in fact constitute a second independent system. Witnesses from OPG stated that:

"There are not, currently, two independent shutdown systems available at Pickering A. However, the equivalent of two independent systems is being installed."

OPG officials also told the Committee that the fact that the more extensive upgrades would result in greater worker exposure to radiation was also a factor in deciding which option to pursue.

The Committee's consultant summed up the issue, stating:

"The agreed set of enhancements is a comparatively cheap option, and will not provide a second, independent fast-acting shutdown system."

Some witnesses also questioned the equivalency of the upgrade option and whether cost, rather than safety, was the deciding factor in the final decision. The expected cost of the approved enhancement is about $30 million (1995$), while the other options ranged from $127 million to $352 million.

One witness stated:

"There is no public access to the debate and the negotiations around what kind of upgrades will be done and whether there are in fact safety trade-offs being made to save money on the whole restart budget."

In light of the evidence:

> ***Recommendation 1:***
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> *The Committee recommends that the Canadian Nuclear Safety Commission "CNSC" maintain an arm's-length relationship with utilities when dealing with compliance to orders on critical matters of safety.*
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> ***Recommendation 2:***
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> *The Committee recommends that substantive discussions such as those related to the safety system upgrades be documented to the extent possible, that those documents be made publicly available and that the public be consulted before final decisions are made.*
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> ***Recommendation 3:***
>
> *The Committee recommends that the CNSC require thorough testing and monitoring of the shutdown system upgrade at Pickering A following its installation and make public all reports of its performance in tests and under operating conditions.*

Dr. Gordon Thompson, the Committee's consultant, noted further that none of the safety improvements promised by OPG have yet been subjected to or included in an appropriate risk assessment. As a result, there is no assessment of the impact of these proposals, on the overall risk profile of the Pickering Station. Before approval is given to restart Pickering it would be prudent to fill this knowledge gap.