Canada's Nuclear Sacrifice Area

Considerations related to the relicensing of the Chalk River Laboratories

a brief
submitted to the
Canadian Nuclear Safety Commission

by the
Concerned Citizens of Renfrew County

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September 6, 2011

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List of Recommendations:

1. **That the CRL licence application be split into several: one for the NRU reactor (and perhaps the Z-2 reactor as well), one for the isotope production operation (including FISST and HEU), one for the radioactive waste storage tanks and dumps (including the remediation work affecting degraded irradiated fuel elements, underground plumes and radioactive sediments in the Ottawa River), and one for the multitude of buildings, radioisotope laboratories, defunct facilities and other activities at CRL.**

2. **That the NRU reactor be licensed for one year – or 18 months – at the most.**

3. **That, in light of the Fukushima disaster, more planning and preparation be done to deal with the aftermath of even the most unlikely combination of failures at NRU.**

4. **That a large leak-proof enclosed reservoir be constructed close to the NRU reactor to accommodate large volumes of heavily contaminated water that may result from a catastrophic failure of the reactor vessel or other relevant SSCs.**

5. **As an important aspect of fostering and maintaining a healthy safety culture in the Canadian nuclear industry, CCRC urges the CNSC to require all workers and managers at Canadian nuclear facilities – as well as the CNSC staff – to study and pass written tests on the human and mechanical failures that led to such nuclear accidents as:**

Chalk River 1952 (NRX),	**Mayak USSR 1957 (Kyshtym),**
England 1957 (Windscale),	**Chalk River 1958 (NRU),**
Idaho Labs 1961 (SL-1),	**Switzerland 1969 (Lucens),**
Alabama 1975 (Browns Ferry fire)	**Pennsylvania 1979 (TMI),**
Ukraine 1986 (Chernobyl),	**Russia 1993 (Tomsk),**
Japan 1999 (Tokaimura),	**Japan 2011 (Fukushima Dai-ichi).**

Failure to pass such a test should necessitate further training in nuclear safety culture.

6. **That CNSC formally reassert its sovereign authority in licensing matters and its independence from the nuclear industry and from political or economic pressures. In addition, given the imminent change of management of CRL and the sale of AECL's reactor division to SNC-Lavalin, CCRC urges that none of the CRL facilities be licensed for more than two years, maximum.**

7. **That, in view of the importance of the NRU reactor, its unanticipated prolonged shutdowns during the current five-year licence period, and unresolved questions regarding its Fitness for Service, CNSC provide for a separate licensing process for the NRU reactor alone.**

8. **That the option of replacing the NRU reactor vessel be examined and discussed at a public hearing as soon as possible, and that a decision on this matter be taken within 12 to 18 months from now (September 6, 2011).**

9. **Given the age of the NRU reactor, the lack of a containment structure, and the lack of insurance, that CNSC require a worst case analysis of radioactive releases in the event of the most catastrophic failure of the NRU reactor, whether considered "credible" or not.**

10. **That CNSC require CRL to develop and deploy technical measures to drastically reduce the emissions of tritium oxide (also known as "tritiated water") into the Ottawa River.**

11. **That CNSC ensure that all radionuclides released offsite from CRL be identified in the licence documents, that the quantities of those releases be expressed in SI units, and that the principal pathways, target organs, and nature of the exposure (internal or external, alpha beta or gamma) be identified as well.**

12. **That AECL be required to provide a complete and detailed inventory of the radioactive and non-radioactive contents of the FISST, complete with a list of all relevant radionuclides contained therein and their estimated quantities in SI units.**

13. **That CRL be given a licence of two years at most to run the molybdenum-99 isotope production facilities, with a requirement that a complete set of plans be**

presented for dealing with the contents of the FISST and the decommissioning of the emptied radwaste tank before a new licence application will be accepted.

14. **That CRL be given a licence of two years at most to run the molybdenum-99 isotope production facilities, with a requirement that AECL develop plans for the production of molybdenum-99 using LEU only before a new licence application will be accepted. [LEU = low-enriched uranium]**

15. **That CNSC request the Government of Canada to ensure that there is no breach of the Bilateral Nuclear Cooperation Agreement between Canada and the United States associated with the repatriation of HEU irradiated fuel from CRL to the USA.**

16. **That CNSC require AECL to produce a complete and comprehensive map and inventory of radioactive waste materials within the CRL site, together with details as to the contents of each repository by radionuclide (in becquerels), and with detailed information on the physical and chemical condition of the waste materials.**

17. **That CNSC require AECL to produce a complete and comprehensive map and inventory of all known underground waste plumes, all available data on groundwater contamination, and all known instances of contaminated soil, together with the nature of the contaminants and the levels of contamination indicated in SI units.**

18. **That CNSC recommend to the Minister of Environment that a complete panel review of the Nuclear Legacy Liabilities Program be undertaken.**

19. **That CNSC undertake an extensive review of its regulatory culture at both the Staff and Commission levels, with the help of outside consultants.**

20. **That CNSC actively cultivate a sense of liaison and partnership with the public.**

21. **That CNSC disseminate objective and balanced information regarding the stochastic nature of cancer induction and genetic damage as well as the scientific evidence underlying the adoption of the linear no-threshold (LNT) model for radiation risks.**

Introduction:

Atomic Energy of Canada Limited (AECL) has submitted an application to the Canadian Nuclear Safety Commission (CNSC) requesting a renewal of the licence for the Chalk River Nuclear Laboratories (CRL) establishment for a period of five years.

Concerned Citizens of Renfrew County (CCRC) is a non-governmental organization of citizens living in the area as neighbours of CRL. CCRC is opposed to a five year licence extension of CRL for a variety of reasons, which will be presented in the following brief. CCRC is concerned about the past, present and future negative impacts of CRL on "the health and safety of persons and the environment." CCRC is also concerned about ensuring that Canada's obligations are met with regard to "the non-proliferation of nuclear weapons and nuclear explosive devices."

Coincidentally, these concerns are in agreement with those expressed in the Nuclear Safety and Control Act of 1997 – the Act that creates the Canadian Nuclear Safety Commission and gives it the authority to grant or withhold licences:

> **3.** The purpose of this Act is to provide for
>
> (*a*) the limitation, to a reasonable level and in a manner that is consistent with Canada's international obligations, of the risks to national security, <u>the health and safety of persons and the environment</u> that are associated with the development, production and use of nuclear energy and the production, possession and use of nuclear substances, prescribed equipment and prescribed information; and
>
> (*b*) the implementation in Canada of measures to which Canada has agreed respecting international control of the development, production and use of nuclear energy, including the <u>non-proliferation of nuclear weapons and nuclear explosive devices</u>.

Unfortunately there is little of substance in the application by AECL, or in the Comments by CNSC Staff, that directly addresses questions of health or the environment, or Canada's international obligations relating to nuclear weapons-usable materials. There is a lot of technical information about equipment and processes of all kinds, and a good deal of discussion of the importance of promoting a "nuclear safety culture" among workers and managers, but very little about off-site repercussions – past, present or future.

The Licence Application

CCRC believes that the current CRL licence application is far too complicated and unwieldy to facilitate a sober review at the level of Commission Hearings and public interventions. The documentation provided touches on a bewildering diversity of facilities, structures, processes, remediation efforts, waste dumps, radioactive emissions and leakages, and deals with them in a superficial and cursory manner. Evidently great efforts have been made in all these areas, but during the Day 1 Hearings, Commissioners were told that the CMD provided little more than a "snapshot" of the situation at CRL.

Yet within the licence application there are major issues of paramount importance, chief among them being the continued safe operation of the deteriorating 54 year old NRU reactor. Due to its prominent role in the production of medical radioisotopes and its prolonged shutdowns during the current licensing period, this reactor has made headlines around the world. Its continued safe operation is undoubtedly the single most important item of business for CRL. Even CNSC Staff are not convinced that NRU will remain fit for service for another five years without additional actions. It is telling that Staff has assigned a BE rating (Below Expectations) in relation to the NRU's Fitness for Service.

Then there is the isotope production process, involving the use of weapons-grade highly-enriched uranium (HEU) targets, which are first irradiated in the NRU reactor and then dissolved in acid to allow for the extraction of the fission product molybdenum-99 – the radioactive parent of technetium-99m, utilized in hospitals throughout the world for diagnostic purposes. There are unique security issues and international non-proliferation considerations surrounding the use of HEU, an immediately weapons-usable material, in a civilian context. And molybdenum-99 extraction results in high-level radioactive liquid waste that is stored in the Fissile Solution Storage Tank (FISST) – a multi-millennium legacy of radiotoxic materials in an acidic liquid solution. As everyone knows, CRL's role as isotope supplier has garnered a great deal of national and international notoriety.

And then there are the legacy radioactive wastes on the CRL site, which have been highlighted by the Auditor General of Canada as constituting a serious outstanding liability that will have to be paid for by the federal taxpayer. The total liability has yet to be accurately determined in dollar terms – although it seems clear that the price tag will be over $3 billion – and routine operations add to the liability year by year. Included are 14 old tanks of high-level radioactive liquid waste, numerous contaminated buildings and laboratories – as well as defunct facilities – that must undergo radioactive demolition work, several waste dumps of various descriptions on the CRL site, significant areas of contaminated soil and buried radioactive waste materials, contaminated groundwater, a number of underground plumes, and radioactive sediment at the bottom of Ottawa River.

Nor are these the only issues. There remains a multitude of buildings and radioisotope laboratories of all kinds on the Chalk River site operating at various hazard levels according to the international IAEA scale, any one of which would be worthy of its own separate CNSC licensing procedure if it were not geographically situated within the boundaries of the CRL site.

CCRC believes that the omnibus nature of the current licensing application is unwise, illogical and counter-productive. The degree of public and political interest in the future of Chalk River has never been greater, and expectations are high that the well-publicized problems at NRU and CRL will be addressed in a cautious and judicious manner by the regulatory agency.

Recommendation 1:

That the CRL licence application be split into several: one for the NRU reactor (and perhaps the Z-2 reactor as well), one for the isotope production operation (including FISST and HEU), one for the radioactive waste storage tanks and dumps (including the remediation work affecting degraded irradiated fuel elements, underground plumes and radioactive sediments in the Ottawa River), and one for the multitude of buildings, radioisotope laboratories, defunct facilities and other activities at CRL.

To approve the current omnibus licence application would be unwise, in the view of CCRC, because it may well contribute to a negative public perception: that CNSC does not regard each one of the above-mentioned features as being of sufficient merit to warrant a full and complete separate review by the Commissioners and by intervenors. Such a perception is not helpful in restoring public confidence to the CNSC licensing process following the regrettable events leading up to the "firing" of the previous Head of the CNSC by the Government of the day.

The sheer number and diversity of issues included in the present licence application tends to restrict the number of questions that can be asked by Commissioners about any one feature. And – given the normal time limitations at CNSC hearings – it prevents intervenors from focusing adequately on the impacts of each feature without omitting or glossing over the impacts of other features of equal or greater importance. The significance of each tends to be drowned in an ocean of technical details about the others. The result is that none of them is subjected to a sufficiently comprehensive level of public scrutiny.

Plan of the Present Submission

This paper will proceed to examine the various portions of the licence application according to the divisions outlined above, concentrating most attention on the NRU reactor, and then progressing to comments on the other topics in order.

Importance of the NRU Reactor

There is no doubt that the NRU reactor – one of the biggest, oldest, and most versatile research reactors in the world – is of enormous importance to Atomic Energy of Canada Limited (AECL) and to the Chalk River Laboratories (CRL).

This ingeniously-designed multi-purpose reactor is at the heart of three of the most important activities undertaken at CRL: (1) the production of a large fraction of the world's medical isotopes; (2) the Canadian Neutron Beam Centre used by researchers in science and industry both here and abroad; and (3) the testing of nuclear fuels and other materials for use in commercial power reactors.

In recent years – since CRL obtained its current five-year licence from CNSC in 2006 – the NRU reactor has also attracted national and international attention due to a series of dramatic events that made headlines around the world.

First came the "isotope crisis" of 2007-2008, precipitated by AECL's voluntary shutdown of the NRU reactor in November 2007 because of a failure of the facility to meet CNSC licence requirements. This was followed in December by the very public "firing" of Linda Keen as Head of the CNSC and the midnight passage of an emergency bill in the House of Commons to order the restart of the NRU reactor.

This remarkable sequence of events was accompanied by a dramatic declaration by then Minister of Natural Resources Gary Lunn that "people will invariably die" [sic] (due to a shortage of medical isotopes for diagnostic testing) if the NRU reactor were to remain shut down for two months or more. Eighteen months later, in 2009, the NRU reactor sprang a leak of radioactively contaminated heavy water coolant and had to be shut down for a duration of 15 months. But at that time no one was fired, panic did not ensue, and the reactor was not forced to restart until extensive repairs were carried out. And there were no deaths reported as a result of the isotope shortage caused by that shutdown.

All of this has made the NRU reactor the subject of a great deal of heightened public awareness and media attention. And that makes the licensing of this facility a matter of particular importance in terms of public safety and public perception. People wonder: "Is the CNSC truly in charge of safety, or not? Does it have the independence it needs?"

By rolling the relicensing of the NRU reactor in with all the other facilities at CRL, CNSC seems to be avoiding the question of who's in charge. When the Fitness for Service of NRU is judged to be "Below Expectations", and when CNSC Staff are insisting there be an extended shutdown of at least a month's duration every year to re-assess NRU's fitness for service, one is tempted to ask: "Why should NRU be given a five year licence under such conditions?" According to the omnibus licence application, it would be impossible to revisit the licence of NRU without reopening the entire dossier on CRL.

Recommendation 2:
That the NRU reactor be licensed for one year – or 18 months – at the most.

The Reason for the 2007 Shutdown

What precipitated the original crisis? In November 2007, it was brought to the Commission's attention that AECL had failed to connect a critically important safety system – an earthquake-resistant electrical supply system – to two of the eight main pumps used to cool the core of the NRU reactor. This electrical connection had not been carried out by AECL even though, more than a year earlier, it was made an explicit condition in the 2006 licence that had been granted to CRL by CNSC.

The idea behind the NRU emergency electrical system is simple: in case of a severe earthquake that might knock out the grid and the other backup electrical supply system, the earthquake-resistant backup electrical system would still be available to run some of the pumps (two out of eight) – enough to keep the core cooled, and prevent overheating, after shutdown. Naturally, if the pumps are not connected to that emergency electrical supply, the entire purpose is defeated.

Canadians can now better understand the important nature of this emergency requirement by reflecting on the recent Japanese disaster. For it was precisely the failure of the cooling pumps at Fukushima Dai-ichi, due to a total electrical blackout both off-site and on-site, which in turn was caused by an earthquake and tsunami, that led to the enormous damage suffered at the reactor complex. Because of the failure of electrical power, three of the six reactor cores suffered total meltdowns, and several of the spent fuel pools severely overheated as well – thereby precipitating the greatest nuclear catastrophe ever to occur in a technologically advanced democratic nation such as Japan.

A sober assessment of the lessons of Fukushima suggests that the earthquake threat to the NRU reactor should be taken very seriously indeed, and it should be recognized that – as Edward Teller was fond of saying – "There is no such thing as a foolproof system, because the fool is always greater than the proof."

Recommendation 3:
That, in light of the Fukushima disaster, more planning and preparation be done to deal with the aftermath of even the most unlikely combination of failures at NRU.

The NRX Accident

While a catastrophe on such a scale as Fukushima Dai-ichi could never occur at the NRU reactor due of its much smaller size, it is a matter of public record that the NRX reactor (a much smaller predecessor of the NRU) experienced the world's first major nuclear accident, at Chalk River, in 1952. NRU is about 10 times larger than the NRX.

Due to a combination of mechanical and operator errors, the NRX reactor suddenly went out of control and rapidly overheated, causing a series of explosions that threw the four-tonne gasholder dome several feet through the air where it lodged in the superstructure, allowing the release of a significant plume of radioactive gases, vapours and cinders into the atmosphere. The original NRX reactor core was totally destroyed; it is buried as a highly radioactive piece of junked equipment on-site at CRL in some unspecified location.

A flatbed truck used to move the intensely radioactive NRX reactor vessel to its "final" resting place had to be driven by a relay team of drivers, each one spending just a very short time in the cab of the truck – putting it into gear, driving it a bit, taking it out of gear, and then running away to make room for the next driver – in order to keep individual radiation doses to a minimum. Some radioactive material accidentally dripped onto the roadway; that portion of the road was dug up and buried as radioactive waste.

Over 600 military personnel – both Canadian and American – were sent to Chalk River to help clean up the mess, including young Jimmy Carter who was then serving in the U.S. Navy's nuclear submarine corps under Admiral Hyman Rickover. Over a million gallons of heavily contaminated water was sluiced into shallow earthen trenches on the Chalk River site as there was no other place to dump the radioactive liquid.

Following the Fukushima disaster, enormous volumes of contaminated water were dumped into the ocean because there was nowhere else to dump it. If the patched-up reactor vessel at NRU were to suffer a major failure, an awful lot of water would have to be flushed through the core to keep it cooled. How would this contaminated water be kept out of the Ottawa River?

Recommendation 4:
That a large leak-proof enclosed reservoir be constructed close to the NRU reactor to accommodate large volumes of heavily contaminated water that may result from a catastrophic failure of the reactor vessel or other relevant SSCs.

As in the case of the vacuum buildings at Pickering, Darlington and Bruce, the best thing that could happen is that such a reservoir would never have to be used. But it would be irresponsible not to have it available.

The Staff have commented that they still do not yet have a satisfactory demonstration from AECL that a large loss-of-coolant accident at NRU is within acceptable regulatory limits. CCRC would like to add however that even with such a demonstration, the backup would still be prudent, as mathematical projections of probability are not binding on reality.

The Nuclear Safety Culture

In a sense, the NRX accident is ancient history and is no doubt forgotten by many. But in another sense, it is an ever-present reminder of the necessity of abiding by Alvin Weinberg's adage enunciated in the Bulletin of Atomic Scientists in 1972: "We nuclear scientists have made a Faustian bargain with society. We offer an inexhaustable source of energy, but in exchange we require eternal vigilance."

In order to maintain eternal vigilance, nuclear workers and managers – and regulators – can never allow themselves to forget the awesome consequences of even seemingly small mistakes or oversights. In large measure, that is what "Safety Culture" in the nuclear industry is all about, or should be all about. Nothing concentrates the mind more than a realistic appreciation of the totally unacceptable scenario of a massive reactor accident due to oversight or design error.

The President's Commission on Three Mile Island (TMI) concluded in 1979 that the single most important cause of the TMI accident was the inappropriate belief on the part of workers and managers – and regulators – that nuclear power is inherently safe, when in fact it should be regarded as an inherently dangerous technology. Unless this attitude changes, said the final report, further accidents of a similar severity will inevitably occur.

> *To prevent nuclear accidents as serious as Three Mile Island, fundamental changes will be necessary in the organization, procedures, and practices – and above all – in the attitudes of the Nuclear Regulatory Commission ...*
>
> *... wherever we looked, we found problems with the human beings who operate the plant, with the management that runs the key organization, and with the agency that is charged with assuring the safety of nuclear power plants ...*
>
> *After many years of operation of nuclear power plants, with no evidence that any member of the general public has been hurt, the belief that nuclear power plants are sufficiently safe grew into a conviction…. The Commission is convinced that this attitude must be changed to one that says nuclear power is by its very nature potentially dangerous, and, therefore, one must continually question whether the safeguards already in place are sufficient …..*

http://www.pddoc.com/tmi2/kemeny/attitudes_and_practices.htm, pages 1 and 2.

Recommendation 5:

As an important aspect of fostering and maintaining a healthy safety culture in the Canadian nuclear industry, CCRC urges the CNSC to require all workers and managers at Canadian nuclear facilities – as well as the CNSC staff – to study and pass written tests on the human and mechanical failures that led to such nuclear accidents as :

Chalk River 1952 (NRX),	**Mayak USSR 1957 (Kyshtym),**
England 1957 (Windscale),	**Chalk River 1958 (NRU),**
Idaho Labs 1961 (SL-1),	**Switzerland 1969 (Lucens),**
Alabama 1975 (Browns Ferry fire)	**Pennsylvania 1979 (TMI),**
Ukraine 1986 (Chernobyl),	**Russia 1993 (Tomsk),**
Japan 1999 (Tokaimura),	**Japan 2011 (Fukushima Dai-ichi).**

Failure to pass such a test should necessitate further training in nuclear safety culture.

The Authority and Independence of the CNSC

When the CNSC renewed the NRU operating licence for five years in 2006, it was understood that seven safety upgrades for NRU had already been installed and were fully functional. One of those was the earthquake resistant DC electrical source, required to ensure a hazard-qualified power supply for the other six safety upgrades (which were: a second independent reactor trip system, a qualified emergency response centre, a new emergency core cooling system, a main pump flood protection system, and a liquid and gaseous confinement boundary).

The Commissioners were understandably shocked when they discovered a year and a half later that the necessary electrical connections had still not been made. Shock turned to anger when an AECL spokesman told the Commission his understanding was that it was standard procedure within the nuclear industry to report that specific improvements had been made even when they hadn't, provided that there was a firm commitment to eventually make those improvements.

It was not the first time that this licensee had misled the Commission on matters of regulatory concern. Some time earlier, it had been revealed that radioactive liquid wastes were still being sluiced into earthen trenches long after the CNSC had been assured that this "disposal" practice had been completely and permanently discontinued at CRL. Such actions on the part of the licencee undermined the authority of CNSC in the public eye, calling into question the validity and the efficacy of the Canadian regulatory process.

To make matters worse, when the Government of Canada intervened in the regulatory process, urging and then forcing the restart of the NRU, apparently against the wishes of the Commissioners, not only the authority but also the independence of the CNSC was dragged into disrepute. Linda Keen, President of the CNSC, was accused of not acting in the public interest by the Prime Minister in the House of Commons, and was subsequently relieved of her responsibilities, as if she – and not AECL – had been responsible for compromising public safety. This action shocked many Canadians. In the minds of some, CNSC had in effect been put into trusteeship by the Government, with new marching orders: don't let licence disputes interfere with isotope production.

It later came to light that some CNSC Staff members were well aware of the fact that the NRU electrical connections had not been made, but failed to inform the Commissioners.

More recently, the Government of Canada has sold the reactor division of AECL and has indicated its intention to re-examine the management of Chalk River Laboratories.

Recommendation 6:
That CNSC formally reassert its sovereign authority in licensing matters and its independence from the nuclear industry and from political or economic pressures. In addition, given the imminent change of management of CRL and the sale of AECL's reactor division to SNC-Lavalin, CCRC urges that none of the CRL facilities be licensed for more than two years, maximum.

The MAPLE Reactors

Other developments at CRL further undermined public confidence in AECL and the CNSC. The NRU reactor, already half a century old, was well past its planned retirement age. AECL had announced to the world a decade earlier that two brand new Multipurpose Applied Physics Lattice Experiment (MAPLE) reactors – MAPLE I and MAPLE II – would be taking over the job of isotope production at Chalk River. Each MAPLE would be able to satisfy the entire world's demand for medical isotopes. This would allow the NRU reactor to be permanently retired by the year 2000 or 2001.

But the MAPLE reactors exhibited a fatal design flaw, referred to as a "positive power coefficient of reactivity". In other words, the reactors had an unfortunate tendency to "run away" whenever the power level was increased – an undesirable and potentially unsafe trait. A large positive power coefficient would be dangerous since it would require a very fast control system to maintain stability.

The AECL engineers who designed the MAPLE reactors were perplexed. They had specifically built these reactors to have a NEGATIVE power coefficient of reactivity. In 2009, after a decade of trying – and failing – to understand why the reactors were misbehaving as they were – despite the combined efforts of AECL, CNSC, the Idaho Nuclear Laboratory and several other prestigious centres of nuclear research – the MAPLE reactors were scrapped and slated for dismantling, without ever having performed a useful function. Public confidence in AECL slumped, and the community of nuclear medicine practitioners was left dumbfounded when the bad news finally came out. The promised land of secure isotope supply through MAPLE had evaporated.

It did not escape public notice that the production of isotopes at Chalk River – and the continued operation of the NRU reactor for that purpose – is very much in the financial interests of a profit-making private company, Nordion, that sells those isotopes. In 2008 Nordion launched a multi-billion dollar suit against AECL and the Government of Canada:

> Nordion is seeking against AECL … damages in the amount of C$1.6 billion for negligence and breach of contract … and, against the Government of Canada, Nordion is seeking … damages in the amount of C$1.6 billion for inducing breach of contract
>
> AECL and the Government of Canada also announced on May 16, 2008 that their decision to discontinue the MAPLE Facilities project would not impact the current supply of medical isotopes; that AECL would continue to supply medical isotopes using the NRU reactor; and that AECL would pursue an extension of the NRU reactor operation beyond the expiry date of its current license of October 31, 2011.
>
> *Nordion's Annual Information Form for the period ending October 31, 2010, p.41*
> *http://www.nordion.com/reports/2010_engaif.pdf*

Again there is a strong suggestion that CNSC might not really be in the driver's seat. Perhaps the CNSC Commissioners and the Staff do not see it that way, but without a separate hard-hitting licensing process for the NRU reactor it is difficult to dispel such suspicions and restore confidence in the independence of the regulatory agency.

Recommendation 7:
That, in view of the importance of the NRU reactor, its unanticipated prolonged shutdowns during the current five-year licence period, and unresolved questions regarding its Fitness for Service, CNSC provide for a separate licensing process for the NRU reactor alone.

The NRU Reactor Vessel Leak of 2009

In May of 2009 AECL discovered that the NRU reactor was leaking heavy water coolant from the core of the reactor. This unwelcome news came close on the heels of the earlier shutdown and isotope crisis. CNSC Staff were particularly chagrined, for they had been assured by AECL during the 2005-2006 licence application that the NRU was "Fit for Service" for the five year period of the licence. Not true, as it was now evident.

Investigation revealed that the lower portion of the reactor vessel was badly corroded, the wall of the vessel had become quite thin in places, and there were two separate penetrations right through the wall of the vessel. None of this had been noticed or reported during the 2005-2006 CRL licence application, by AECL or by CNSC, despite the past history – decades earlier – of the NRU reactor vessel becoming corroded and requiring replacement. Long before the 2009 shutdown it was apparent to informed observers that another calandria replacement was likely just around the corner:

> NRU's calandria, the vessel which contains its nuclear reactions, is made of aluminum, and was replaced in 1971 because of corrosion. But it has not been replaced since, although this second replacement is likely needed. A complete shutdown of perhaps one year would be needed for the replacement. One strong advantage of NRU's design is that it can be taken apart to allow for replacements such as this.
>
> http://en.wikipedia.org/wiki/National_Research_Universal_reactor

Given this history, it is very surprising – after evidence of extensive corrosion in 2009 – that apparently neither AECL nor CNSC Staff insisted on, or even suggested, having the NRU calandria replaced with a new one. Instead they proceeded to repair the corroded and compromised vessel – likely incurring far greater radiation doses for workers and perhaps requiring an even longer shutdown than would have been needed for vessel replacement. AECL's 2010 request to restart NRU revealed that the old vessel had not even been fully assessed for damage, even though CNSC Staff were consulted throughout:

> A comprehensive condition assessment of the NRU reactor vessel was performed by AECL to evaluate the state of the vessel, the extent of the corrosion damage, the general fitness for service and the proposed repair option. <u>CNSC staff defined the necessary assessment areas</u> ….
>
> Video inspections of the exterior of the reactor vessel wall were performed by AECL to identify corroded areas, signs of leakage, and any other anomalies ….
>
> There have been active leak areas in the reflector for a long time. The visual inspection results showed widespread corrosion around the base of the annulus at the lower vessel wall. In some locations, the lip … was corroded away and the gutter filled with corrosion products.
>
> AECL used the results of the visual inspections to perform Non-Destructive Examinations (NDE), using Ultrasonic Testing (UT) and Eddy Current Testing (ET) to determine the wall thickness and to gain an understanding of the vessel condition.
>
> The pre-repair NDE was divided in 4 phases as more advanced NDE and tools were developed with the goal of providing a 100% scan of the vessel's circumference <u>at the elevation of the leak and at any other areas of concern.</u>

> The results [Refs. 5 to 9] confirmed heavy corrosion at the floor level of the annulus but revealed only limited corrosion in the rest of the vessel.
>
> In the region of heavy corrosion, two types of corrosion features were revealed by the NDE. Regional corrosion producing a scalloped area of reduced wall thickness above the annulus floor and highly-localized deep corrosion pockets at the level of the annulus floor. Such a deep corrosion pocket was responsible for the leak and the NDE revealed another location of through-wall corrosion ….
>
> AECL inspection program covered the full circumference of the vessel at the elevation of the leak as well as thickness profiles over the full height of the vessel at designated locations. CNSC staff considers the NDE results provided by AECL are adequate to determine areas requiring repair in that they provide an overview of the morphology and the extent of the vessel wall loss.
>
> CMD_10-h12-1.pdf p. 13 (pdf)
> 3.1 Vessel Condition Assessment

Due to the still-uncertain condition of the reactor vessel, as well as other conditions related to the aging of the plant, CNSC Staff has recommended a planned outage of at least one month a year to reassess the Fitness for Service of NRU. CCRC has earlier recommended that the NRU licence be approved for one year only, or for a maximum of 18 months.

Recommendation 8:
That the option of replacing the NRU reactor vessel be examined and discussed at a public hearing as soon as possible, and that a decision on this matter be taken within 12 to 18 months from now (September 6, 2011).

A Caveat on the Continued Operation of NRU

For the record, CCRC does not consider it reasonable or acceptable to expose the people of the Ottawa Valley to the inherent risks associated with continuing to operate the geriatric NRU nuclear reactor.

CCRC does not have confidence that this reactor will be operated safely for years to come. Nor does CCRC – or, apparently, CNSC Staff either – have full confidence in the competence of those in charge:

> The SCA [Safety and Control Area] 'Management System' covers the framework that establishes the processes and programs required to ensure an organization achieves its safety objectives, continuously monitors its performance against these objectives and fosters a healthy safety culture. The compliance rating for this area is Below Expectations based on long-standing Deficiencies.
>
> *page 20, CMD 11 H-7, Evaluation of Licence Application, May 2011*

AECL managers at CRL are the ones who decreed that the NRU should be retired in 2000. They are the ones who secured funding to build two new MAPLE reactors to replace the NRU, yet failed to get those small 10 megawatt reactors to function safely. They are the ones who, in 2005-2006, assured CNSC Staff that the NRU vessel was fit for another five years of operation.

CCRC has no confidence that these individuals can be trusted to safely operate a reactor 20 times more powerful than the MAPLES for 5-10 years, with a patched-up and corroded reactor vessel, and with aging systems and components. In the past, CRL managers have kept CNSC in the dark about the true state of the NRU reactor on more than one occasion.

In nuclear matters, given the stakes, people must know where to put their trust. CCRC believes that the CNSC Commissioners bear not only a legal, but a personal moral responsibility to ensure that political, economic, or bureaucratic expediency is not allowed to compromise the health and safety of persons and the environment.

If the NRU reactor were to suffer a catastrophic reactor vessel rupture, a large quantity of radioactive fission products could enter the atmosphere and flood into the Ottawa River – perhaps drifting over the Nation's Capital, possibly tainting the drinking water of millions. Commissioners need to be better informed about the scope of these potential hazards.

Recommendation 9:
Given the age of the NRU reactor, the lack of a containment structure, and the lack of insurance, that CNSC require a worst case analysis of radioactive releases in the event of the most catastrophic failure of the NRU reactor, whether considered "credible" or not.

Mitigating Radioactive Releases at CRL

CCRC would like to highlight the discrepancies that exist in how two different instances of radioactive releases – one onsite, and one offsite – are treated by CNSC and AECL at CRL. Both examples deal with the release of tritium into the environment. CCRC believes the difference in approaches is instructive and revealing.

Case 1. The NRU Rod Bay Leak (on-site)

The first instance deals with a leak of tritium-contaminated water from the NRU Fuel Rod Bay, where irradiated fuel rods extracted from the NRU reactor are stored. The problem of eliminating the leak is addressed with determination and a variety of technical measures:

> AECL reported the leak of tritiated water from the NRU Reactor rod bays in 2006. At the time of licence renewal, additional monitoring wells were installed in the sand space around the rod bays and the analyzed water was found to contain radionuclide contamination and chemical characteristics that generally match the water in the rod bays.
>
> During the licence period, AECL has undertaken several initiatives to mitigate the rod bay leakage, including:
> • repairs to accessible rod bay walls by grouting seams and visible cracks;
> • reduction of tritium in the moderator by replacing the heavy water inventory in 2010.
>
> AECL had planned to encapsulate the NRU Reactor rod bays to reduce leakage into the environment. Based on low predicted efficiency, these plans

> have been cancelled. Instead, engineering efforts have been applied to develop additional mitigating options for the rod bay leakage.
>
> Future activities to reduce the impact of tritium, mostly covered by the Isotope Supply Reliability Program (ISRP) funding include [39]:
> • Reduction of tritium carry-over to the rod bay.
> • NRU Reactor rod bay water replacement. Full replacement of the rod bay water inventory is planned for November 2011, with a final target date, as per IIP [7], of June 2012. This involves the replacement of 1.2 million litres (1200 m^3) of water using the "thermo-stratification" principle to maximize the tritium level reduction. The water removed is to be stored in storage tanks at site. This storage facility is currently being constructed.
> • Design and construction of a light water detritiation facility (LWDF) to process low tritiated water, including the water removed from the rod bays. This project is targeted for 2015.
>
> … CNSC staff are satisfied with the actions taken by AECL to date. CNSC staff have accepted the plans proposed by AECL to continue to minimize, as low as reasonably possible, the tritium impact on both workers' hazards and uncontrolled releases to the environment.
>
> CMD 11-H7, Staff Comments, Section E.2, p.111 [pdf]

It is gratifying to observe the impressive variety of persistent efforts being made at CRL to reduce the amount of tritium leaking from the NRU rod bay, ranging from such simple measures as grouting the walls to such ambitious tasks as replacing over one million litres of contaminated water from the rod bays, putting it into storage tanks, and building a detritiation facility. Moreover, CNSC is right on the job, to ensure that tritium hazards to workers and releases to the environment are minimized "as low as reasonably possible".

During the Day 1 Hearings, Ramzi Jammal made it clear that the objective is to reduce the leakage – and the hazard – to zero, and that CNSC will hold AECL to it:

> There has been a continuous decrease of the leak or the -- "la fuite" – from the Rod Bay with respect to the tritium. They've taken multiple actions and multiple measures because -- the reason I know this is because I had to approve them, and we were in direct communication with the CNO [Chief Nuclear Officer] and we gave them the approval in order to put those actions in place. So the reduction has been -- has taken place, and it has been a huge reduction. Are we going towards zero? We would love to go towards zero, but again it's based on the impact, and we're going towards zero, and AECL will have to commit towards zero over a period of time.
>
> Ramzi Jammal, Transcript, page 77

Although not an explicit example of ALARA Principle (to keep all radiation exposures "As Low As Reasonably Achievable"), CNSC Staff is clearly motivated here by a similar philosophy. The goal is to become non-polluting and risk-free by achieving zero emissions.

Case 2. Tritium Effluents into the Ottawa River (off-site)

The bulldog-like determination of CNSC Staff to reduce emissions by all means possible, so evident in the above example, somehow vanishes entirely when it comes to tritium leaking into the Ottawa River:

> The NRU Reactor rod bay leak constitutes a minor amount of the total quantity of water released from the CRL site to the Ottawa River, and tritium concentration downstream from the CRL site (approximately 8 Bq/L at Petawawa) is well below the most stringent standards for drinking water. Therefore, CNSC staff consider the impact on the public due to this leak to be negligible.
>
> CMD 11-H7, Staff Comments, Section E.2, p.111 [pdf]

There is an interesting discrepancy in attitude here. While it is acknowledged that far more tritium is pouring into the Ottawa River every day than is leaking from the NRU Rod Bay, there is no discussion whatsoever of any efforts by CNSC or AECL to minimize those releases "as far as reasonably possible". It's as if the CNSC is only concerned with onsite risks and impacts and not with offsite risks and impacts – exactly the opposite of what one might be led to expect by reading the mandate of the CNSC as laid down in the Act.

It seems the public is not as deserving as CRL workers to have their tritium hazards reduced to zero or "as low as reasonably possible". It seems the Ottawa River – a source of drinking water for millions of people downstream – is less deserving of becoming risk-free and uncontaminated than the area around the NRU Rod Bay located on the CRL site.

In fact the overwhelming impression that emerges from the licence application and the Staff Comments is that only onsite activities are of interest or importance, and then almost entirely from a physical or engineering point of view. There is virtually no discussion of levels of radioactive contaminants in fruits and vegetables, in rainfall or snowfall, in animals and fish, or in human beings. There is no discussion of radioactive contamination finding its way off site by way of animals, birds, insects or humans. Or even by wind and weather. Nor is there any indication of how these radioactive materials could adversely affect human beings or other living things if they do escape from the site. It is if the CRL staff and the CNSC staff are working side by side in a hermetically sealed box, shut off from the "real world" of bustling communities, living things, and healthy food and drink.

Nor does the CNSC Staff make it clear that, ironically, the largest and most significant "source" of radioactive tritium going into the Ottawa River is the CRL Waste Management Facility – because that facility does nothing to remove tritium from the waste streams.

CCRC finds it unacceptable that no explicit consideration is given to drastically reducing the amount of tritium going into the Ottawa River every year from the CRL site. Where are the mitigation measures we saw in the case of the NRU Rod Bay leak? Where are the ingenious engineering strategies? Where is the determination of CNSC Staff to bring about zero emissions, by setting goals and targets for AECL to achieve? Where is the detritiation plant, such as the one that has been promised for the NRU Rod Bay Pool?

Recommendation 10:
That CNSC require CRL to develop and deploy technical measures to drastically reduce the emissions of tritium oxide (also known as "tritiated water") into the Ottawa River.

Although CNSC Staff and AECL do not regard the tritium levels in the Ottawa River to constitute an unacceptable health risk, it is unjustifiable to assert that there is no health risk whatsoever, as this is not supported by the best available scientific evidence. When millions of people are chronically exposed to even a small annual dose, year after year, fatal and non-fatal health effects can indeed occur as a result. As these tritium exposures offer no benefit to those exposed, the ALARA principle should be applied in full force.

Reporting Radioactive Emissions from CRL

The expressed purpose of the Nuclear Safety and Control Act (see Article 3) is to limit the "risks to the health and safety of persons and the environment that are associated with the development, production and use of nuclear energy," as well as risks to national security.

In article 8 of the Act, the CNSC is created as an agency of Her Majesty, and in article 9 the duties of the CNSC are laid out as follows:

> **9.** The objects of the Commission are
>
> (*a*) to regulate the development, production and use of nuclear energy and the production, possession and use of nuclear substances, prescribed equipment and prescribed information in order to
>
> (i) prevent unreasonable risk, to the environment and to the health and safety of persons, associated with that development, production, possession or use,
>
> (ii) prevent unreasonable risk to national security associated with that development, production, possession or use, and
>
> (iii) achieve conformity with measures of control and international obligations to which Canada has agreed; and
>
> (*b*) to disseminate objective scientific, technical and regulatory information to the public concerning the activities of the Commission and the effects, on the environment and on the health and safety of persons, of the development, production, possession and use referred to in paragraph (*a*).

Apart from national security matters and international obligations, the role of the CNSC is to protect and to instruct. The health and safety of persons is to be protected, along with the environment. The public is to be instructed, in an objective and scientific manner, about the effects on health and the environment that might be caused by licensed facilities.

In the CRL licence application, it is clear that a great deal of effort is expended by CNSC Staff to oversee the licensee's work in plugging leaks, repairing or emptying defective waste storage tanks, retrieving and consolidating degraded irradiated fuel wastes, securing or dismantling radioactive buildings and equipment, monitoring the movement of underground plumes of radioactive material, upgrading and maintaining the safety systems of reactors, reporting radioactive effluents and incidents, and so forth. But there is a dearth of information concerning those aspects that are central to the role of the CNSC according to the Act: the actual and potential effects on the health and safety of persons and the environment as a result of all these activities.

CNSC Staff actions are clearly important, as they are ultimately oriented towards preventing risks to the health and safety of persons and the environment, but the connection is never made altogether clear. The nature of the risks is never explained or quantified. The word “cancer”, for example, is never even mentioned. The concept of “genetic effects” is equally absent. The most likely pathways of radioactive materials released from CRL through the environment to human and non-human receptors are nowhere described. There is no mention that women may be more vulnerable to tritium exposure than men – even though this finding comes from research conducted at CRL – or that children and embryos are much more susceptible to radiation damage than adults.

But the problem is much more basic than that. Profound differences exist in the risks and environmental characteristics of diverse radioactive materials. These are nowhere addressed. For example, in CMD 11-H7, reported airborne emissions from CRL are limited to tritium (hydrogen-3) and argon-41. It is not clear why emissions of fission products and actinides from isotope production are not listed. At any rate, argon-41 and tritium are entirely different kinds of pollutants, following different pathways through the environment of living things, posing different kinds of risks. Yet none of this is explained or even hinted at.

Argon-41 is a chemically inert radioactive gas that gives off penetrating gamma radiation, similar to x-rays, thus irradiating people externally and fleetingly from on high as the gas passes overhead. But Argon-41 is chemically inert, so it cannot contaminate food and water the way tritium does. Tritium, on the other hand, gives off a non-penetrating form of radiation – a very weak form of beta radiation – that poses virtually no external risk; but tritium is chemically active and readily incorporated into all living things. Once inside the body, tritium becomes an internal source of radiation, some of it becoming bound into organic molecules (organically bound tritium OBT). Thus argon-41 poses a brief external hazard while tritium poses a chronic internal hazard.

But there are other radionuclides having very different characteristics emitted from the CRL molybdenum-99 production stack and from waste management areas, such as iodine-131, xenon-133, tellurium-132, and various alpha-emitters. Unlike argon-41 or tritium, which do not concentrate in the food chain or in any particular bodily organ, iodine-131 can re-concentrate by orders of magnitude in passing from air, to rain, to grass, to cow, to milk, to the thyroid gland of a person (possibly a child) who drinks that milk. Iodine-131 is one of the most pernicious radionuclide released from Chernobyl and from Fukushima during the respective accidents. And at CRL, in the week from June 18-25, 2008, AECL reports there were 500,000 becquerels of iodine-131 released to the air, exceeding the action level of 453,000 becquerels per week, as seen on page 78 [pdf] of CMD 11-H7.1 .

Other radionuclides that are emitted in smaller amounts from CRL include such diverse materials as cesium-137 (a beta emitter with a 30-year half-life that concentrates in the soft tissues) and alpha-emitting actinides such as plutonium with much longer half-lives, that lodge in the lungs and in the bones. If there is one piece of data that CNSC should be obligated to provide, it is all relevant information on radioactive effluents and emissions.

CCRC believes that it is one of the legal responsibilities of the CNSC to disseminate "objective" and "scientific" information on such matters. "Objective" means that it shouldn't be just industry PR talk, or sound like it either; "scientific" means it shouldn't be based on mere opinions or one-sided evidence, but on a mature consideration of all the evidence. "Disseminate" means that it should be thrust into people's hands, so to speak, and not just buried in some dusty filing cabinet or as a footnote to some technical report.

Recommendation 11:

That CNSC ensure that all radionuclides released offsite from CRL be identified in the licence documents, that the quantities of those releases be expressed in SI units, and that the principal pathways, target organs, and nature of the exposure (internal or external, alpha beta or gamma) be identified as well.

The Hazards of Isotope Production

Producing a steady supply of medical isotopes at CRL for diagnostic use in hospitals around the world is not a simple or hazard-free undertaking. There are in fact many significant hazards – hazards to health and safety, to the environment, and to national and international security – at every step in the process.

First we have the reactor safety problems associated with forcing a 54-year old reactor to run non-stop most of the time, to irradiate the "targets" where molybdenum-99 is created.

Then there is the importation, storage and handling of weapons-grade uranium from the USA, which entails extraordinary security measures – because such material is the highest quality nuclear explosive in the world. Anyone stealing such material can use it to make an atomic bomb of a particularly simple design: a so-called "gun-type" atomic bomb that does not require shaped plastic explosives or anything of a similarly exotic nature.

Unlike most power reactor fuel, high-enriched uranium (HEU) is also capable of spontaneous criticality – in other words, it does not require any other material as a "moderator" or as a "starter" in order to achieve a self-sustaining chain reaction. If a sufficient quantity of HEU is assembled in a suitable geometric configuration, a "criticality event" will occur, releasing a powerful blast of highly penetrating neutron radiation and an enormous amount of destructive energy.

HEU is the raw material from which molybdenum-99 is produced. When an HEU target is exposed to the neutrons streaming out of the core of the NRU reactor, the uranium atoms split (or "fission") and many broken pieces of uranium atoms ("fission products") are produced inside the target material. One of those fission products is molybdenum-99, which has become the backbone of Canada's medical isotope business.

But the irradiated target is intensely radioactive when it comes out of the reactor, and it contains dozens of other fission products – some of them gases, some vapours, some metals – as well as very heavy actinide elements, many of them giving off alpha radiation.

Next the irradiated target has to be dissolved in acid, releasing the fission products and actinides into the atmosphere and into the liquid solution. The radioactive emissions that come out of the molybdenum-99 stack are similar in nature to some of the emissions of radioactivity from Fukushima – but in much smaller amounts.

The molybdenum-99 can now be chemically separated from the acid solution containing the other fission products and the actinides. The radioactivity of the fission products is so intense that heat continues to be generated within the liquid solution just because of the radioactive disintegration of unstable atoms. This heat generation cannot be stopped because radioactivity cannot be turned off.

Until 8 years ago, the intensely radioactive and corrosive liquid left over from molybdenum-99 production was dumped into the Fissile Solution Storage Tank (FISST) – so called because it still contains the highly fissile, highly-enriched uranium (HEU) in an acidic solution. Although in liquid form, that uranium is still weapons-usable if it is extracted from the solution. And because it is highly enriched, the possibility of an accidental criticality event is still very real.

The wastes in the FISST are extremely toxic and will remain so for many thousands of years, although as time goes by the radioactivity and the heat generation will diminish.

Recommendation 12:
That AECL be required to provide a complete and detailed inventory of the radioactive and non-radioactive contents of the FISST, complete with a list of all relevant radionuclides contained therein and their estimated quantities in SI units.

Deterioration of the FISST

The CNSC Staff document alludes to the deteriorating condition of the FISST:

> The FISST is a double-walled stainless steel tank that was put in service in 1986 to store liquid waste from the Mo-99 extraction process. AECL discontinued use of the FISST in 2003. The liquid waste is now cemented and transferred to the CRL Waste Management Areas.
>
> The tank is approximately 95 percent full and is monitored continuously for level, temperature, pressure and possible leaks. It is required to be sampled once a month for analysis. It is also under the surveillance of the IAEA and safeguards program.
>
> The FISST is equipped with three thermowells - stainless steel tubes equipped with thermocouples that are used to monitor temperature of the FISST solution. The three thermowells extend vertically down into the FISST from the top of the tank.
>
> In June 2006, FISST solution was found to have seeped inside thermowells #2 and #3. Thermowell #2 was abandoned and capped and in December 2008 a plug was installed in the lower portion of thermowell #3. Leak detectors were also installed in both thermowells #1 and #3, which are still used for temperature monitoring. On November 5, 2009, during a video inspection, liquid was found inside thermowell #3.

Alternative methods for measuring temperatures in the FISST have been put in place – which is necessary due to the possibility that an accidental criticality event could drive the temperature up and challenge the integrity of the tank. But plans to deal with the contents of the FISST are still not even formulated. With a five year licence extension, it is unclear that plans will be any further advanced in dealing with this difficult, expensive and dangerous situation. If the FISST tank were to fail, the onsite consequences would be spectacularly unpleasant and offsite consequences could also be quite significant.

> Although the FISST is fit for service, CNSC staff have concerns about the challenges AECL faces due to the degradation of some support and monitoring system components. CNSC staff requested information from AECL on their plans to process the FISST waste and empty the tank [72]. AECL is currently exploring options for long-term management of the waste in the FISST (see section 4.9); however, there are no firm plans to empty the contents of the tank at this time.

Recommendation 13:
That CRL be given a licence of two years at most to run the molybdenum-99 isotope production facilities, with a requirement that a complete set of plans be presented for dealing with the contents of the FISST and the decommissioning of the emptied radwaste tank before a new licence application will be accepted.

Eliminating Weapons Grade Uranium

From 1957 until 1964, NRU – along with all other nuclear reactors in Canada – was fuelled with natural uranium. It produced 200 megawatts of heat but no electricity. It was designed as a research reactor only, and was mainly used as a source of neutrons. In 1964 NRU was converted to use highly enriched uranium (HEU) fuel, generating 60 megawatts of heat. Because the HEU fuel was so much richer in the fissile isotope, U-235, the neutrons obtained were abundant even though the power level was lower.

Throughout the seventies and eighties, weapons-grade HEU was purchased from the USA for use in a variety of very small Canadian SLOWPOKE (Safe Low-Power Critical Experiment) research reactors, as well as two larger research reactors: one at McMaster University and the other (NRU) at Chalk River. HEU was also used for “booster rods” in commercial CANDU power reactors – to assist them in restarting after a brief shutdown. Beginning in 1972, HEU was used for yet another purpose: as a “target” for the mass-production of molybdenum-99, first at McMaster University and then at CRL.

With the rise of international terrorism and the realization that nuclear weapons may spread to other countries and to subnational groups, concern mounted over the availability of HEU – the nuclear explosive material of the highest quality for bomb-making. The US decided to stop selling HEU abroad, eliminate HEU from all civilian reactors and other civilian facilities insofar as that was possible, and repatriate all irradiated HEU fuel back to the USA for safekeeping.

And so NRU was converted a second time, in 1991 – this time to run on low-enriched uranium fuel (LEU) at about 20 percent enrichment, producing 125 megawatts of heat. Meanwhile the other research reactors were weaned off the use of HEU as well.

But molybdenum-99 production at CRL is still based on using highly enriched uranium "targets". AECL has obtained a special exemption from the US allowing CRL to continue to use weapons-grade uranium for this purpose for the time being,. But Canada has made a firm commitment to eliminate the use of HEU in all civilian contexts. This entails developing cost-effective ways of producing molybdenum-99 using low-enriched uranium (LEU) only. There is no doubt this goal is achievable; it is already being done elsewhere.

One of the important aspects of the CNSC mandate as described in the Nuclear Safety and Control Act (Art. 9) is to "prevent unreasonable risk to national security" and to "achieve conformity with measures of control and international obligations to which Canada has agreed". Accordingly, CCRC urges CNSC to insist that AECL pursue vigorously the development of an LEU-based molybdenum-99 production process, so that the use of HEU can be completely eliminated in Canada, as it has already been eliminated as fuel for Canadian nuclear research reactors and as booster rods for commercial power reactors.

Recommendation 14:
That CRL be given a licence of two years at most to run the molybdenum-99 isotope production facilities, with a requirement that AECL develop plans for the production of molybdenum-99 using LEU only before a new licence application will be accepted.

Repatriation of Irradiated HEU to the USA

CNSC Staff refers to the repatriation of irradiated HEU to the USA as follows:

> **3.11.2.3 Waste Repatriation**
> At the Nuclear Security Summit held in Washington D.C. in April, 2010, Canada's Prime Minister announced the repatriation of American-origin spent highly enriched uranium fuel currently stored at the CRL site. Additional information is provided in CMD 11-H7.A (confidential).

The HEU in question consists of SLOWPOKE fuel assemblies, booster rods, and irradiated fuel elements from earlier years of NRU operation. Much of the information connected with these shipments is necessarily confidential because of the high security risk with HEU.

This material, currently stored at CRL, is not easily accessible for theft or transport because of the high radiation fields associated with fission products which are always present in irradiated fuel; nevertheless HEU is a strategic nuclear material and must be handled with extreme care and extraordinary security requirements under all circumstances.

In a different vein, however, CCRC wishes to advise CNSC of a possible violation of the Bilateral Nuclear Cooperation Agreement between Canada and the United States. In the 1980s, irradiated HEU fuel was periodically trucked from CRL to Savannah River National Laboratory (SRNL) in exchange for a cash credit on CRL's next purchase of HEU. At that time it was discovered by a Canadian non-governmental organization that the residual HEU in the irradiated CRL fuel was being extracted – through a reprocessing plant on site – and re-used by SRNL in the fabrication of driver rods for dedicated plutonium production reactors – an integral part of the US nuclear weapons supply system.

These transactions were in violation of Canada's international obligations under the Bilateral Nuclear Cooperation Agreement with the USA. According to that Agreement, nuclear materials exported from Canada are to be used only for peaceful, non-explosive end-uses, which was not the case in this instance. The facts of this case were presented to Douglas Roche, who was at that time Canada's Ambassador for Disarmament, and soon thereafter the shipments of irradiated HEU fuel from CRL to SRNL were halted.

Recommendation 15:
That CNSC request the Government of Canada to ensure that there is no breach of the Bilateral Nuclear Cooperation Agreement between Canada and the United States associated with the repatriation of HEU irradiated fuel from CRL to the USA.

Map and Inventory of Radioactive Wastes at CRL

The recent decision of several major industrial nuclear-powered countries such as Germany, Switzerland, Italy, and possible even Japan, to phase out of nuclear power over the next decade or two, raises questions about the future of the nuclear industry in Canada. The fact that no new power reactors have been ordered in Canada for more than thirty years, and that overseas sales of reactors have been too few and far between to allow the industry to maintain itself on a self-sustaining basis, forces us to confront the possibility that nuclear power may also disappear in this country. The recent sale of AECL's reactor division to a private company, SNC-Lavalin, together with the Government's declared intention "to get out of the isotope business", reinforces the importance of planning for the possibility of a non-nuclear Canada.

Many AECL veterans have either retired, passed away, or moved on to other jobs, and many more will be gone over the next few years. It is vitally important, and very much in the national interest, that as much knowledge as possible be recorded regarding the multi-billion dollar liabilities that are scattered above-ground or buried underground throughout the CRL site in the form of radioactive wastes. After all, problems of waste consolidation, decommissioning, decontamination and long-term management will last for at least 100 years after the last reactors and radioisotope laboratories have been shut down permanently. And not everyone knows "where all the bodies are buried", so to speak.

Even though the current CRL licence application addresses technical problems at many different repositories of radioactive waste materials located within the boundaries of the CRL site, there is no detailed map or complete inventory of all the nuclear wastes at CRL.

Recommendation 16:
That CNSC require AECL to produce a complete and comprehensive map and inventory of radioactive waste materials within the CRL site, together with details as to the contents of each repository by radionuclide (in becquerels), and with detailed information on the physical and chemical condition of the waste materials.

Recommendation 17:
That CNSC require AECL to produce a complete and comprehensive map and inventory of all known underground waste plumes, all available data on groundwater contamination, and all known instances of contaminated soil, together with the nature of the contaminants and the levels of contamination indicated in SI units.

The Nuclear Legacy Liabilities Program

Many of the radioactive wastes at Chalk River Laboratories are "historic" or "legacy" wastes, some dating back to the era when production of plutonium for the US and UK nuclear weapons programs was a significant activity.

Section 4.9.1 of the Nuclear Legacy Liabilities Program refers to development of a "joint administrative protocol for the program" by the CNSC and AECL that will "establish clear milestones to track progress and measure success" and will "set the framework for grouping of planned decommissioning, waste management, and environmental remediation and restoration projects into one integrated EA."

While this may be a step in the right direction, it does not go far enough. CCRC has repeatedly called for an integrated environmental assessment of the Nuclear Legacy Liabilities Program (NLLP) at the highest level – that is, a public Panel Review. Given the large expenditures of taxpayer money in the NLLP, given the complexity and inter-connectivity of the activities it funds, given the historical importance of Chalk River to all Canadians, given the great deal of public interest and concern in attempting to restore the Chalk River site to a permanent safe condition, no other process is acceptable.

CMD 11-H7 is virtually silent on the issue of waste disposal – or, more accurately, long-term waste management – at Chalk River. There is only one passing reference to it in section 3.11.2.1, which says that

> AECL is currently developing a detailed Integrated Waste Plan to include future radioactive waste streams generated at the CRL site, including those resulting from the NLLP. The plan identifies waste types, required processing, storage and future disposal paths."

Even though is is not documented in the CMDs provided to the Commissioners, it is no secret that there is a great deal of current activity at Chalk River focused on the potential suitability of the CRL site for permanent geological disposal of radioactive wastes – possibly including high-level fuel wastes.

AECL's drilling of boreholes has been discussed at the Environmental Stewardship Council. At next week's conference (September 11-14, 2011) on *Waste Management, Decommissioning and Environmental Restoration for Canada's Nuclear Activities*, an entire session, entitled *Geological Disposal of Nuclear Fuel Waste – Site Characterization*, will be devoted to the results of the Chalk River borehole studies.

At the CRL relicensing hearing in 2006, a CCRC spokesperson intervened to remind those attending the hearing that the possibility of in-ground nuclear waste disposal at Chalk River had already been thoroughly investigated in the 1990's by a federally-funded Siting Task Force – an agency mandated to find a willing host community for over a million tonnes of historic radioactive waste from the Port Hope area.

Technical studies produced at that time described the bedrock in the CRL area as fractured and permeable with rapid groundwater movement through the site into the Ottawa River. The area was noted to be seismically active; the Ottawa River is itself a major fault line.

Figures 6.9 and 6.10 from pages 100 and 101 of the 1995 technical report entitled "Preliminary Performance Assessment of a Proposed Low-Level Radioactive Waste Disposal Facility – Town of Deep River PA-2" illustrated the projected migration of radium, uranium and arsenic into the Ottawa River from the underground waste storage cavern that was being proposed at that time to hold the legacy radioactive wastes from Port Hope Ontario.

Municipalities downstream from Chalk River on the Quebec and Ontario sides of the Ottawa River did not take kindly to this information. In 1997, 23 municipalities and both county councils from Pontiac and Renfrew Counties passed resolutions which demanded "that the federal government abandon plans for radioactive waste disposal at the Chalk River property of AECL." These resolutions also urged the federal government "to immediately commence an environmental assessment and clean-up of the Chalk River property of AECL."

While we applaud the investment through the Nuclear Legacy Liabilities Program in clean-up of the Chalk River site, we reiterate our call for a public Panel Review of these clean-up activities.

Furthermore, we caution the CNSC to take note of the fact that Chalk River is clearly not a place to dispose of radioactive waste, and that there is widespread understanding and agreement on this point in all of the downstream communities.

Recommendation 18:
That CNSC recommend to the Minister of Environment that a complete panel review of the Nuclear Legacy Liabilities Program be undertaken.

Appendix: Towards a Healthy Regulatory Culture

In the wake of the Fukushima disaster, people throughout the world have seen how difficult it has been to get dependable information from the Japanese nuclear industry or from the Japanese regulatory agency.

Recently, the political responsibility for the regulatory agency has been transferred to the Japanese Department of Environment in an effort to create a greater degree of separation between the promoters of nuclear power and its regulators.

Here in Canada, the CNSC and AECL still both report to the same cabinet member – the Minister of Natural Resources. Nevertheless, the Nuclear Safety and Control Act instructs CNSC to "disseminate" information to Canadians on the risks of nuclear power in an "objective" and "scientific" manner, without fear or favour. It is a remarkably enlightened mandate. Seldom has a piece of legislation been so clear in its statement of purpose.

And if that stated purpose is embraced by CNSC and made one of its guiding principles, CCRC believes that ordinary Canadians will become more supportive and appreciative of the difficult and important technical work that CNSC is called upon to do.

What is needed is a profound change in the "regulatory culture" of the CNSC to match the equally profound change in "safety culture" that CNSC is helping to foster at AECL and CRL. Improving the safety culture is referred to repeatedly in the documents accompanying the CRL licence application; it requires changing fixed attitudes and challenging old assumptions.

Improving the regulatory culture means taking a fresh look at the nature of CNSC's mandate. CCRC believes that CNSC should act not only as a defender of the public interest in terms of health, safety and the environment, but also as an honest broker between those who are promoters of the industry and those who are legitimately fearful of being negatively impacted by it, as so many thousands of Japanese citizens have been since the 3/11 disaster.

The 2010 CNSC Annual Report has a phrase dramatically displayed on its front cover.

Fact: Nuclear in Canada is Safe.

This statement is not only incorrect (it is an opinion and not a fact) it is also inappropriate (since it trivializes people's concerns over nuclear hazards). It reflects a misguided mindset on the part of the CNSC. People want to be listened to and have their concerns understood and acted on; they do not welcome denial of danger and bland reassurance.

Hopefully, the CNSC Staff and CNSC licensees do not actually believe this "fact" to be true. As the President's Commission on Three Mile Island pointed out, the greatest enemy of nuclear safety is complacency and the false belief that nuclear is inherently safe. Indeed, the CRL licensing documents are full of details of the hard work that is being done by AECL and CNSC to try to make this inherently dangerous technology safer at that site. If nuclear were truly safe, there would be no need for a Nuclear Safety Commission.

On a pragmatic level, the Act decrees that CNSC should act so as to "prevent unreasonable risk". But what is an unreasonable risk? The ALARA principle, espoused by CNSC, states that all radiation exposures shall be kept "As Low As Reasonably Achievable". Who then decides what is reasonably achievable? And is that the same thing as "safe"?

The words "reasonable" and "unreasonable" are not scientific or objective words. They require that a political judgment be made based on balancing conflicting considerations. Evidently it is not up to the nuclear industry alone to decide what is reasonable. So who decides, and how is that decision made? How is the balance of conflicting interests to be achieved? This is not a scientific or a technical matter to be resolved by engineers. It requires an open, transparent, fully-informed decision-making procedure, utilizing the best objective scientific information available, involving the people potentially affected.

Recommendation 19:
That CNSC undertake an extensive review of its regulatory culture at both the Staff and Commission levels, with the help of outside consultants.

It is clear that CNSC has a legal obligation to serve the Canadian public first and foremost, not to promote or to support the nuclear industry; that's why the CNSC was created. To do its job more effectively, CNSC might want to cultivate a sense of liaison and partnership with the public. Members of the public could be invited to communicate their concerns informally as well as formally, to engage in dialogue with staff members, to request and obtain up-to-date information on the nature of the hazards associated with radioactivity and nuclear facilities, and to offer suggestions for improving the services provided by CNSC.

Recommendation:
That CNSC actively cultivate a sense of liaison and partnership with the public.

The Scientific Basis of ALARA

ALARA, now considered a fundamental principle of radiation protection, was first enunciated in the 1977 Report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). It had two parts to it. First, there should be no unnecessary exposures to radiation without some compensating benefit. Second, all exposures that are considered necessary are to be kept as low as reasonably achievable.

The scientific basis for this principle is the broad consensus in the independent scientific community that the incidence of radiation-induced cancers – and other so-called stochastic effects, such as genetic damage – depends not on the individual radiation doses received by each person (expressed in sieverts), but by the collective "population dose" (expressed in person-sieverts). The population dose is the sum of all the individual doses. It is often estimated by multiplying average dose by the number of those affected.

According to the linear non-threshold (LNT) dose-response model, the number of excess cancers caused by radiation exposure to a population is directly proportional to the excess population dose. In both cases, the word "excess" means "above background". Thus cutting the excess dose in half will cut the number of excess cancers by half, cutting the excess dose by a hundred will cut the excess cancers by a hundred, and so on. But the people who get cancer are just as sick, and may well end up just as dead, no matter how many of them there are. The severity of the health effect is in no way reduced by having a lower radiation dose; it is only the number of victims that changes.

This implies that zero excess risk can only by obtained by achieving zero excess exposure. As long ago as the 1920s, experiments with fruit flies by the Nobel-prizing geneticist H. J. Muller showed that a single photon of ionizing radiation delivered to a single cell can produce DNA damage leading to macroscopic genetic abnormalities. Thus any excess radiation exposure level, no matter how low, is expected to cause a small number of excess cancers if a large enough population is exposed at that level.

In 2007 the National Academy of Sciences BEIR-VII Committee concluded the same:

> WASHINGTON (June 2007) — A preponderance of scientific evidence shows that even low doses of ionizing radiation, such as gamma rays and X-rays, are likely to pose some risk of adverse health effects, says a new report from the National Academies' National Research Council.
>
> The report's focus is low-dose, low-LET — "linear energy transfer" — ionizing radiation that is energetic enough to break biomolecular bonds. In living organisms, such radiation can cause DNA damage that eventually leads to cancers. However, more research is needed to determine whether low doses of radiation may also cause other health problems, such as heart disease and stroke, which are now seen with high doses of low- LET radiation.
>
> The study committee defined low doses as those ranging from nearly zero to about 100 millisievert (mSv) ….
>
> "The scientific research base shows that there is no threshold of exposure below which low levels of ionizing radiation can be demonstrated to be harmless or beneficial," said committee chair Richard R. Monson, associate dean for professional education and professor of epidemiology, Harvard School of Public Health, Boston.
>
> National Academy Science Media Release on BEIR-VII Report, 2007.

As a corollary to the LNT model, there is no scientific evidence for a "safe" dose of radiation. Any "acceptable" radiation dose must be based on a risk-benefit trade-off; the question is whether the benefit is worth any excess cancers that might result.

> The probabilistic nature of stochastic effects makes it impossible to make a clear distinction between 'safe' and 'dangerous', a fact that causes problems in explaining the control of radiation risks. The major policy implication of a non-threshold relationship for stochastic effects is that some finite risk must be accepted at any level of protection. Zero risk is not an option.
>
> ***INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION: HISTORY, POLICIES, PROCEDURES*** *http://www.icrp.org/docs/Histpol.pdf*

It is important to realize that evidence against a "safe threshold" of exposure extends to all carcinogens with mutagenic properties, and not just to atomic radiation alone:

> The distinction between carcinogens likely causing tumours by interaction with the genetic material (genotoxic) and carcinogens causing tumours by other mechanism not involving genotoxicity (non-genotoxic) is the major determinant for the selection of risk assessment methodologies. A genotoxic chemical or physical agent [is one that] has the ability to induce mutations or so-called indicator effects which are mechanistically associated with the formation of mutations (e.g. induction of DNA modifications, DNA repair, or recombination).... Genotoxic agents are considered not to have a threshold but induced increases in DNA damage are linearly related to the administered dose.
>
> EU Health and Consumer Protection Directorate-General, January 2009
> http://ec.europa.eu/health/ph_risk/committees/04_scher/docs/scher_o_113.pdf

Recommendation:

That CNSC disseminate objective and balanced information regarding the stochastic nature of cancer induction and genetic damage as well as the scientific evidence underlying the adoption of the linear no-threshold (LNT) model for radiation risks.