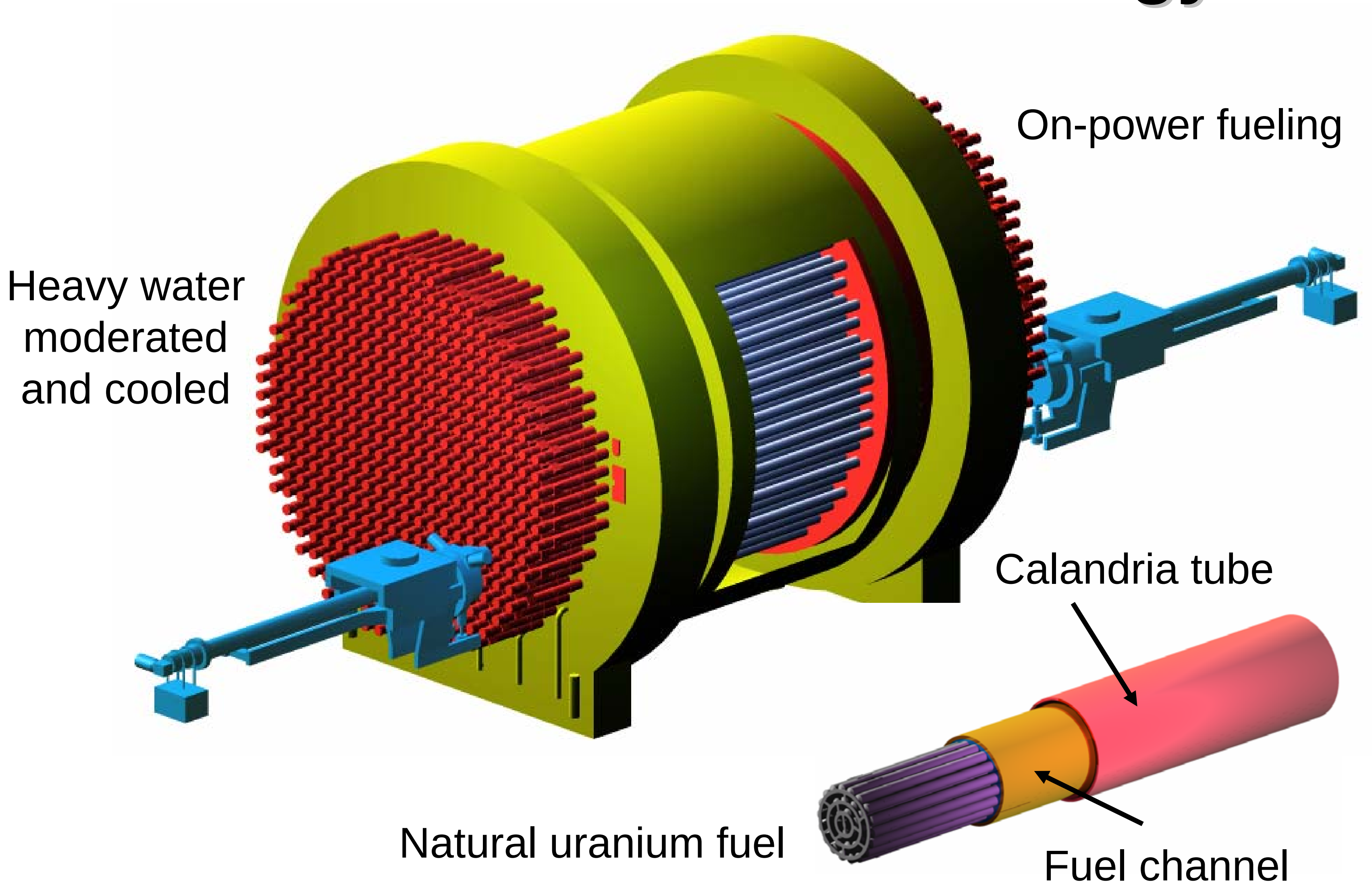
CNA Communications Workshop

Communicating About Nuclear Issues: Nuclear Power Plants

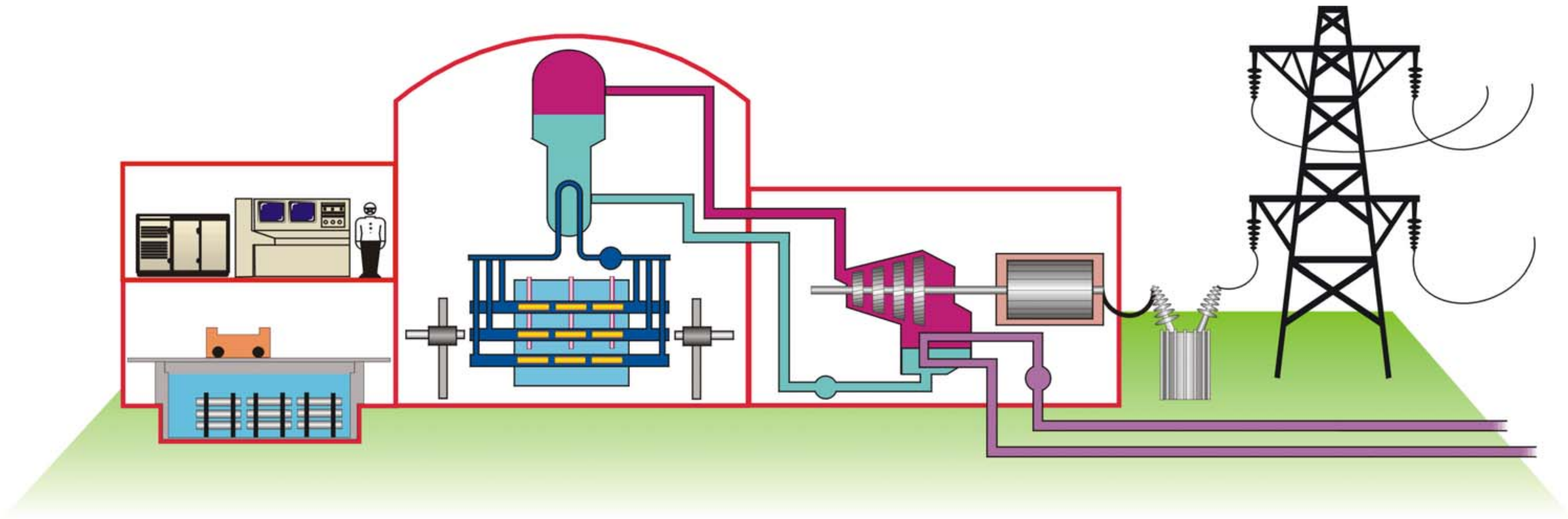
Darlington Generating Station
April 8, 2004

NUCLEAR POWER PLANTS

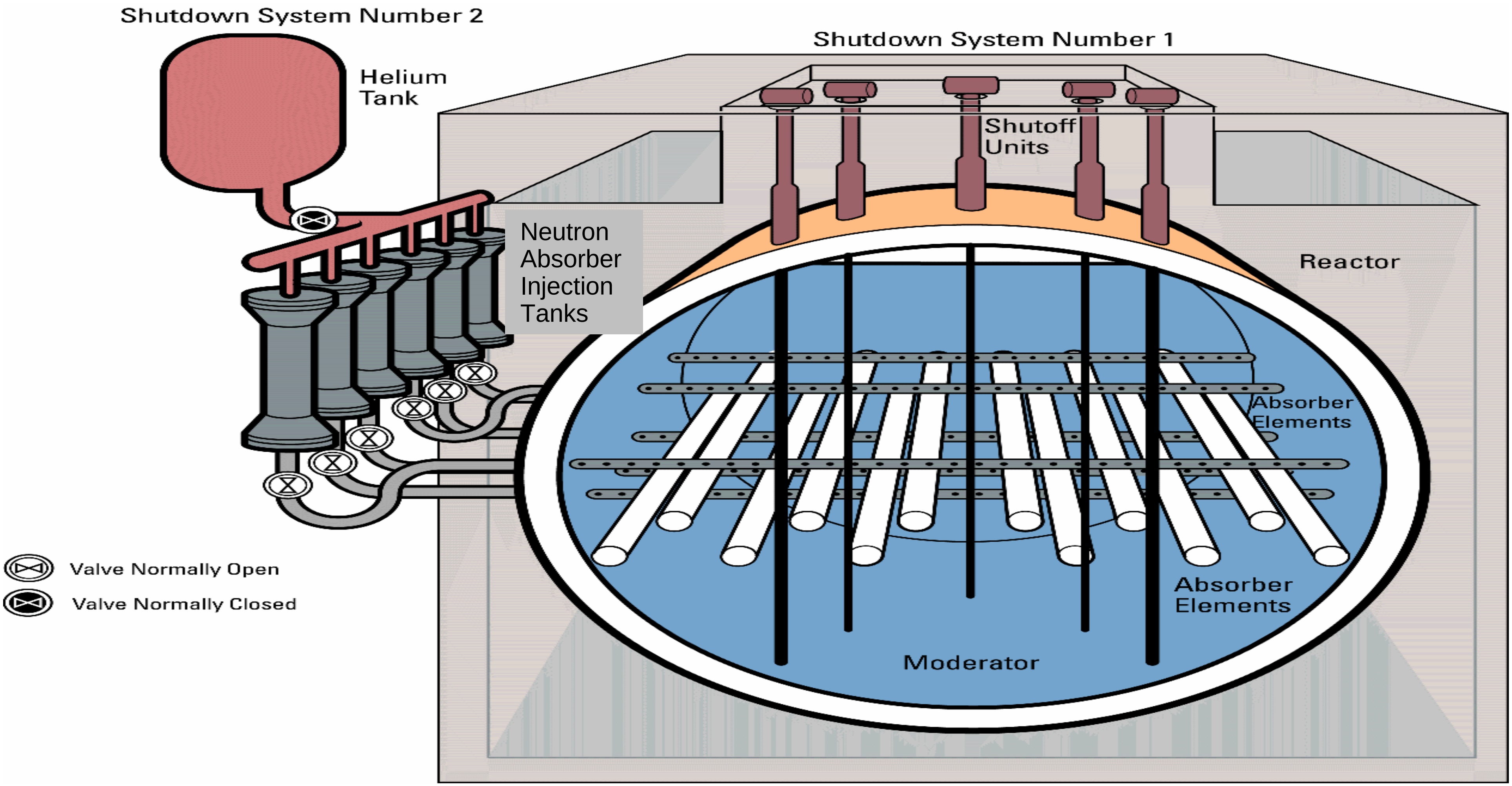
The CANDU® Technology



CANDU Reactor System



CANDU Shutdown Systems



Nuclear Safety

Nuclear Safety Objectives

Fundamental Nuclear Safety Objective

To protect individuals, the members of the general public and the natural environment from harm resulting from the commissioning, operation or decommissioning of a nuclear facility by establishing and maintaining in all nuclear facilities effective defences against radiological hazards.

Nuclear Safety (cont'd)

Radiation Protection Objective

To ensure that during all operational states of a nuclear facility the radiation exposure of persons working within the facility and the radiation exposure of persons living in the environs of the facility due to any planned or unplanned release of radioactive material, in either waterborne or airborne effluents, are controlled below prescribed limits and are as low as reasonably achievable.

Nuclear Safety (cont'd)

Technical Safety Objective

To take all practicable measures (as reasonably and understandably expected by individuals, the general public and regulatory authorities) to prevent failures in nuclear facilities and to mitigate the consequences of any failures, should they occur.

Nuclear Safety (cont'd)

Nuclear Safety Philosophy and Analytical Approach

Fulfillment of the three Safety Objectives requires that nuclear facilities be designed, constructed, commissioned, operated and decommissioned so as to ensure that all sources of radiation exposure are kept under strict technical and administrative control.

Nuclear Safety Philosophy and Analytical Approach (cont'd)

Thus, the comprehensive safety analysis and evaluation involve examination of:

- all planned normal operational modes of the facility;
- expected plant performance during normal operation and in response to abnormal operational occurrences;
- *design basis failures;* and
- failure sequences that may lead to consequences beyond prescribed limits.

The Nuclear Safety Concept of Defence in Depth

The concept of *DEFENCE in DEPTH* is an approach to safety that establishes multiple (overlapping) layers of protection, whether organizational, behavioural or of engineering design, in order to ensure that if a failure were to occur, it would be quickly detected, corrected or compensated for.

The Nuclear Safety Concept of Defence in Depth (cont'd)

The defence in depth concept involves:

- **minimization of failures;**
- **protective systems to detect, correct or to compensate for failures; and**
- **containment barriers to limit the release to the environs of radioactive materials in the event of any failure, minor or major, or a series of failures including *serious failures.***

Levels of Defence

First Level:

Minimization of deviations from normal operating states and, consequently, the minimization of equipment or system failures.

Second Level:

Detection and correction of deviations from normal operating states to prevent such deviations from resulting in an equipment or system failure.

Third Level:

Incorporation of design features which are recognized as inherently safe.

Levels of Defence (cont'd)

Fourth Level:
The provision of a *containment system* designed to cope with the consequences of *design basis failures and "beyond design basis failures".*

Fifth Level:
The incorporation into the overall design of the nuclear power plant of measures established on the basis of integral testing to be the most effective in mitigating the consequences of releases of radioactive materials resulting from either *design basis or beyond design basis* postulated failures.

Licensing

"Whereas it is essential in the national interest to make provision for the control and supervision of the development, application and use of atomic energy, and to enable Canada to participate effectively in measures of international control of atomic energy which may hereafter be agreed upon."

The preamble to the Atomic Energy Control Act of Canada, August 31, 1946.

Licensing (cont'd)

- The Atomic Energy Control Act was proclaimed on October 12, 1946 and on that day, pursuant to Article 3 of the Act, the Atomic Energy Control Board was created.

- On May 31, 2000, the Nuclear Safety and Control Act entered into force and the Atomic Energy Control Board (AECB) transmuted into the Canadian Nuclear Safety Commission (CNSC).

The Canadian Nuclear Safety Commission

The role of the Canadian Nuclear Safety Commission (CNSC) is to regulate the nuclear industry in Canada in such a manner that the development, application and use of nuclear energy and the manifold agricultural, industrial, medical, scientific and educational applications of nuclear materials and their derivatives do not pose an unreasonable risk to the health, safety and security of Canadians and to their natural environment.

The Regulatory Process

The regulatory process in Canada that governs the licensing of nuclear research and power reactors "outside of the fence of the Federal Government" began to be developed in 1956, with the authorization of McMaster University to proceed with the construction of a small, pool-type, enriched uranium fuelled research and teaching reactor within the City of Hamilton.

The Regulatory Process
(cont'd)

Over the 1960s and 1970s the regulatory process for nuclear power reactors evolved into five specific stages of licensing:

- Site approval
- Construction approval (Construction Licence)
- Commissioning approval
- Operating approval (Operating Licence)
- Decommissioning approval

Site Approval

Each Site Evaluation Report documented:

- site characteristics that could affect the impact of any release of liquid or gaseous radioactive effluents on the natural environment and persons living in the environs of the site;

- site characteristics that might result in external events that, in turn, might affect the operation of the plant such as seismicity, tornadoes, flooding, industrial plant, pipeline and transportation failures; and

- the preliminary design of the plant.

Site Approval (cont'd)

Any future site approval by the CNSC will require a comprehensive environmental assessment prepared in accordance with the provisions of the Canadian Environmental Assessment Act.

Construction Licence

The construction licence for the Darlington Generating Station was issued in September 1981. The primary submissions required by the AECB were:

- **a preliminary Safety Analysis Report**
- **detailed commissioning specifications and procedures;**
- **a description of the overall quality assurance program governing the design, procurement, manufacture, construction, commissioning and operation of the plant;**
- **a detailed plan for the training of control room and field operators, maintainers and other essential personnel.**

Commissioning Approval

The commissioning process developed by Ontario Hydro for the Nuclear Power Demonstration (NPD) Generating Station at Rolphton, Ontario was adopted for all CANDU stations in Canada.

“Phase “A” Commissioning was authorized by the AECB in a step-by-step manner as the construction testing of systems was completed by construction forces and the systems turned over to operations personnel.

This series of step-by-step commissioning approvals by the AECB (with the operators and maintainers doing 99.9 % of the task) and the subsequent provision of commissioning completion assurances by operations staff led to the issuance of the Operating Licence.

Operating Licence

The operating licence is a very detailed specification of the operational limits and conditions governing all process systems, safety systems and safety-support systems.

It defines the *SAFE OPERATING ENVELOPE* for the plant and the *LICENSING BASIS.*

Prerequisites for an Operating Licence include:

- Final Safety Report;
- Commissioning Completion Assurance;
- list of the operations personnel designated by the (AECB/CNSC) as Authorized Nuclear Operators;
- comprehensive Operating Policies and Principles;
- standard operating procedures and abnormal incident procedures;

Prerequisites for an Operating Licence include:

- waste and hazardous substance management and disposal procedures;

- on-site and off-site emergency procedures

- Security Plan and Procedures; and

- proof of third party liability insurance coverage as required by the Nuclear Liability Act of Canada.

Decommissioning Approval

The Nuclear Safety and Control Act of Canada requires that operators of nuclear facilities make provision for the decommissioning of existing or proposed facilities.

Requirements:

- **decommissioning plans;**
- **verifiable estimates of the costs of implementing the plans; and**
- **financial measures to ensure that the costs of decommissioning will be met.**

Effluent Monitoring

The regulations made under the Canadian Nuclear Safety and Control Act specify dose limits for workers and for members of the general public based on the recommendations of the International Commission on Radiological Protection.

For workers, the limit is a five year, average annual limit of 20 mSv (a total of 100 mSv over the five year period) with a maximum in any one year of 50 mSv.

For members of the general public the annual limit is 1 mSv.

Effluent Monitoring (cont'd)

Power reactor operating licences incorporate radioactive material emission limits for each type of radioactive material that could enter an effluent stream. These *DERIVED EMISSION LIMITS (DELs)* are based upon the fundamentally important dose limit for members of the general public.

To ensure that airborne or waterborne releases of radioactive materials from nuclear power plants are minimized, the operators have established control targets of 1 % of the DELs.

In its Annual Report for 2002-2003, the CNSC stated that "for nuclear generating stations …. exposures to the public were less than one per cent of the regulatory limit ".

Waste Management

The generation of radioactive waste in a nuclear power plant is kept to the minimum practicable because:

- it is a matter of high quality operational performance;
- it makes good economic sense; and most importantly
- it accords with the principle of keeping radiation exposure doses to workers and to members of the public as low as reasonably achievable.

Spent Fuel

Spent nuclear power reactor fuel, more recently termed "used fuel", has been safely stored in below-ground, water-filled, reinforced concrete structures since the early 1960s and in above-ground, dry-storage, reinforced concrete, double carbon steel-lined structures since the early nineties.

Some persons question the longevity of reinforced concrete storage containers. Apparently, they have never visited the Colosseum in Rome which was constructed about 80 A.D. by Vespasian and Titus long before high strength, reinforced concrete had been developed.

Spent Fuel (cont'd)

- In a 1978 joint statement, the governments of Canada and Ontario directed AECL to develop the concept of deep geologic disposal of spent fuel. Ten years later, AECL completed its task.
- On October 4, 1989, the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel was established to review the results of AECL's work.
- More than nine years later, in February, 1998 the Panel submitted its Report to the Government in which it stated that "…from a technical perspective, safety of the AECL concept has been on balance adequately demonstrated …… but, from a societal perspective, it has not".

Spent Fuel (cont'd)

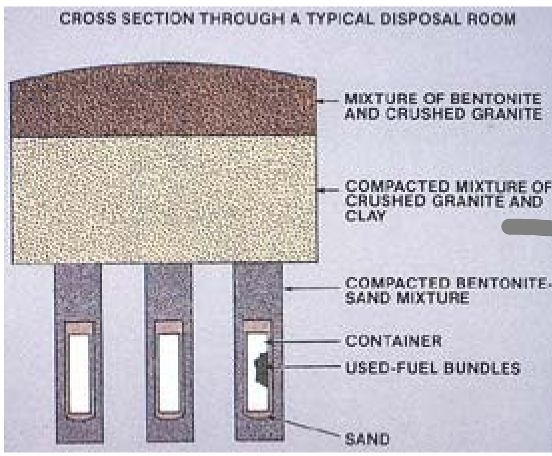
In 1996, the Federal Government formally allocated long-term responsibilities for the management and ultimate disposal of radioactive wastes produced by nuclear power plants to the owners of these plants.

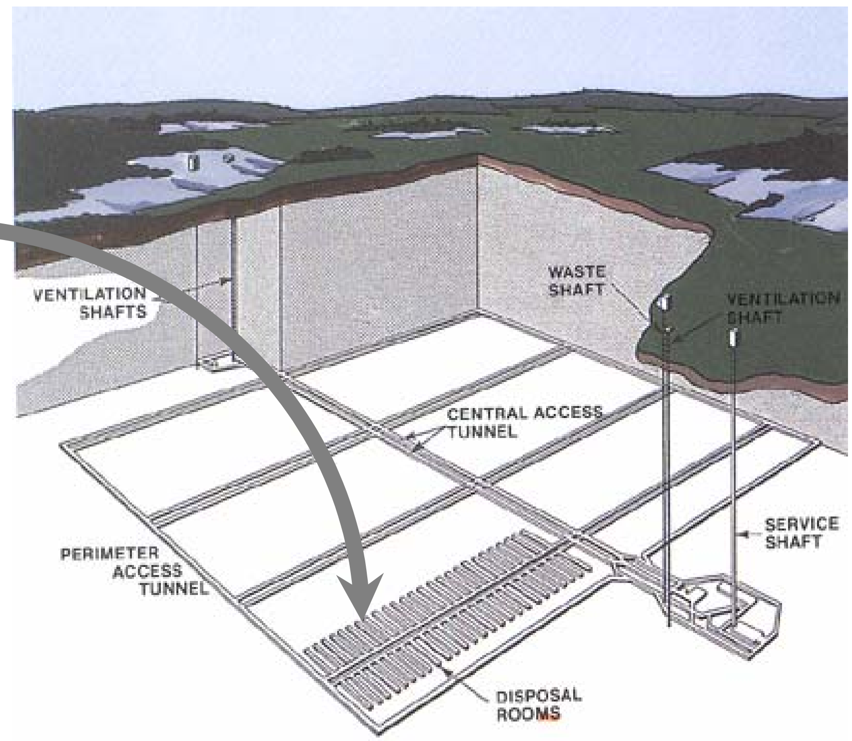
The Nuclear Fuel Waste Act came into effect on November 15, 2002. It established the Nuclear Waste Management Organization (NWMO). The principal parties are OPG, Hydro Quėbec and N.B. Power.

The NWMO reports to the Federal Government annually and it is scheduled to submit its recommendations by November 15, 2005.

AECL's Concept for Deep Geological Disposal

Containment, 500-1000 m underground, in the stable rock of the Canadian Shield





Based on projected reactor capacity, a single disposal facility could accommodate Canada's used fuel beyond the year 2035.

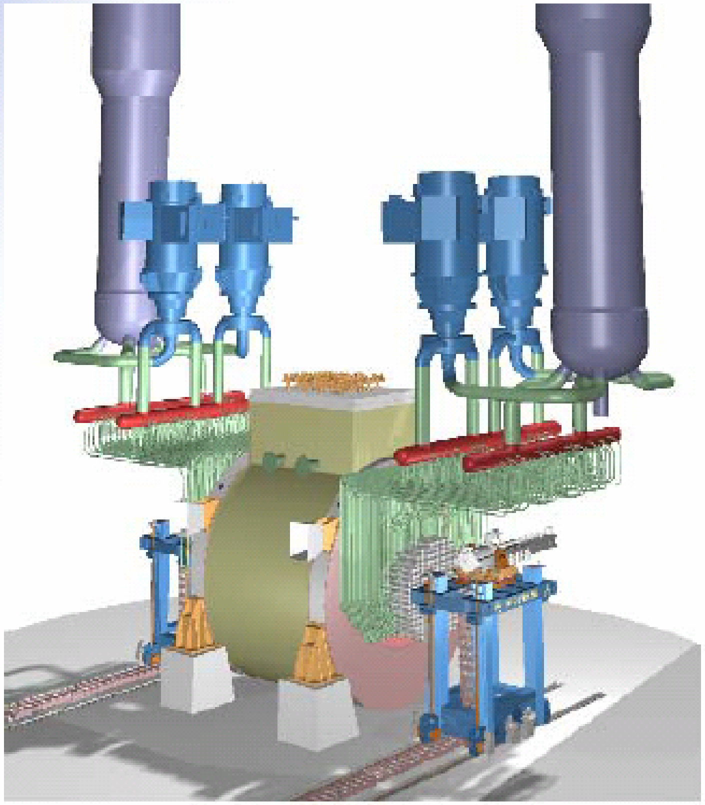
Spent Fuel (cont'd)

One point of interest about spent nuclear fuel is that, in comparison to other industrial wastes, it is relatively very low in volume. This is because of its high energy density.

At the end of 1998, the total volume of spent fuel in Canada was about 5,500 cubic metres or about the volume of 3 international hockey rinks (4 NHL rinks) or 3 Olympic size swimming pools, which are approximately 50 m x 18.3 m x 2 m (1830 cubic metres). An Olympic soccer field, filled to 1.3 metres would hold all of this spent fuel.

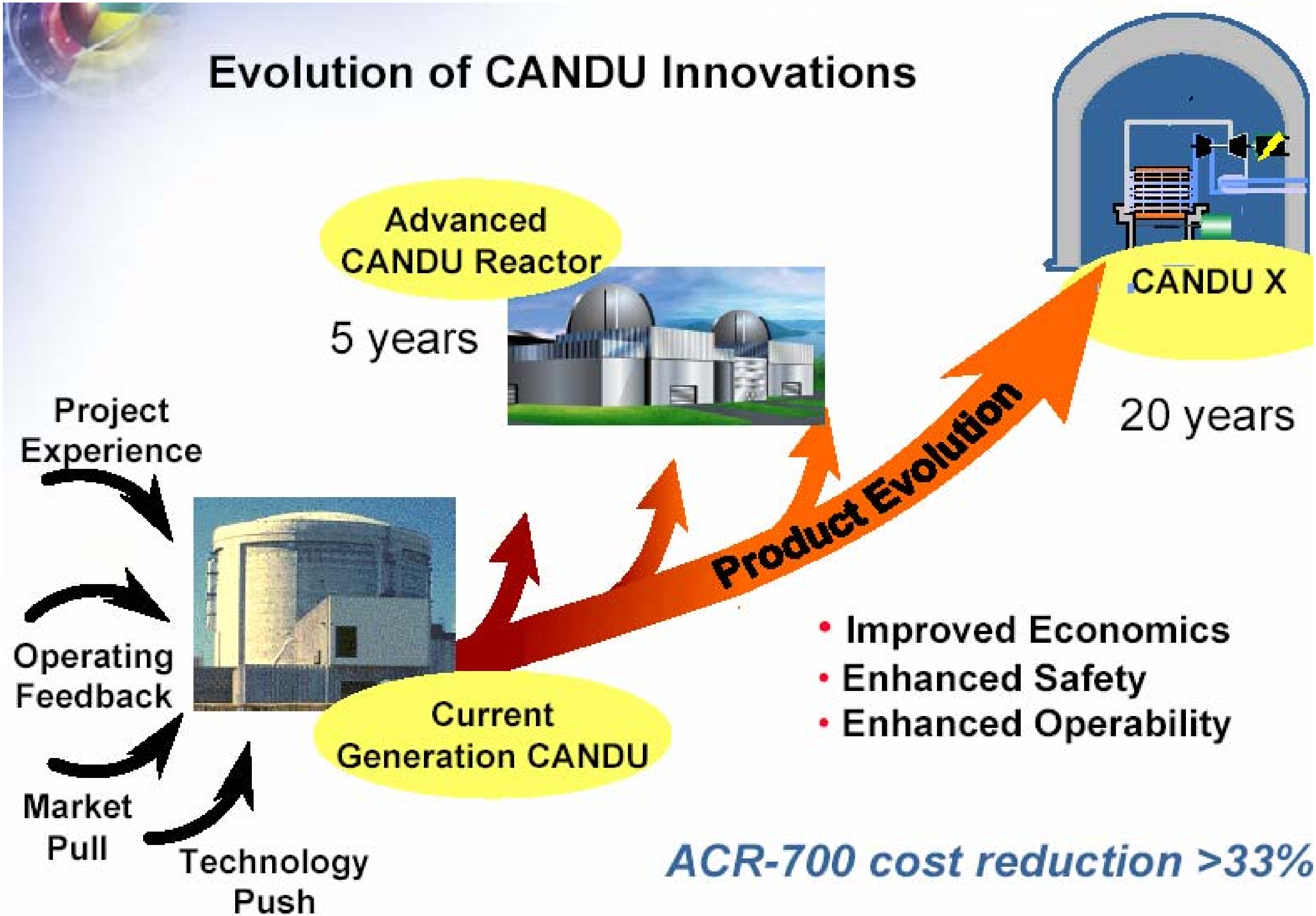
Advanced CANDU Reactor (ACR™)

Significant capital cost reduction – competitive with natural gas – achieved by:



- evolutionary design (equivalent 700 Mwe but a smaller design)
  - 33% reduction in containment
  - fuel life extended up to three times
  - 60% reduction in core volume
  - 75% reduction in heavy water
  - two-thirds less spent fuel
- advanced construction techniques
  - modular, pre-fabricated design
  - 48-month project schedule, 36 months to build
- commercial agreements with British Energy and Hitachi, Ltd.
- ACR introduced to US in June 2002

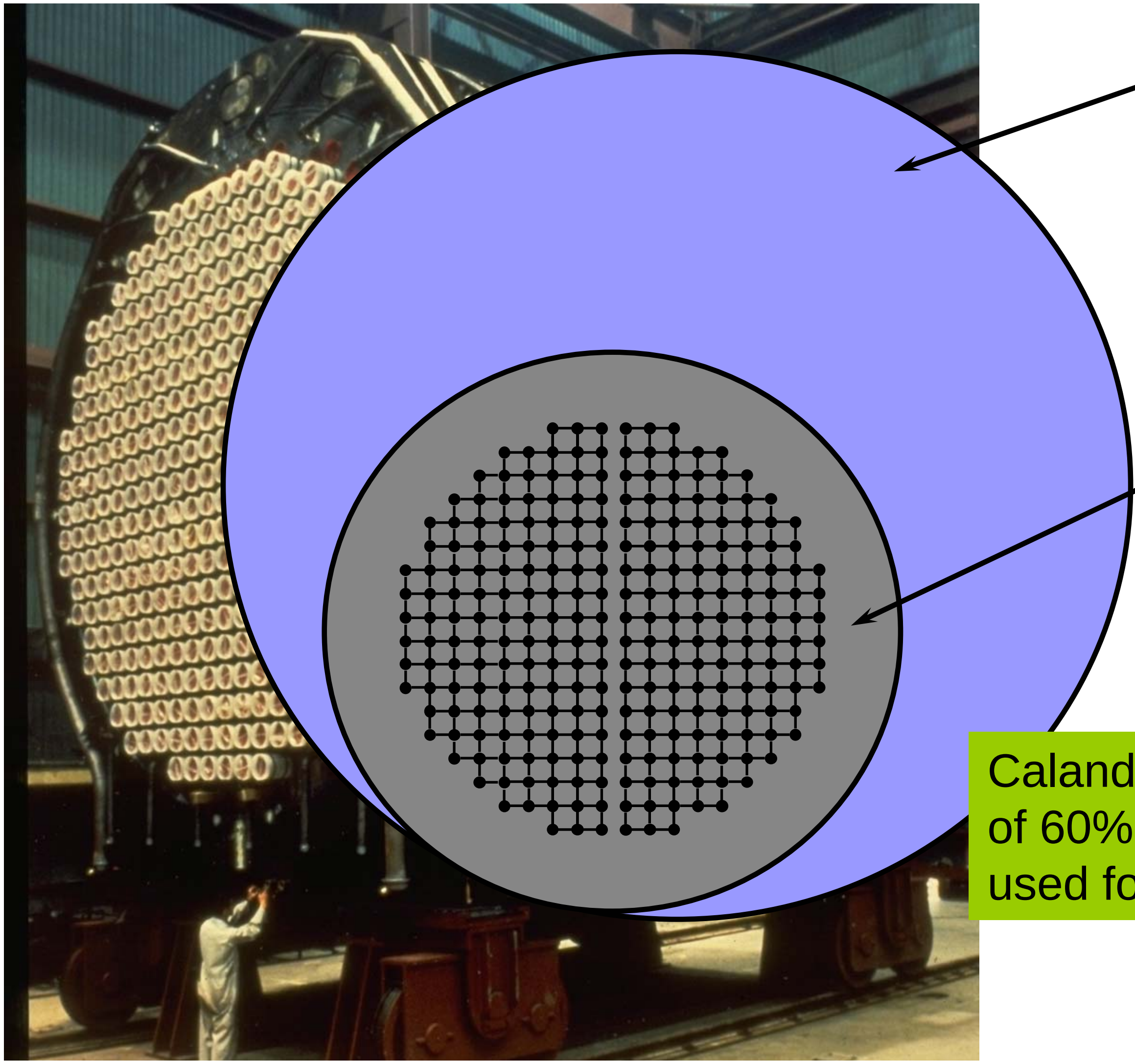
Evolution of CANDU Innovations



- Improved Economics
- Enhanced Safety
- Enhanced Operability

ACR-700 cost reduction >33%

Advanced CANDU Reactor (ACR™)



CANDU 6
728 MW(e)
380 channels
Diameter = 7.6 m

ACR 700:
731 MW(e)
284 channels
Diameter = 5.2 m

Calandria volume reduced by factor of 60% and 25% less heavy water used for same power.