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ACR-1000™ Project – Licensing Opportunities and Challenges

by

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Outline

- Introduction
- Overview of the ACR-1000™ design
- ACR-1000 Pre-project Regulatory Design Reviews
- Conclusions and Final Remarks

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Atomic Energy of Canada Limited

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- **Established in 1952 to lead the Canadian nuclear industry.**
- **33 CANDU reactors in-service worldwide**
- **Over 4,800 employees**
- **CANDU recognized as one of the top 10 major engineering achievements of the past century in Canada.**
- **World records in construction and commissioning.**
- **Advanced R&D Facilities**
- **AECL is a fully integrated company: reactor designer, vendor, project management, R&D, nuclear services, refurbishment, waste management, worldwide**

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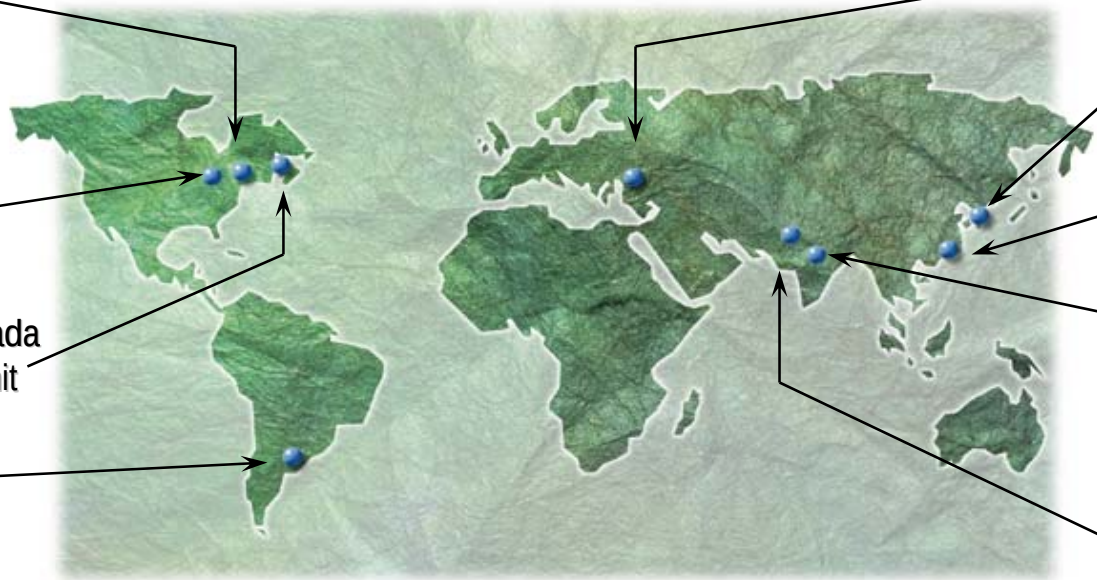
CANDU™ – A Global Success

Quebec, Canada
Gentilly 2 1 unit

Ontario, Canada
Darlington 4 units
Pickering 6 units
Bruce 8 units

N.Brunswick, Canada
Point Lepreau 1 unit

Argentina
Embalse 1 unit



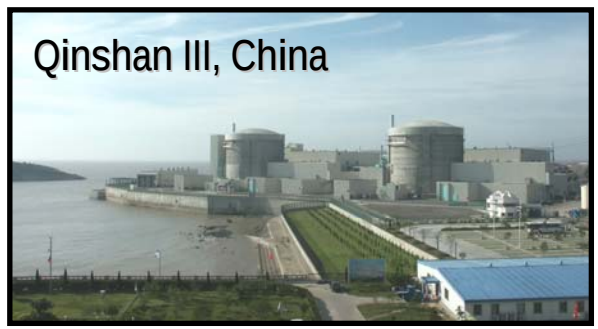
Romania
Cernavoda 2 units
+ 2 units planned

South Korea
Wolsong 4 units

China
Qinshan 2 units

India
2 CANDU units
15 PHWR units,
3 units under construction

Pakistan
KANUPP 1 unit



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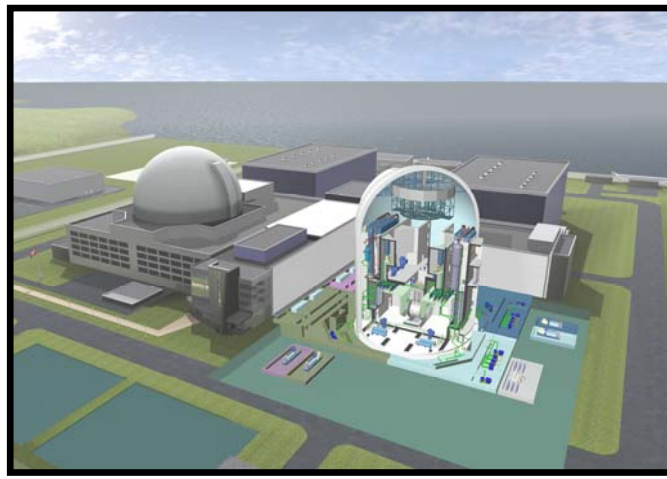
AECL's Power Reactor Products

ACR-1000 (Advanced CANDU Reactor)

- 1200 MWe class reactor
- Generation III+ technology
- Combines experience of CANDU 6 with new CANDU concepts
- Light water cooling & low enriched fuel
- Enhanced safety, economics, operability



EC6 (Enhanced CANDU 6)

- 740 MWe class
- Heavy water moderated and cooled, natural uranium fueled
- Based on the Qinshan project
- Enhanced to meet current regulatory requirements in Canada and internationally

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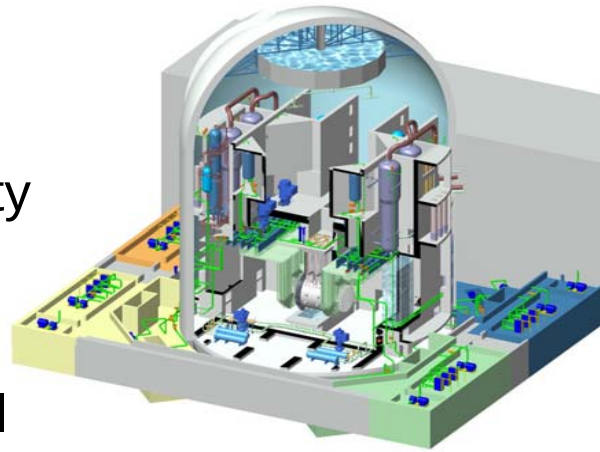
ACR-1000 Outline

- **Safety enhancements**
  - Latest international requirements for new plants (passive safety; design margins; physical protection)
- **Improved economics**
  - Simplification; standardization; constructability
- **Operational enhancements and high performance**
  - Operator feedback and intelligent operational support
  - Longer regular operating period (3 years) and shorter outage time
  - Human factors
  - Maintainability
  - High QA standards



ACR-1000 designed to meet Generation III+ requirements

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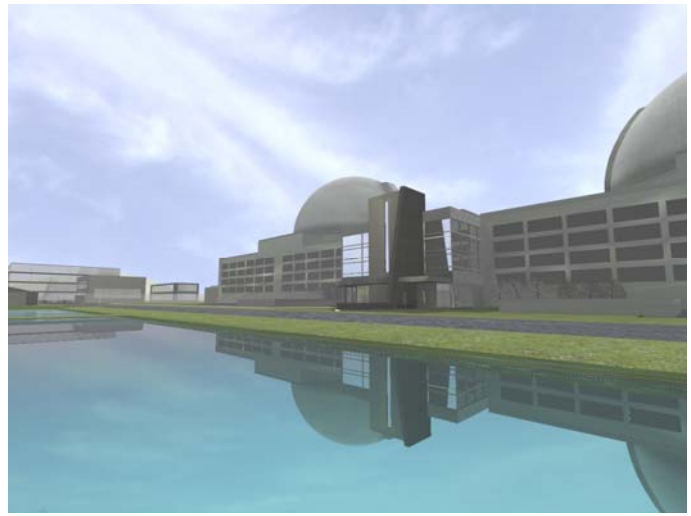
ACR-1000 CANDU-Generic Features

ACR-1000 evolves from the successful CANDU 6 family of units & combines domestic and offshore experience:

- Modular horizontal fuel channels
- Simple fuel bundle design
- Separated coolant from moderator
- High neutron efficiency
- Cool, low pressure heavy water moderator
- On-power fuelling
- Passive shutdown systems
- Water-filled reactor vault
- Accessible reactor building while on power



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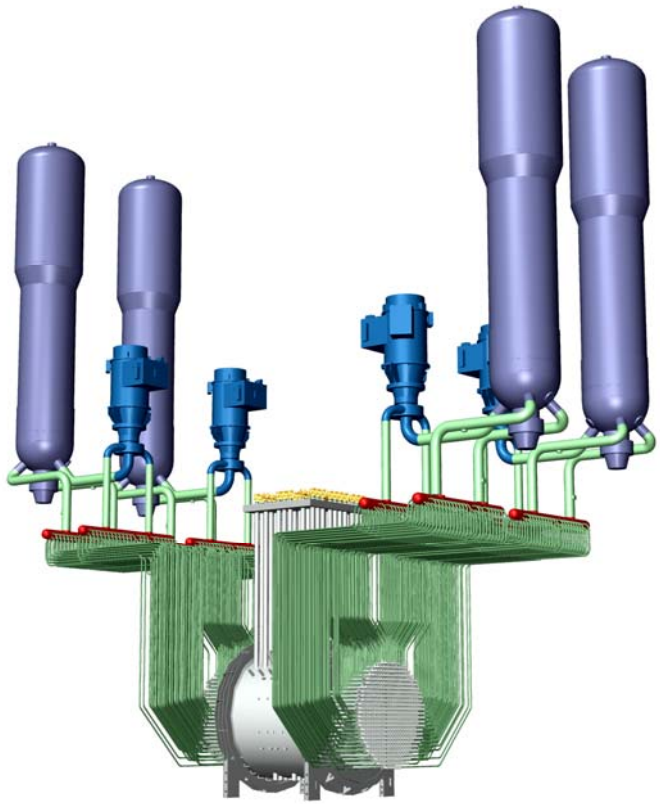
ACR-1000 Design Innovations

- Low enriched fuel
- Light water coolant
- Higher thermal efficiency
- Enhanced passive safety features
- Smaller reactor core with improved stability and output
- Design features for simpler operations & maintenance → higher CF (> 93%)
- Optimized plant arrangement
- Advanced construction methods



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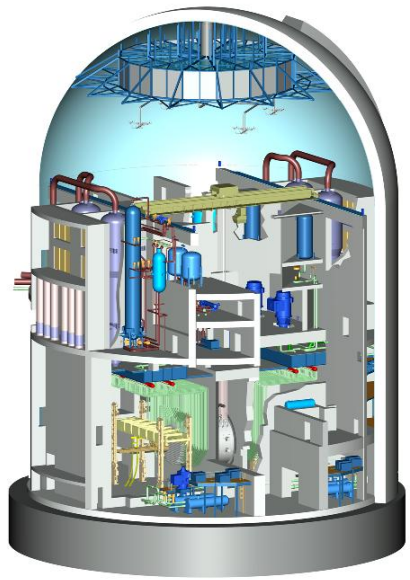
ACR-1000 Design Overview - 1

- Excellent balance of inherent, passive and engineered safety features
- Safety design approach based on defence-in-depth in design including five classical physical barriers
- Defence-in-depth extended to management activities, including organizational, safety, and behavioral aspects
- Independence and separation principle used extensively
  - **Physical and functional separation of systems important to safety**
  - **Redundant systems and subsystems where required**
  - **Four quadrant separation philosophy concept applied for systems important to safety**



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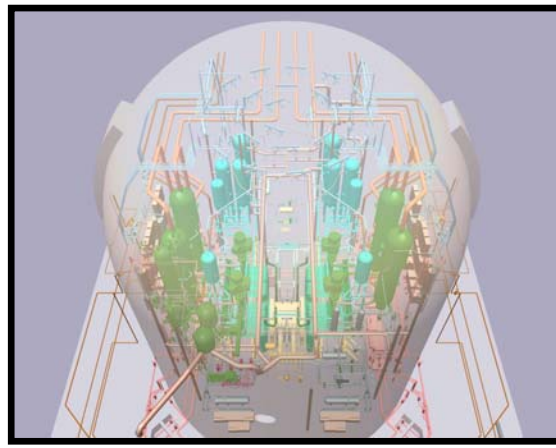
ACR-1000 Design Overview - 2

- Safety systems – traditional CANDU design philosophy
- Two fully diverse, fully capable and separate shutdown systems in addition to the reactor regulatory system
  - Shutdown System 1 – insertion of vertical mechanical rods
  - Shutdown system 2 – insertion of neutron-absorbing solution in the moderator
- Emergency Core Cooling System consists of high-pressure Emergency Injection System and Long Term Cooling system
- Containment system
- Emergency Feed-water System provides water to the steam generators secondary side



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ACR-1000 Pre-Project Regulatory Reviews

- Objectives:
  - **Identify any potential regulatory issues early in the design, so there is time to address them before project commitment**
  - **Mitigate and reduce licensing risk, and ensure cost and schedule of the project is acceptable before a project is committed**
  - **Ensure good understanding, implementation and compliance with the regulatory requirements expected of new NPPs in Canada, and in foreign jurisdictions, which are higher compared to the past regulatory practice**

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Review by US Nuclear Regulatory Commission during 2002 - 2004

- ACR-700 (predecessor of ACR-1000)
- Driver - AECL's business opportunity in US
- Review of twelve focus topics
- Review documented in the PASAR and concluded with:

"…*Notwithstanding, based on the information provided, the staff believes at this time that AECL will ultimately be able to satisfactorily address these policy, regulatory, and technical issues during the design certification review.*"

Earlier Regulatory Reviews of ACR - 2

Pre-project Reviews by CNSC

- **ACR-700** (2003 – 2005) focus on design requirements, R&D support and analysis (CNSC reviewed 100 documents)
- **ACR-1000** (2005 – 2006) Common Focus Topics (compliance, safety analysis, PSA, design of major systems, human factors, software) - 51 documents reviewed

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Earlier Regulatory Reviews of ACR - 3

2007 - 2008 General Design Assessment of ACR-1000 by the UK Regulators:

- Nuclear Directorate of Health & Safety Executive (Nuclear Installation Inspectorate (NII) & Office of Civil Nuclear Security (OCNS), Environmental Agency and Scottish Environmental Protection Agency
- International Atomic Energy Agency's (IAEA's) help in technical reviews

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Conclusions of the UK Review

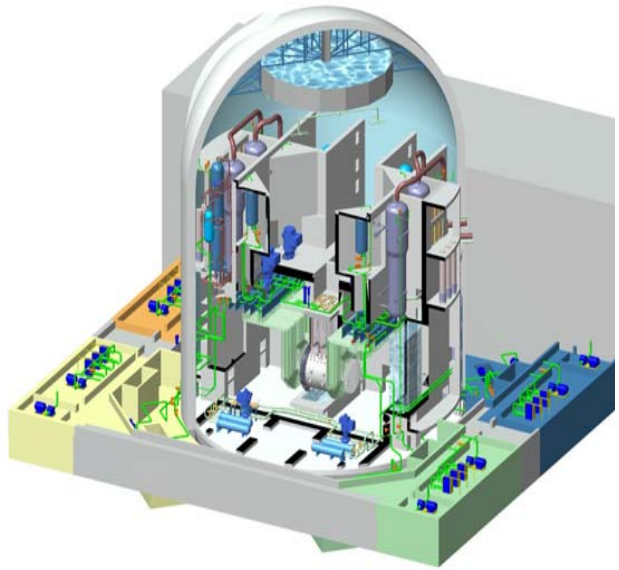
NII: *"NII has not found any safety or security shortfalls that are so serious as to rule out at this stage eventual construction of the ACR-1000 design on licensed sites in the OK"*

IAEA: *"IAEA did not reveal any fundamental safety problems with the ACR-1000***"**

Due to new build priorities in Ontario in Canada, AECL suspended its application from GDA in the UK in April 2008 putting on hold Phases 3 & 4.

AECL-CNSC Regulatory Interactions

- New regulatory framework has been introduced in Canada
- AECL was involved in pre-consultation review of "Requirements for Design of Nuclear Power Plants" (RD-337) with compliance assessment early in the design process
- AECL assessed compliance of the ACR-1000 design with RD-337, RD-310 and R-7, -8, -9, -77, etc.
- AECL reviewed and addressed in the ACR-1000 design CNSC General Action Items (GAIs) and Operating Experience (OPEX) issues



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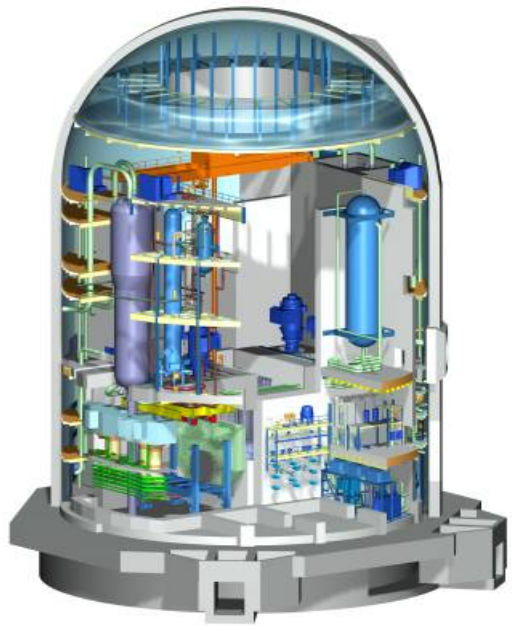
AECL-CNSC Review Framework

(April 1, 2008 – August 30, 2009):

Phase 1: an overall assessment of design intent compliance with CNSC requirements and meeting the expectations for new NPPs in Canada

Phase 2: focuses on technical design details to identify any potential fundamental barriers to licensing in Canada

Phase 3: (Sep. 1, 2009 – Sep. 30, 2010):
Review by CNSC of the implementation of AECL's planned activities integral to a number of focus areas and selected topics which have been reviewed and discussed during Phase 2



CNSC Pre-project Review - 2

- **Review objectives:**
  - **Assess whether the ACR-1000 design as submitted was, at an overall level, compliant with the CNSC regulatory requirements;**
  - **Assess whether the design provisions provided for selected review focus areas met the CNSC's expectations for new nuclear power plants in Canada; and**
  - **Identify, based on the review of the focus areas, whether there were any potential fundamental barriers to licensing the ACR-1000 design in Canada.**

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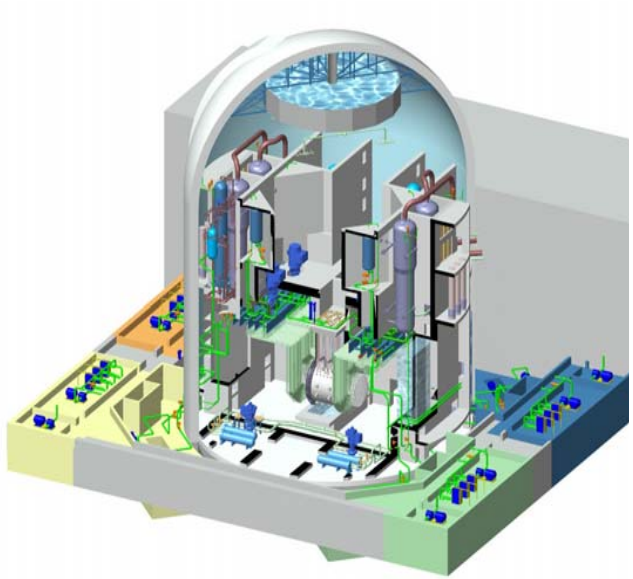
CNSC Pre-project Review - 3

Phase 1:

- **Review included**: safety principles, SSCs important to safety, design robustness against malevolent acts, safety analysis demonstrating adequacy of the design
- Ended in December 2008,
- **Review concluded that**: "*At an overall level the design intent is compliant with the CNSC regulatory requirements and meets the expectations for new nuclear power plants in Canada" and*

"CNSC staff did not find any issues that would lead to significant design changes"



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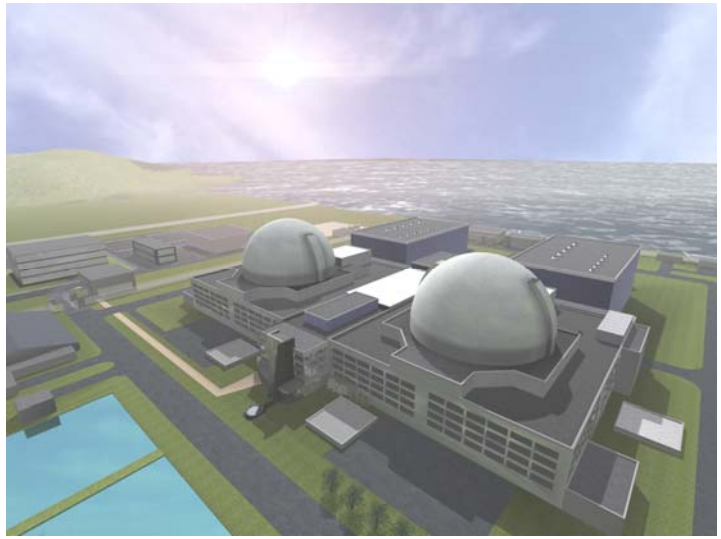
CNSC Pre-project Review - 4

Phase 2 focus topical areas:

- Defence –in-depth, Classification of Structures, Systems and Components (SSCs) and Regulatory Dose Limits
- Reactor Physics Aspects of Nuclear Design
- Fuel Mechanical and Thermalhydraulics Design
- Emergency and Long Term Core Cooling and Emergency Feedwater System
- Containment and Reactor Auxiliary Building
- Safety Analysis (deterministic and probabilistic)
- Heat Transport System Pressure Boundary
- Robustness, Security and Safeguards
- Severe Accident Prevention and Mitigation
- Quality Assurance in Design and Safety Analysis



- Reactor Control System
- Shutdown Means
- Fire Protection
- Radiation Protection
- Out–of–Core Criticality
- Human Factors
- R&D

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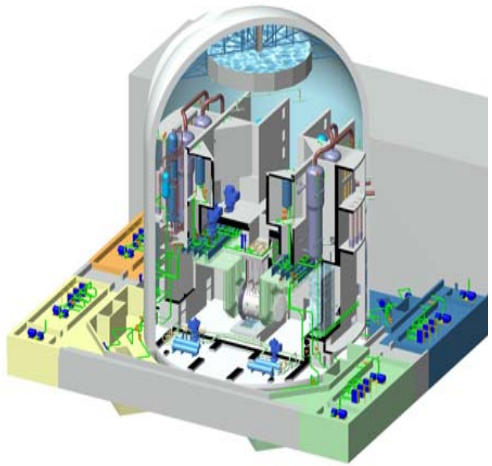
CNSC Pre-project Review - 5

CNSC Phase 2 review completed, and final report issued at the end of August 2009, Executive Summary put on the CNSC web site



Review key conclusions:

- AECL provided sufficient documentation details
- In the reviewed focus topics CNSC staff did not identify any fundamental barriers to licensing ACR-1000 in Canada
- Completion of the R&D program is of key importance for the construction licence review
- ACR-1000 commissioning program is an important component of design verification, particularly in the areas where innovative design features are implemented

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Conclusions & Final Remarks

- AECL has devoted considerable effort to review, assess and address Canadian and international regulations in the ACR-1000 design so that the reactor was fully compliant with current regulations
- AECL has engaged the CNSC, US NRC and UK regulators to evaluate the robustness and safety of ACR-1000 and used their feedback to improve the design
- Phase 1 of the current CNSC pre-project review confirmed that at an overall level ACR-1000 is compliant with Canadian regulations
- Phase 2 is of the current CNSC review confirmed that ACR-1000 design does not have any fundamental barriers to licensibility of ACR-1000 in Canada

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