nwmo

NUCLEAR WASTE MANAGEMENT ORGANIZATION

SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

August 2003

NWMO BACKGROUND PAPERS
3. HEALTH AND SAFETY

3-3 STATUS OF CANADIAN AND INTERNATIONAL EFFORTS TO REDUCE THE SECURITY RISK OF NUCLEAR FUEL WASTE

Science Applications International Corporation
(SAIC Canada)

NWMO Background Papers

NWMO has commissioned a series of background papers which present concepts and contextual information about the state of our knowledge on important topics related to the management of radioactive waste. The intent of these background papers is to provide input to defining possible approaches for the long-term management of used nuclear fuel and to contribute to an informed dialogue with the public and other stakeholders. The papers currently available are posted on NWMO's web site. Additional papers may be commissioned.

The topics of the background papers can be classified under the following broad headings:

1. **Guiding Concepts –** describe key concepts which can help guide an informed dialogue with the public and other stakeholders on the topic of radioactive waste management. They include perspectives on risk, security, the precautionary approach, adaptive management, traditional knowledge and sustainable development.
2. **Social and Ethical Dimensions** - provide perspectives on the social and ethical dimensions of radioactive waste management. They include background papers prepared for roundtable discussions.
3. **Health and Safety –** provide information on the status of relevant research, technologies, standards and procedures to reduce radiation and security risk associated with radioactive waste management.
4. **Science and Environment –** provide information on the current status of relevant research on ecosystem processes and environmental management issues. They include descriptions of the current efforts, as well as the status of research into our understanding of the biosphere and geosphere.
5. **Economic Factors** - provide insight into the economic factors and financial requirements for the long-term management of used nuclear fuel.
6. **Technical Methods** - provide general descriptions of the three methods for the long-term management of used nuclear fuel as defined in the NFWA, as well as other possible methods and related system requirements.
7. **Institutions and Governance** - outline the current relevant legal, administrative and institutional requirements that may be applicable to the long-term management of spent nuclear fuel in Canada, including legislation, regulations, guidelines, protocols, directives, policies and procedures of various jurisdictions.

SAIC Canada Ottawa • Halifax
Information, Environmental and Engineering Solutions Division

QUALITY ASSURANCE AND MANAGEMENT SYSTEM	
Report Title	Status of Canadian and International Efforts to Reduce the Security Risk of Nuclear Fuel Waste
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SUMMARY

The Nuclear Waste Management Organization (NWMO) was established under the Nuclear Fuel Waste Act (NFWA) to investigate approaches for managing Canada's used nuclear fuel. The review of different management options involves issues ranging from the identification of societal, ethical and community implications, to specific issues of safety and security in transportation and storage of used nuclear fuel. The NWMO commissioned the preparation of a number of background papers on specific topics. One of these topics – the status of Canadian and international efforts to reduce the security risk of nuclear fuel waste – is addressed in this paper.

The background paper is divided into three parts. Part I contains the introduction, aim and scope, and a brief description of the generation and management of nuclear fuel waste in Canada. Part II contains the body of the paper providing a factual accounting of current Canadian and international efforts for reducing the security risk associated with nuclear fuel waste. Part III contains a glossary, references and a selected bibliography.

In developing the information contained in this background paper, SAIC Canada reviewed the following public record documents:

a. Canadian legislation, regulation and policy;
b. Canadian public threat assessment documents;
c. International Atomic Energy Agency conventions, technical reports, technical documents, and information circulars; and
d. US Nuclear Regulatory Commission regulations.

In all aspects of nuclear security, it is the licensee that is responsible for meeting or exceeding the requirements of the Nuclear Security Regulations. It is a condition of the licence issued to operate a Class I nuclear facility that all requirements of the Regulations are met.

The events of September 11, 2001 necessitated a review of the security arrangements that were in place at Class I nuclear facilities at the time. The Canadian Nuclear Safety Commission issued directions to the licensees to increase security arrangements. The licensees have complied with those directions.

Canada, in cooperation with the International Atomic Energy Agency, applies safeguards requirements as conditions of licences. The safeguards are implemented by the licensee. Safeguards requirements include accounting and reporting requirements, physical security measures and support for inspection and verification.

The Nuclear Waste Management Organisation is required to study the following three approaches for nuclear fuel waste management, at a minimum:

a. deep geological disposal in the Canadian Shield;
b. storage at nuclear reactor sites; and
c. centralised storage either above or below ground.

All the above approaches are subject to regulation under the existing Nuclear Security Regulations since nuclear fuel waste is considered a Category II nuclear material. Indeed any approach to the management of nuclear fuel waste will be subject to the Nuclear Security Regulations as amended over time.

Nuclear fuel waste management is also subject to IAEA safeguards.

PART I

1. INTRODUCTION

The Nuclear Waste Management Organization (NWMO) was established under the Nuclear Fuel Waste Act (NFWA) to investigate approaches for managing Canada's nuclear fuel waste. The review of different management options involves issues ranging from the identification of societal, ethical and community implications, to specific issues of safety and security in transportation and storage of used nuclear fuel. The NWMO commissioned the preparation of a number of background papers on specific topics. One of these topics is addressed in this paper – the status of Canadian and international efforts to reduce the security risk of nuclear fuel waste.

SAIC Canada was contracted by the NWMO to develop the background paper presented here.

1.1 AIM AND SCOPE

The aim of this background paper is to provide a factual overview of the current status of Canadian and international efforts to reduce the security risk posed by nuclear fuel waste.

The primary focus of this paper is on the security efforts of the Canadian and international nuclear community. However, to understand why such security efforts are required, it is necessary to have a basic familiarity with the threat environment and the approach taken to manage that environment.

1.2 NUCLEAR FUEL WASTE

Before going further, a number of questions must be addressed.

First, what is nuclear fuel waste? As defined by the Nuclear Fuel Waste Act (NFWA) [1], nuclear fuel waste is the irradiated fuel bundles removed from a commercial or research nuclear fission reactor. At present, Canada does not reprocess nuclear fuel waste although that may be a future consideration. Simply stated, reprocessing separates fissile materials (uranium and plutonium) from the remaining nuclear fuel waste (fission products, zirconium cladding, etc). The remaining waste is referred to as "high level waste" (see the Glossary for definitions).

Second, what is security? The International Atomic Energy Agency (IAEA) [2] defines security as the measures to prevent the loss, theft or unauthorised transfer of radiation sources or radioactive material. Security is sometimes confused with safety. Safety is freedom from danger or risk. In the context of nuclear fuel waste, this represents freedom from the effects from the ionising radiation and thermal radiation emitted by the nuclear fuel waste.

Third, why is it necessary to provide security for nuclear fuel waste?

There are two fundamental reasons. First, nuclear fuel waste is highly radioactive. The physical and administrative security measures applied to the management of nuclear fuel waste contribute to the protection of public health and safety by restricting access to a potentially hazardous radiological environment.

Second, nuclear fuel waste contains fissile materials (uranium and plutonium) that are highly attractive materials for countries seeking to develop a nuclear weapons program and for theft or sabotage by terrorists.

Finally, what has any of this to do with the Nuclear Waste Management Organization?

The Nuclear Fuel Waste Act established the NWMO for the following specific purposes:

a. to investigate and propose an approach or approaches to the Government of Canada for the management of nuclear fuel waste; and
b. to implement the selected approach.

In proposing an approach or approaches for managing nuclear fuel waste, the NWMO must ensure that all technical, administrative and financial aspects have been investigated. Security is included in each of these aspects. Security solutions are typically both technical and administrative and there are financial implications associated with each. Additionally, the proposed approach or approaches must have public acceptance. If security is either not addressed or inadequately addressed, it is unlikely that public acceptance will be forthcoming.

In implementing the selected approach, the NWMO will require Canadian Nuclear Safety Commission (CNSC) licences, one to construct the facility and a second to operate the facility. Granting of the licences will require the NWMO to successfully demonstrate, among other things, that all security requirements are met.

1.3 CONCLUSION

In defining an approach for the future management of nuclear fuel waste, the NWMO must address how they will secure the waste for public health and safety and for national security. The following sections of the background paper provide an overview of current security requirements and a consideration of their application for a future approach to nuclear fuel waste management.

2. NUCLEAR FUEL WASTE GENERATION AND MANAGEMENT

2.1 INTRODUCTION

Waste management is an integral activity of waste generation and is not unique to the nuclear industry. However, the isolation and containment of nuclear fuel waste for geological time periods is unique to the nuclear industry.

This section of the background paper provides an overview of how nuclear fuel waste is generated, particularly in Canada, and how it is currently managed both here and abroad.

2.2 CANDU FUEL CYCLE

The current CANDU (Canadian Deuterium Uranium) fuel cycle consists of five stages: mining, milling and refining, fuel fabrication, reactor operation and nuclear fuel waste storage. The CANDU fuel cycle is an open or once-through cycle since the fuel is used once and then removed and stored.

Each stage of the CANDU fuel cycle is regulated by the CNSC for radiological safety. Additionally, each stage has IAEA safeguards applied as licence conditions. CNSC Nuclear Security Regulations apply to Category I, II and III nuclear material (nuclear fuel waste is considered Category II nuclear material) and to nuclear facilities consisting of a nuclear reactor that may exceed 10MW thermal power during normal operation (i.e. commercial power reactors).

CANDU fuel fabrication creates a fuel bundle that is about the size of a typical fireplace log. The fuel bundle consists of tubular zirconium alloy sheaths containing ceramic uranium oxide pellets. A typical bundle weighs 24 kilograms including approximately 19 kilograms of uranium.

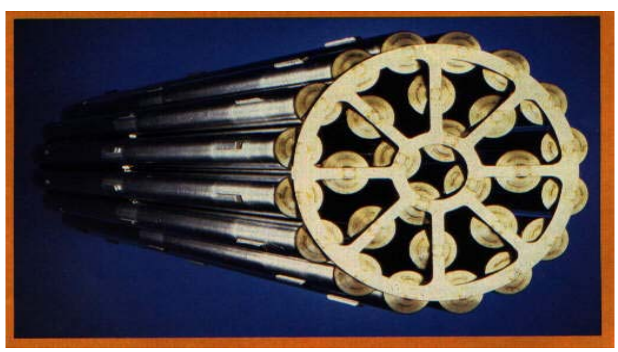

Figure 2-1: CANDU Fuel Bundle

2.3 NUCLEAR FUEL WASTE GENERATION

Canada has 22 CANDU commercial power reactors: 20 in Ontario, one in Quebec and one in New Brunswick. At the present time, only 14 reactors (12, 1 and 1) are in operation. Two Bruce A and four Pickering A reactors are scheduled to return to service in the summer 2003.

Figure 2-2: Darlington Generating Station (4 CANDU Reactors)

Nuclear fuel waste is generated by commercial power reactors at a rate of about 85,000 fuel bundles per year. Using as a baseline the 1.2 million spent fuel bundles in storage in 1996 quoted in the Canadian Environmental Assessment Agency Environmental Assessment Panel report *Nuclear Fuel Waste Management and Disposal Concept* [3], by the end of 2002 this number may have increased to about 1.6 million weighing approximately 39,200 tonnes.

There are fission reactors for other commercial purposes and for research in Canada as follows:

a. five Slowpoke II research reactors (Edmonton, Saskatoon, Kingston, Montreal and Halifax);
b. the pool-type research reactor at McMaster University in Hamilton;
c. the National Research Universal (NRU) reactor at Chalk River Laboratories; and
d. the MDS Nordion Maple Reactors (2) at Chalk River Laboratories for isotope production.

The volume of nuclear fuel waste produced by the above reactors is insignificant in comparison to the amount produced by the commercial power reactors. There is also legacy waste from decommissioned reactors (Douglas Point, Gentilly 1 and Nuclear Power Demonstrator (NPD)). However, again, the volume is insignificant in comparison to that produced by the active commercial reactors.

Nuclear fuel waste is non-combustible; it cannot ignite either spontaneously or if placed in a fire. Nuclear fuel waste cannot explode in a nuclear explosion.

2.4 NUCLEAR FUEL WASTE MANAGEMENT

2.4.1 Current Canadian Approach

Currently, nuclear fuel waste management is the responsibility of the generators of the waste. Nuclear fuel waste generated by the nuclear utilities is stored either indoors in water-filled pools or in concrete canisters at the nuclear reactor site that generated the waste. Storage, by definition, is an interim measure with the objectives of managing nuclear fuel waste in a safe, reliable and economic manner while ensuring the integrity of nuclear fuel waste for future retrievability (i.e. transportation, long term management and, eventually, possible disposal). The nuclear utilities are increasing their dry storage capacity to ensure sufficient storage capacity at the sites to accommodate all the nuclear fuel waste produced to the end of the life of the existing reactors.

2.4.1.1 Water-filled Pools

All nuclear fuel waste is initially stored in water-filled pools. The water provides both cooling and radiation shielding. Cooling is very important as the nuclear fuel waste has an extremely high thermal content when initially removed from the reactor. The water-filled pools or bays are extremely robust. They are constructed of reinforced concrete, lined to prevent leaks and designed to withstand an earthquake.

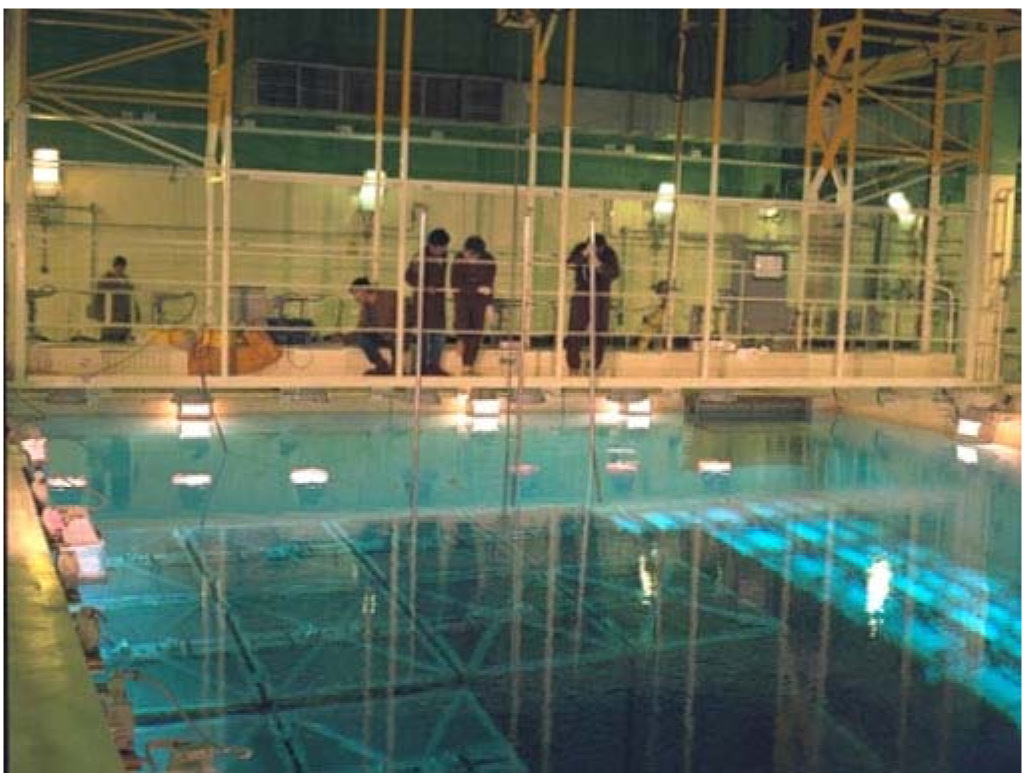

Figure 2-3: Water-Filled Waste Fuel Bay

The robust design of the pools for radiation safety also benefits security. Additionally, the pools are located within the protected area of the facility and therefore not easily accessible. Also, both the high thermal radiation and ionising radiation mitigate against handling without sophisticated equipment.

As noted earlier in Section 2.2 of the background paper, IAEA safeguards are applied to nuclear fuel waste management. Each fuel bundle is numbered and tracked from fabrication to fuelling the reactor to removal as nuclear fuel waste. Additionally, cameras record all human activity in the area around the water-filled pools where the nuclear fuel waste is stored.

After about ten years in the water-filled pools, the nuclear fuel waste activity and rate of heat generation have decreased sufficiently to permit safe transfer to dry storage, if desired.

2.4.1.2 Dry Storage

Three dry storage methods for nuclear fuel waste are currently in use in Canada. Two systems were developed by AECL and the other by OPG.

One AECL-developed system is known as Modular Air-Cooled Storage (MACSTOR). MACSTOR uses a highly efficient heat-rejection system and shielding capabilities to safely store nuclear fuel waste. These concrete units have a double containment system that shields the public and the environment from the radiation being generated by the nuclear fuel waste. The MACSTOR system is in use at Hydro-Quebec's Gentilly 2 generating station.

Figure 2-4: MACSTOR System

The other AECL-developed dry storage system is a silo-like structure called a concrete canister. Originally developed for enriched uranium from research reactors, it was further developed for CANDU nuclear fuel waste. Each canister holds a number of baskets containing 60 fuel bundles. The system is in use by New Brunswick Power at its Point Lepreau generating station.

The OPG-developed system is a concrete dry storage container (DSC) system that is transportable. Individual containers are constructed of reinforced concrete 60 centimetres (23 inches) thick lined inside and out with 2 centimetre thick steel. The DSCs are 2.1m x 2.4m x 3.5m and hold 384 CANDU fuel bundles in four racks each containing 96 fuel bundles. An empty DSC weighs 63 tonnes and with the added fuel bundles weighs approximately 72 tonnes.

For loading, a DSC is placed in the water-filled bay and loaded while submerged in the water. A temporary transfer seal is applied and the DSC is transferred by a specially designed vehicle from the generating station to the on-site dry storage facility where the DSC is purged of water, the lid is welded to the base, the vent port is seal-welded, the DSC is filled with helium and checked for leaks, the remaining drain port is seal-welded and the DSC is transferred to the storage building. DSCs are currently in use at the Pickering Waste Management Facility and at the Western Waste Management Facility (Bruce generating station).

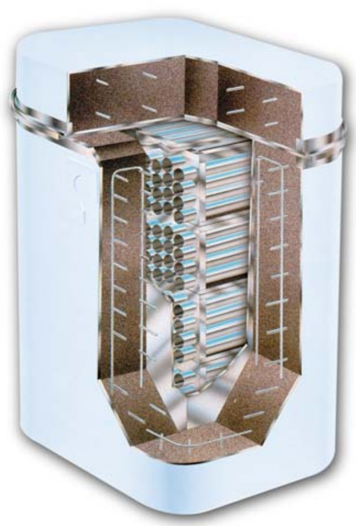

Figure 2-5: Dry Storage Container

Once again, IAEA safeguards are applied. Each numbered fuel bundle is tracked to account for its location in the dry storage system. For example, each OPG-designed DSC is individually numbered. A specific fuel bundle can, therefore, be tracked to a specific DSC. Additionally, an IAEA-applied seal is installed on each DSC when closed. Any tampering or breakage of the seal would be noticed by inspectors and an investigation would be initiated.

2.4.2 Approaches Used Internationally

Storage, with or without reprocessing, is the current approach most used internationally. For illustrative purposes, Finland, France, Germany, the Netherlands, the United Kingdom (UK) and the United States (US) have been selected.

2.4.2.1 Finland

Finland's fuel cycle is an open or once-through cycle similar to Canada's. Nuclear fuel waste is currently stored above ground by the utilities generating the waste.

2.4.2.2 France

Unlike Canada, France has a closed fuel cycle and reprocesses its nuclear fuel waste. The waste material generated during reprocessing is called High Level Waste (HLW). This material is vitrified and stored above ground. France also reprocesses the nuclear fuel waste of other countries (e.g. The Netherlands, Germany).

2.4.2.3 Germany

German policy is for **all** radioactive waste to be disposed of in deep geological formations. However, to date the facility has not been constructed. Germany sends its nuclear fuel waste to France for reprocessing. The HLW generated is returned to Germany. The HLW is stored above ground.

2.4.2.4 The Netherlands

All the nuclear fuel waste generated by the two commercial nuclear reactors (one operational and one shutdown) in the Netherlands is sent to either France or the UK for reprocessing. The HLW generated as a result of the reprocessing will be returned to the Netherlands for storage in an engineered facility that is under construction. Nuclear fuel waste from research reactors is not reprocessed but will be stored at the central storage facility.

2.4.2.5 The United Kingdom

Nuclear fuel waste in the UK is reprocessed. The current UK policy requires the above ground storage of vitrified HLW for at least 50 years.

2.4.2.6 The United States

In the US, most nuclear fuel waste generated by commercial reactors is stored in water-filled pools either on site at the location where it was generated or off site at engineered storage locations. Some, about five percent, is stored in dry storage casks. The US has approved a deep geological repository (Yucca Mountain) that is under construction.

2.5 NUCLEAR FUEL WASTE REPROCESSING

As an open or once-through fuel cycle, the Canadian approach does not reprocess nuclear fuel waste. However, as noted above, other countries do reprocess.

Reprocessing is the recovery of fissile and fertile material for further use from nuclear fuel waste by chemical separation of uranium and plutonium from other transuranic elements and fission products. Through this process, the uranium and plutonium in the nuclear fuel waste is made available for reuse. Reprocessing has the potential to reduce the volume of material requiring storage or disposal as only the HLW from the reprocessing should require storage or disposal. The liquid HLW from reprocessing is typically vitrified to a glass-like form for storage.

2.6 NUCLEAR FUEL WASTE TRANSPORTATION

The current Canadian approach to nuclear fuel waste management, storage, requires no transportation off the site where the waste was generated. CANDU nuclear fuel waste is moved from the reactor to the water-filled storage bays through a water-filled channel. Where dry storage is available how the nuclear fuel waste is transferred depends on the dry storage system. For instance at the Pickering generating station, it is moved from the water-filled storage bays to the dry storage facility in DSCs by a specially designed transporter.

2.7 CONCLUSION

This section has considered how nuclear fuel waste is generated and how it is managed post-generation. Both nationally and internationally, the most used approach to nuclear fuel waste management is storage, either with or without reprocessing. As in Canada, the majority of countries adopt the approach that the producer of the waste is responsible for its safe and secure management.

PART II

3. THREAT ENVIRONMENT

3.1 INTRODUCTION

The events of September 11, 2001 (9-11) presented a rude wake-up call to the world concerning the potential for acts of international terrorism to be perpetrated anywhere in the world. Information developed during the war in Afghanistan that Al Qaida was seeking nuclear weapons and materials highlighted the need for increased vigilance and security of nuclear facilities and materials.

This section of the background paper considers the threat environment that presently exists and the potential impact it has for the security of nuclear fuel waste.

3.2 GENERAL

One Canadian think tank, the Mackenzie Institute, believes there may be as many as 10,000 terrorists in Canada [4]. However, they also acknowledge that many are living a peaceful existence for now. The actual number is irrelevant since the existence of a known criminal or terrorist cell in a particular area does not necessarily equate to a legitimate or credible threat. For a threat to be credible, a potential adversary must, at a minimum, possess both a capability and intention to use the capability.

What is a terrorist? There is no standard or generally accepted definition. Each country defines terrorist or terrorism in a manner consistent with its internal and external policies. In Canada, the *Criminal Code* [5] defines “terrorist group” as a group that has as one of its purposes or activities facilitating or carrying out any terrorist activity, is a listed entity as defined in the *Criminal Code*, or is an association of such entities. The *Criminal Code* defines “terrorist activity” as one of the following:

a. an activity that is an offence under any one of the UN anti-terrorism conventions and protocols listed in section 83.01(1)(a); or
b. an activity that is taken or threatened for political, religious or ideological purposes and threatens the public or national security by killing, seriously harming or endangering a person, causing substantial property damage that is likely to seriously harm people or by interfering with or disrupting an essential service, facility or system as described in section 83.01(1)(b).

Generally, potential adversaries are either internal or external to the organization. An internal adversary is an employee or contractor with legitimate access to a particular site who, for whatever reason, deliberately initiates a course of action that puts the facility and/or its inhabitants at risk. An external adversary is an individual or group outside the organization without legitimate access to the facility. Potential external adversaries include environmental activists, organised crime and terrorists. The external adversary could become an internal adversary by becoming an employee or through coercion of an employee or employees.

3.3 CANADIAN CONTEXT

A phenomenon of the late twentieth century, and still occurring, is the disgruntled employee who uses violence against fellow employees in the workplace setting (sometimes referred to as “going postal” since one of the first instances occurred in a US postal facility). It happens rarely in Canada, but cannot be completely discounted.

Organised crime, at least in Canada, persists in its “traditional” areas of crime including drugs, gambling, loan-sharking, money laundering, prostitution and human smuggling. A move into the theft of nuclear materials, including nuclear fuel waste, would be out of character for organised crime in Canada.

According to CSIS [6], terrorism in Canada can be divided into four categories:

a. religious extremism (with Islamic extremism being the most serious threat at present);
b. state-sponsored terrorism (exemplified by the current regime in Iran);
c. secessionist violence (e.g. Sikh extremism and separatist movements in Sri Lanka, Turkey and other countries); and
d. domestic extremism (including, but not limited to, certain elements of animal rights, anti-globalisation and white supremacist groups).

However, within Canada, most terrorist-related activities support actions elsewhere, and are linked to homeland conflicts. Such activities include fund-raising efforts, lobbying, procuring weapons and material, and coercing and manipulating immigrant communities.

Anti-nuclear groups in Canada have not resorted to the extremism demonstrated, for instance, by anti-globalisation supporters. The violence associated with anti-globalisation demonstrations has largely been attributed to a few people whose sole purpose is mayhem. It is possible that anti-nuclear demonstrations could be high-jacked by the same type of people for the same purpose. This could put a nuclear fuel waste management facility at physical risk.

Since 9-11, a recurring theme in media articles is what would be the radiological consequences of 9-11 type attack on a nuclear facility. Because of the robust design of a nuclear facility, the potential for radiological consequences would be very small. There may be surface damage to dry storage systems but it is unlikely that the system would be breached releasing radioactivity to the environment.

In November 2002, news media reports [7] listed a variety of targets in Canada. Included in the list of 22 “most vulnerable sites” were some, but not all, of the Class I nuclear facilities in Canada. The list included the Pickering and Point Lepreau nuclear generating stations and Chalk River Laboratories. Nobody took ownership of the list, although the news media claimed the list was from a US government study.

No credible direct threat to a Canadian nuclear facility and/or nuclear fuel waste has ever been publicly acknowledged. The operative word is “credible”. As noted above there have been suggestions in the media and elsewhere that nuclear facilities may be targeted by terrorists. However, none of these threats has proved to be credible.

3.4 INTERNATIONAL CONTEXT

The IAEA has identified the requirement to reduce three categories of risks from nuclear terrorism [8]. The categories are:

a. **Nuclear Facilities**. The primary risks associated with nuclear facilities would involve the theft or diversion of nuclear material from the facility, or a physical attack or act of sabotage designed to cause an uncontrolled release of radioactivity to the surrounding environment;
b. **Nuclear Material**. According to IAEA experts, terrorists obtaining nuclear weapons would be the most devastating scenario. While the possibility cannot be excluded, it is highly unlikely that terrorists could use diverted nuclear material to manufacture and successfully detonate a nuclear bomb, in the view of IAEA Director General Mohammed ElBaradei; and
c. **Radioactive Sources**. Experts are concerned that terrorists could develop a crude radiological dispersal device (a so-called "dirty bomb") using radioactive sources commonly used in every day life. The number of radioactive sources around the world is vast: those used in radiotherapy alone are in the order of ten thousand. There are also a number of radioactive sources, many of them abandoned, others simply "orphaned," that are outside of any regulatory control.

The latter category is generally considered the most pressing since many nations' security and accounting arrangements for radioactive sources are marginal at best. Unfortunately, not all countries have the same security standards. While the nuclear power industry generally has high security standards, the security of radioactive materials and radioactive waste at facilities such as small research centres is not as well organised.

The IAEA, Russia and the US have formed a tripartite arrangement in an attempt to deal with the magnitude of the "Russian problem". With the dissolution of the Soviet Union, Russia inherited an estimated 603 metric tonnes of highly enriched uranium and plutonium in forms highly attractive for theft.

3.5 CONCLUSION

Subsequent to the events of 9-11, there is at least the perception, if not the reality, that the threat has changed. Those charged with national security are still assessing the "new" threat. The threat environment is continually evolving. It is a dynamic environment strongly influenced by world events.

Specific concerns have been raised nationally and internationally concerning the threat to the nuclear power generation industry (including nuclear fuel waste management). While a variety of potential threats are recognised, to date, none have materialised as a direct credible threat to nuclear fuel waste management in Canada.

One reason for the lack of a credible threat is the security arrangements required for nuclear fuel waste. Terrorists, and others, tend to select “soft” targets, facilities with inadequate or no security. Another reason for the lack of a credible threat to nuclear fuel waste is the robust design of the dry storage systems. The radiation shielding requirements necessitate significant mass between the nuclear fuel waste and the external environment. As previously mentioned in Section 2.4, the OPG-designed DSC weighs approximately 72 tonnes when full, not something that can be easily moved or removed without specialised equipment.

4. SECURITY

4.1 INTRODUCTION

This background paper section considers the primary functions of a security program and the risk management approach for determining how much security is enough.

As mentioned in Section 1, the IAEA defines security as the measures to prevent the loss, theft or unauthorised transfer of radiation sources or radioactive material. The term "physical protection" is also used. The IAEA defines physical protection as the measures for the protection of nuclear materials or authorised facilities designed to prevent unauthorised access or removal of fissile material or sabotage with regard to safeguards as, for example, in the *Convention on the Physical Protection of Nuclear Materials*.

4.2 GENERAL

Breaches of security or physical protection systems may be considered as naïve or malicious. The naïve intruder is an individual or group that inadvertently enters a protected area. They have no purpose there but neither do they have any intent to cause damage or harm. Additionally, they may be at risk of significant exposure to ionizing radiation and, if for no other reason than their own health and safety, must be removed from the area.

The malicious intruder is an individual or group intent upon causing damage (vandalism or sabotage), theft or harm to individuals.

4.3 PURPOSE

The primary functions of a comprehensive security program are:

- deterrence;
- detection;
- assessment;
- delay; and
- response.

4.3.1 Deterrence

Deterrence is achieved by implementing a comprehensive security program that adversaries perceive as too difficult to defeat or overcome. The security measures make the protected material, information or facility an unattractive target.

4.3.2 Detection

Detection is the discovery of an attempted or actual intrusion of a protected area or system with the objective of unauthorised removal or sabotage of material, systems or facilities, or threat to persons.

4.3.3 Assessment

In addition to determining the cause of an alarm (detection), assessment provides the specific details such as what, who, where, when and how many in a timely manner. This information is essential for determining the appropriate response.

4.3.4 Delay

Delay is an important element of a comprehensive security program. Delay of the adversaries is achieved through the use of barriers (e.g., fences, walls, locks, etc). Delay is often achieved by a series of successive barriers sometimes referred to as layered defence or defence in depth. Delay provides the time necessary for responders to interpose themselves between the adversaries and their target. Delay must be sufficient to prevent adversaries from accomplishing their mission before interdiction by the response force.

4.3.5 Response

Having assessed the attempted or actual intrusion, an appropriate response force must be rapidly dispatched to interdict the adversaries. Depending on the mandate of the response force, its purpose may be to introduce further delay pending the arrival of the police of local jurisdiction, or the response force may be authorised to use deadly force to prevent the adversaries from reaching their target.

4.4 RISK MANAGEMENT APPROACH

The nature of the potential threat is diverse. Preparing for all possible contingencies is not practical, so a risk management approach has been adopted by the CNSC. Risk management is a systematic and analytical process to consider the likelihood that a threat will endanger an asset and to identify actions to reduce the risk and mitigate the consequences of an attack. Risk can never be reduced to zero; there will always be residual risk. Risk management includes three primary elements:

a. a threat assessment;
b. a vulnerability assessment; and
c. a critical infrastructure assessment.

4.4.1 Threat Assessment

Threat assessments are decision support tools that assist organizations in security program planning and key efforts. A threat assessment identifies and evaluates threats based on various factors, including capability and intentions as well as the potential lethality of an attack. Within the nuclear industry, this is known as the *design basis threat*. By identifying and assessing threats, organizations do not need to rely on worst-case scenarios to guide planning and resource allocation. Worst-case scenarios focus on vulnerabilities that are virtually unlimited and require extraordinary resources to address.

4.4.2 Vulnerability Assessment

A vulnerability assessment is a process that identifies weaknesses that may be exploited by an adversary and suggests options to eliminate or mitigate the identified weaknesses.

4.4.3 Critical Infrastructure Assessment

A critical infrastructure assessment is a process that systematically identifies and evaluates an organization's assets based on the importance of its functions or attractiveness as a target. The CNSC refers to critical infrastructure assessments as *vital area studies*.

4.5 CONCLUSION

In Canada, a risk-based approach to a comprehensive security program is used. The CNSC, with the assistance of CSIS, the RCMP, police of local jurisdiction and licensees, establishes the design basis threat, assesses vulnerabilities and determines vital areas. The facility operators establish their specific security programs to successfully meet all five functions of a comprehensive security program.

5. CANADIAN NUCLEAR SECURITY CONTEXT

5.1 INTRODUCTION

The nuclear industry in Canada is highly regulated, possibly the most regulated industry in the country. This background paper section provides an overview of the security specific regulation that applies to nuclear fuel waste.

5.2 NUCLEAR SAFETY AND CONTROL ACT

The *Nuclear Safety and Control Act* (NSC Act) is relatively new legislation. It received Royal assent on 20 March 1997 but only came into force on 31 May 2000. It replaces the *Atomic Energy Control Act*.

The purpose of the NSC Act [9] 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, the health and safety of persons and the environment 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 non-proliferation of nuclear weapons and nuclear explosive devices.

Previously, in Section 1.3, the rationale for securing nuclear fuel waste was presented as public health and safety and national security. Therefore, the NSC Act clearly applies to nuclear fuel waste management.

5.3 GENERAL NUCLEAR SAFETY AND CONTROL REGULATIONS

Readers of this background paper expecting to find specific details of the security measures taken by the nuclear utilities and/or Chalk River Laboratories (CRL) will be disappointed. Such information is prescribed by Section 21 of the General Nuclear Safety and Control Regulations. Prescribed means access to the information is restricted to those with a need to know.

The prescription of security information is not unusual or unwarranted. Government and industry routinely restrict access to such information. In the wrong hands, specific security information provides a detailed road map for overcoming security measures.

5.4 NUCLEAR SECURITY REGULATIONS

The Nuclear Security Regulations pursuant to the NSC Act are applicable to Category I, II and III nuclear material and a nuclear facility consisting of a nuclear reactor that may exceed 10 MW thermal power during normal operations (e.g. commercial power reactor). Nuclear fuel waste is considered Category II nuclear material [10].

The Nuclear Security Regulations are the means by which the CNSC specifies the security requirements for nuclear facilities. The requirements are based on the comprehensive security program methodology detailed previously in Section 4.2. The Regulations include, but are not limited to, the following:

a. general obligations (i.e. where a nuclear facility must be located);
b. requirements concerning protected and inner areas (i.e. types of barriers for enclosing a protected area, intrusion detection);
c. requirements for entry into protected and inner areas (i.e. authorisation, monitoring and preventing entry);
d. requirements for nuclear security guards (i.e. training); and
e. requirements for protection arrangements and security drills.

Among other things, the Regulations make it very clear that sabotage of a nuclear facility or nuclear materials and theft of nuclear materials is unacceptable. The Regulations state in part under *Monitoring and Removal*:

> *Every licensee shall ensure that Category I, II or II nuclear material is not removed from a protected area or an inner area unless the removal is carried out in accordance with a license.*

and under *Unauthorised Persons*:

> *No licensee shall permit an unauthorised person to enter or remain in a protected area or an inner area*.

In all aspects of nuclear security, it is the licensee that is responsible for meeting or exceeding the requirements of the Regulations. It is a condition of the licence issued to operate a Class I nuclear facility that all requirements of the Regulations are met. A nuclear fuel waste management facility is considered a Class I nuclear facility.

5.5 CNSC ORDER #01-1

CNSC Order Number 01-1 was issued 18 October 2001. One reason for Order #01-1 was the acts of terrorism on 11 September 2001. The Order was issued to direct specific licensees to take additional measures for the security of nuclear facilities and nuclear materials.

5.6 SAFEGUARDS REQUIREMENTS

In the Canadian context, there are no safeguards regulations. Safeguards requirements are specified as conditions of licences. In the CANDU fuel cycle, safeguards are applied in each stage of the fuel cycle starting in the mining stage through to the nuclear fuel waste management stage.

Safeguards are a verification system that is established in accordance with a safeguards agreement, in Canada's case, the *Agreement between the Government of Canada and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-proliferation of Nuclear Weapons*. Safeguards are measures for "the timely detection of the diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection." [11]

Safeguards are implemented by the licensee by:

a. providing information concerning the purpose, location, design, and operation of the facility to the CNSC and the IAEA for review and verification;
b. maintaining accounting records for the nuclear material at the facility and operating records for the facility for inspection by the IAEA;
c. submitting periodic and special reports to the CNSC and the IAEA on changes in inventory within each designated area of the facility and on unusual incidents affecting nuclear materials; and
d. providing access and support to IAEA personnel for performing their inspections and servicing their safeguards systems and equipment.

5.7 REGULATORY GUIDES

The CNSC also provides guidelines for the licensees to assist them in meeting their obligations. Regulatory Guide G-274, *Security Programs for Category I or II Nuclear Material or Certain Nuclear Facilities*, is intended to assist licence applicants, other than for a licence to transport, prepare and submit the information required by the Nuclear Security Regulations.

Regulatory Guide G-274 [12] outlines among other things:

a. the security information that should typically be included;
b. how the security information should be organised and presented to assist the CNSC review and processing of the application; and
c. the administrative procedures to be followed for preparing, submitting or revising the security program description.

Regulatory Guide G-208, *Transportation Plans for Category I, II or III Nuclear Material*, is intended to assist applicants for a licence to transport prepare and submit a written transportation security plan that meets the requirements of Section 5 of the Nuclear Security Regulations.

Regulatory Guide G-208 [13] outline among other things:

a. the information that should typically be included in the transportation security plan;
b. the transport security measures that should be taken into account when developing the transportation security plan; and
c. how the transportation security plan should be handled to conform to requirements related to confidentiality and national security.

5.8 LICENSEE SECURITY COMMITMENT

Licensees, in particular the Class I nuclear facility operators, take security very seriously; not just because the CNSC directs that they do but because it makes good business sense. Prior to 9-11, the threat environment for Canadian nuclear facilities was believed to be relatively benign. The licensee security programs were sufficient for that environment.

Since 9-11, there is at least the perception, if not the fact, that the threat environment has changed. The licensees (and the CNSC) were quick to recognise the changed environment. Each Class I nuclear facility incorporates a range of security features, some visible and some unseen. These features were quickly reviewed and additional features were added to meet the new threat. Additional features include, but are not limited to, the following:

a. an armed on-site response force;
b. protection against forced vehicle entry into the protected area;
c. improved security screening of employees and contractors; and
d. enhanced inspection of individuals and vehicles entering the protected area.

5.9 CONCLUSION

The CNSC establishes the security requirements based on the threat environment. The requirements are expressed in the Nuclear Security Regulations and in licence conditions. Additionally, IAEA safeguards requirements are expressed as licence conditions. The current approach to nuclear fuel waste management, storage, is subject to the Nuclear Security Regulations and to IAEA safeguards. Figure 5-1 on the following page illustrates the Canadian nuclear security environment.

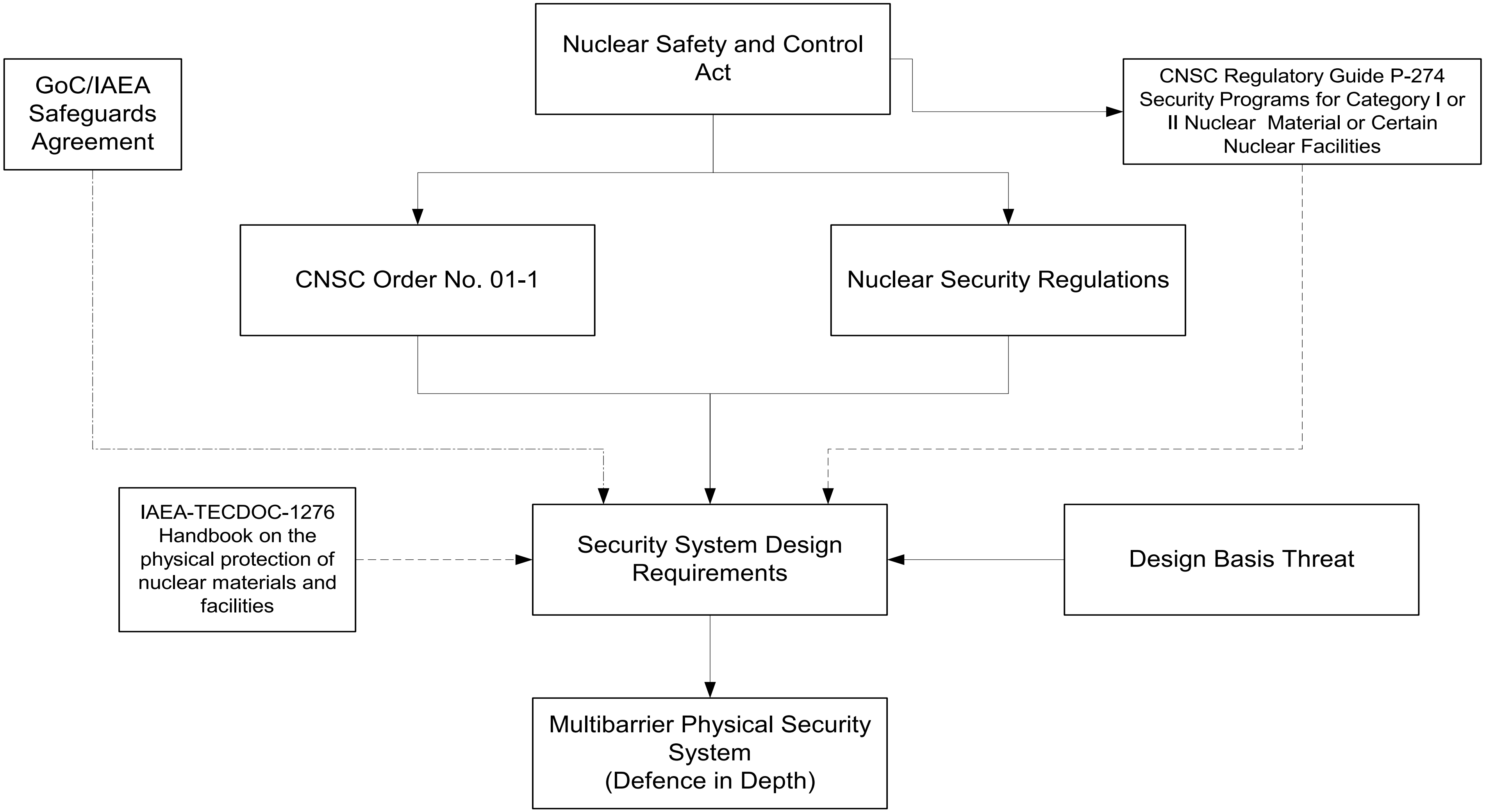

Figure 5-1: Canadian Nuclear Security Environment

6. INTERNATIONAL NUCLEAR SECURITY REQUIREMENTS

6.1 INTRODUCTION

At a press conference in November 2001, IAEA Director General Mohammed ElBaradei stated in part *"In the long term, we need to ensure all countries have a stringent nuclear security framework in place – with high standards to abide by, state-of-the-art equipment and people trained in security"* [8].

This background paper section considers nuclear security requirements from the international perspective.

6.2 EXISTING SITUATION

The IAEA recommended standards for physical protection, IAEA INFCIRC/225/Rev. 4 (Corr.), *The Physical Protection of Nuclear Materials and Facilities*, were not designed for the threat posed by today's terrorists and national practices often fall short of even these recommendations.

Currently, there are no binding international standards for the physical protection of nuclear material, including nuclear fuel waste. The IAEA has been seeking, on a priority basis, to broaden the scope of the *Convention on the Physical Protection of Nuclear Material* to cover additional activities. In particular the IAEA is seeking consensus on amendments to make it applicable within States, not just to transport between States.

A priority for the IAEA is to increase the number and scope of its International Physical Protection Advisory Service (IPPAS) missions as well as its workshops designed to help States assess possible threats. In addition, the IAEA intends expanding its program aimed at increasing the capabilities of Member States to detect and respond to theft, illicit trafficking, and other malicious use or threatened use of nuclear material.

In the June 2003 issue of the IAEA Bulletin [14], an article summarising the Stanford-Salzburg Plan for the physical protection of nuclear materials listed the following six recommended elements for consideration in addition to the on-going IAEA efforts to improve physical protection practices:

a. establish a global list of physical protection priorities;
b. create a multilateral security cooperation system;
c. create an international Nuclear Threat Protection Task Force;
d. establish an International Radioactive Material Tracking Centre;
e. develop a Nuclear Security Bonus System; and
f. establish a Global Partnership Cooperation Committee between the IAEA and the G8 States (Canada, France, Germany, Italy, Japan, Russia, UK and US).

6.3 CONCLUSION

Not unlike other United Nation's agencies, the IAEA must achieve consensus before moving forward on issues, even those as timely as security. The process is often slow, cumbersome and easily derailed. That notwithstanding, the IAEA has recognised the need for improved security arrangements and is pressing States to increase their efforts in this area.

7. NUCLEAR FUEL WASTE SECURITY

7.1 INTRODUCTION

With regard to a nuclear fuel waste management facility, the primary risks involve theft or diversion of nuclear material at or en route to the facility, or physical attack or act of sabotage intended to cause an uncontrolled release of radioactivity to the environment.

This background paper section considers the existing regulations, how they apply currently and whether they would apply to any future approach to nuclear fuel waste management.

7.2 STORAGE

In the context of the current CANDU fuel cycle, nuclear fuel waste is stored at the facility where it is generated and is subject to the same security requirements as exist for the generating facility. The types of stage presently used in Canada were described in Section 2. The general requirements were previously cited in Section 5.3.

One proposed approach for the future is to aggregate the nuclear fuel waste for centralised storage. Nuclear fuel waste is considered Category II nuclear material therefore a centralised storage facility would be subject to the Nuclear Security Regulations.

Whether storage on site or centralised storage is selected for the future, safeguards would still apply. There would remain a requirement to accurately and consistently account for nuclear fuel waste and to secure the facility against unauthorised access or diversion of nuclear material.

7.3 DISPOSAL

A deep geological repository presents an interesting security situation. While the repository is in active operation (i.e. still receiving nuclear fuel waste) the security requirements will be as for a Class I nuclear facility and Category II nuclear material. If Canada continues with the open or once-through fuel cycle, the repository will be designed such that the nuclear fuel waste is irretrievable. When the repository reaches capacity and is back-filled with the surface area returned to its natural state, what then are the security requirements?

Based on the AECL-proposed design, the nuclear fuel waste would be 500 – 1000 metres below the surface in the Canadian Shield, some of the hardest and most ancient rock on Earth. Properly constructed and back-filled, any attempt to reach the nuclear fuel waste would require almost the same effort as the original construction of the facility. The on-going security requirements post-closure may be reduced or possibly eliminated given the considerable security afforded by the design of the repository. Until an approach is proposed by the NWMO and accepted by the Government of Canada, it is unlikely that a decision on security requirements post-closure will be made.

7.4 REPROCESSING

As the current Canadian CANDU fuel cycle is an open cycle, reprocessing is not a stage in the cycle. However, there is no legislation specifically prohibiting the reprocessing of nuclear fuel waste. Therefore, reprocessing could be included as part of a future storage or disposal approach. As alluded to in Section 2.5, reprocessing has the potential to reduce the volume of material requiring storage or disposal and, from a purely waste management perspective, is appealing for that reason.

Canada does not currently reprocess nuclear fuel waste for two fundamental reasons. First, Canada is a net exporter of uranium. In other words, Canada has sufficient natural uranium to meet its own needs and a surplus for export to other countries for peaceful purposes. Second, the uranium (and plutonium) recovered in reprocessing are not required by Canada for any other peaceful purpose and are in a form that makes them extremely attractive to countries desiring to establish a nuclear weapons program.

From a security perspective, the problem is not the remaining HLW. The problem is the recovered uranium and plutonium. Canada could ship the nuclear fuel waste to another country for reprocessing as is done currently by countries like The Netherlands. The recovered uranium and plutonium then become the security problem of the reprocessing country as only the HLW is returned to Canada. Alternatively, the reprocessing could be done in Canada as part of our overall approach to nuclear fuel waste management. In this case, potentially, the NWMO becomes responsible for the security of the highly attractive recovered uranium and plutonium until such time as it is returned for fuel fabrication.

7.5 TRANSPORTATION

Any future Canadian approach to nuclear fuel waste management that includes centralisation for storage or disposal will have transportation requirements. The primary concern for the transportation of the highly radioactive nuclear fuel waste from the generation site to a centralised disposal or storage facility is the health and safety of persons and the environment should there be a transportation accident. The security required for the transportation of nuclear fuel waste enhances the safety aspects.

Any approach that centralises nuclear fuel waste for either disposal or storage will have transportation security requirements for the movement of the nuclear fuel waste from the existing storage facility to the new centralised location for disposal or storage. The NWMO will be responsible for meeting the security requirements.

Nuclear fuel waste is considered Category II nuclear material. The licensee must apply for a licence to transport Category II nuclear material. The application must contain, in addition to the information required by the Packaging and Transport of Nuclear Substances Regulations, a detailed transportation security plan.

Section 5, *Licence to Transport Category I, II or III Nuclear Material*, of the Nuclear Security Regulations describes the information for inclusion in the plan. It includes, but is not limited to, the following:

a. a threat assessment;
b. proposed security measures; and
c. arrangements for a response force.

The security plan submitted with the licence application is reviewed prior to issuing a licence by CNSC staff in the Security and Emergency Response Division for compliance with the Regulations and a best practices approach to the security arrangements.

Nuclear fuel waste will likely be transported in its DSC or similar container either by road, rail or a combination thereof. Although significant security measures are required for transport, the DSC does not represent a particularly attractive target for theft or sabotage. Assuming an adversary successfully negates the security arrangements, the weight of the DSC precludes easy removal and would require specialised handling equipment. A successful breaching of the DSC to remove the fuel bundles will expose terrorists to high radiation levels.

7.6 CONCLUSION

The security requirements for Class I nuclear facilities and Category II nuclear material (as revised over time) will be applied to any future approach to nuclear fuel waste management.

PART III

8. CONCLUSION

Nuclear fuel waste is highly radioactive and contains fissile materials (uranium and plutonium) attractive for theft or sabotage. For those reasons, nuclear fuel waste must be secured. Through a risk-based approach, the CNSC has established the threat and developed security requirements to meet that threat. These requirements are reflected in the Nuclear Security Regulations and in licence conditions.

The present waste management approach, storage, is required by legislation and regulation to meet the security requirements established by the CNSC. Additionally, IAEA safeguards that include accounting and physical security requirements are applied as licence conditions.

However, to date there has been no publicly acknowledged credible threat to nuclear fuel waste. The physical security measures and administrative controls applied to nuclear fuel waste have a considerable deterrent effect. In addition, the design of the various dry storage containers to inhibit the release of radioactivity also provides significant security for the nuclear fuel waste. Any attempt at theft or sabotage of nuclear fuel waste would require considerable specialised resources, including technically knowledgeable personnel, that are likely unavailable to the current crop of potential terrorists.

Since the threat environment is dynamic, it is not unreasonable to expect that the threat may change over time and necessitate changes to security requirements. That notwithstanding, nuclear fuel waste management will be subject to nuclear security requirements for the foreseeable future regardless of the waste management approach adopted.

9. GLOSSARY

CNSC. The Canadian Nuclear Safety Commission is the federal government agency responsible for the regulation of the Canadian nuclear industry.

Category II Nuclear Material. As applied to fuel in the Nuclear Security Regulations [10] pursuant to the NSC Act, fuel consisting of depleted or natural uranium, thorium, or low-enriched fuel (less than 10% fissile content) and containing more than 500 g of plutonium.

Disposal. As defined in IAEA Safety Series No. 111-G-1.1, *Classification of Radioactive Waste* [15], the emplacement of waste in an approved, specified facility (e.g. geological repository) without the intention of retrieval. Disposal also covers the direct discharge of effluents (e.g. liquid and gaseous wastes) into the environment, with subsequent dispersion.

High Level Waste. As defined in IAEA Safety Series No. 111-G-1.1, *Classification of Radioactive Waste* [15], (10 The radioactive liquid containing most of the fission products and actinides present in spent fuel and forming the residue from the first solvent extraction cycle in reprocessing and some of the associated waste streams. (2) Solidified high level waste from (1) and spent fuel (if it is declared a waste). (3) Any other waste with an activity level comparable to (1) or (2). High level waste in practice is considered long lived. One of the characteristics that distinguishes HLW from less active waste is its level of thermal power.

IAEA. The International Atomic Energy Agency is the United Nations agency responsible for radiation safety and nuclear safeguards.

Nuclear Fuel Waste. As defined by the Nuclear Fuel Waste Act [1], the irradiated fuel bundles removed from a commercial or research nuclear fission reactor.

Nuclear Material. As defined by the IAEA in the Safety Glossary [2], version 1, plutonium except that with isotopic concentration exceeding 80% in plutonium-238, uranium-233, uranium enriched in the isotope 235 or 233, uranium containing the mixture of isotopes in nature other than in the form of ore or ore-residue, and any material containing one or more of the forgoing.

Nuclear Security Regulations. Regulations pursuant to the NSC Act for the security of Category I, II and III nuclear materials and Class I nuclear facilities.

Nuclear Utilities. In the Canadian context, this refers to the four companies that currently operate the 22 CANDU commercial power reactors in Canada (Ontario Power Generation (OPG) Inc, Bruce Power Inc, Hydro-Quebec and New Brunswick Power).

Prescribed Information. As defined in the General Nuclear Safety and Control Regulations [16] pursuant to the NSC Act, information prescribed by Section 21 of the Regulations (i.e. the security arrangements, security equipment, security systems and security procedures established by a licensee in accordance with the Act, the regulations made under the Act or the licence, and any incident relating to security).

Repository. As defined in IAEA Safety Series No. 111-G-1.1, *Classification of Radioactive Waste* [15], a nuclear facility where radioactive waste is emplaced for disposal. Future retrieval of waste from the repository is not intended.

Reprocessing. As defined in IAEA Safety Series No. 111-G-1.1, *Classification of Radioactive Waste* [15], recovery of fissile and fertile material for further use from spent fuel by chemical separation of uranium and plutonium from other transuranic elements and fission products. Selected fission products may also be recovered. This operation also results in the separation of waste.

Safeguards. As defined in the General Nuclear Safety and Control Regulations [16] pursuant to the NSC Act, a verification system that is established in accordance with a safeguards agreement (e.g. *Agreement between the Government of Canada and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-proliferation of Nuclear Weapons*).

Storage. As defined in IAEA Safety Series No. 111-G-1.1, *Classification of Radioactive Waste* [15], the placement of waste in a nuclear facility where isolation, environmental protection and human control (e.g. monitoring) are provided and with the intent that the waste will be retrieved for exemption, processing and/or disposal at a later time.

Vitrification. As defined in IAEA Safety Series No. 111-G-1.1, *Classification of Radioactive Waste* [15], the process of incorporating materials into a glass or glass-like form. Vitrification is commonly applied to the solidification of liquid high level waste from the reprocessing of spent fuel.

Waste Management. As defined in IAEA Safety Series No. 111-G-1.1, *Classification of Radioactive Waste* [15], all activities, administrative and operational, involved in the handling, pre-treatment, treatment, conditioning, transportation, storage and disposal of waste from a nuclear facility.

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b. IAEA INFCIRC/164, *Agreement Between the Government of Canada and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons*, 2 June 1972 (the Agreement entered into force on 21 February 1972).
c. IAEA INFCIRC/164/Add. 1, *Protocol Additional to the Agreement Between the Government of Canada and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons*, 19 July 2000.
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e. IAEA-TECDOC-1276, *Handbook on the Physical Protection of Nuclear Materials and Facilities*;
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