Regulatory Challenges Presented by SMR Technologies

CNSC Presentation to IAEA Technical Meeting on Technology Assessment of Small Modular Reactors for Near Term Deployment

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Outline

- Canadian Nuclear Safety Commission
- Small Modular Reactor (SMR) discussion paper
- Status of Vendor Design Reviews in Canada
- Implications of new reactor technologies (SMRs and Advanced Reactors) in pre-licensing and licensing processes
Established May 2000, under the 
*Nuclear Safety and Control Act*

Replaced the Atomic Energy Control Board, established in 1946 under the 
*Atomic Energy Control Act*

The CNSC regulates all nuclear-related facilities and activities

*Over 70 years of experience*
Our Mandate

- Regulate the use of nuclear energy and materials to protect the *health, safety* and *security* and the *environment*
- Implement Canada’s *international commitments* on the peaceful use of nuclear energy
- Disseminate *objective scientific, technical* and *regulatory information* to the public
CNSC Regulates all Nuclear-Related Facilities and Activities

The fuel cycle
- Uranium mines and mills
- Uranium fuel fabrication
- Nuclear power plants
- Waste management facilities

Other facilities and activities
- Nuclear substance processing
- Industrial and medical applications
- Nuclear research and educational facilities
- Export/import of controlled nuclear substances

Over the entire lifecycle
Independent Commission

- Quasi-judicial administrative tribunal
- Independent Commission members
- Public hearings
- Supported by Secretariat and independent legal services
- Decision can only be reviewed by the Federal Court

*Transparent, science-based decision-making*
Objectives of the CNSC’s SMR discussion paper and general trends from consultation comments
To address growing stakeholder interest in SMRs, CNSC issued a discussion paper and sought feedback from a wide audience to understand:

- Some of the key regulatory issues that may need to be resolved
- The adequacy of existing regulatory framework tools to address potential projects
- Potential changes to regulatory framework tools to ensure novel approaches are appropriately considered
The major themes of the consolidated comments are:

1. There is no need for significant changes to the CNSC’s regulatory framework
2. There are no insurmountable roadblocks to licensing SMR units in Canada under the existing regulatory framework
3. Achieving common understanding on application of the graded approach between SMR designers or proponents and the CNSC would be beneficial
4. The licensing process should be streamlined to take into account use of identical SMR modules (e.g. design acceptance regime)
Outcome of consultation: What We Heard Report, (WWHR) posted on CNSC Website on September 19, 2017

WWHR provided on next steps and implications to the regulatory framework:

- consideration of amendments to the *Nuclear Security Regulations*
- providing greater clarity on application of the graded approach
- providing greater clarity on licensing for SMRs
- reviewing related CNSC regulatory documents
Status of Vendor Design Reviews in Canada
Pre-Licensing Engagement

- Stakeholders encouraged to engage with CNSC early
- Vendor Design Review is one process used to engage with reactor technology vendors:
  - provides feedback on vendors’ efforts to address Canadian requirements in their design and safety analysis activities
  - focuses on the vendors’ processes used to develop the design
  - allows for early identification of key issues and any potential fundamental barriers to licensing
  - identifies research activities in order to support design review and future licensing requirements

*The Commission retains the final licensing decision*
## Phase 1 CNSC Vendor Design Reviews in Progress

<table>
<thead>
<tr>
<th>Country of origin</th>
<th>Company</th>
<th>Reactor type / output per unit</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada / U.S.</td>
<td>Terrestrial Energy</td>
<td>Molten salt integral / 200 MWe</td>
<td>In progress – pending completion October 2017</td>
</tr>
<tr>
<td>U.S. / Korea/ China</td>
<td>UltraSafe Nuclear/Global First Power</td>
<td>High temperature gas prismatic block / 5 MWe</td>
<td>In progress – pending completion March 2018</td>
</tr>
<tr>
<td>Canada</td>
<td>LeadCold Nuclear</td>
<td>Molten lead pool fast spectrum / 3 – 10 MWe</td>
<td>In progress</td>
</tr>
<tr>
<td>Canada / U.S.</td>
<td>StarCore Nuclear</td>
<td>High temperature gas prismatic block / 10 MWe</td>
<td>Service Agreement under development</td>
</tr>
<tr>
<td>U.S.</td>
<td>Advanced Reactor Concepts</td>
<td>Sodium pool fast spectrum /100 MWe</td>
<td>In progress- pending completion Feb. 2019</td>
</tr>
<tr>
<td>U.K.</td>
<td>U-Battery</td>
<td>High temperature gas prismatic block / 4 MWe</td>
<td>Service Agreement under development</td>
</tr>
</tbody>
</table>
Vendor: Terrestrial Energy

Review in progress

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical capacity</td>
<td>200 (MW)</td>
</tr>
<tr>
<td>Fissile content</td>
<td>Low enriched U-235 initial fuel and makeup fuel</td>
</tr>
<tr>
<td>Moderator</td>
<td>Hexagonal graphite elements</td>
</tr>
<tr>
<td>Design life of each</td>
<td>7 years (replaceable core)</td>
</tr>
<tr>
<td>core module</td>
<td></td>
</tr>
<tr>
<td>Spent core storage</td>
<td>On-site</td>
</tr>
</tbody>
</table>

IMSR-400 facility cross section – Courtesy Terrestrial Energy
### Vendor:
**UltraSafe Nuclear/Global First Power**

<table>
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<tr>
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<tbody>
<tr>
<td>Electrical Capacity (MW)</td>
</tr>
<tr>
<td>Fissile Content (fuel particles in coated particles embedded in carbon moderator matrix)</td>
</tr>
<tr>
<td>Design Life of each core module</td>
</tr>
<tr>
<td>Spent Core Storage</td>
</tr>
</tbody>
</table>
**Vendor: LeadCold Nuclear**

Cross section of reactor core module – courtesy *LeadCold Nuclear*

<table>
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<tr>
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<tbody>
<tr>
<td><strong>Electrical Capacity (MW)</strong></td>
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<td><strong>Fissile Content</strong></td>
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<tr>
<td><strong>Moderator</strong></td>
</tr>
<tr>
<td><strong>Design Life of each core module</strong></td>
</tr>
<tr>
<td><strong>Spent Core Storage</strong></td>
</tr>
</tbody>
</table>
Vendor: StarCore Nuclear

View of entrance to StarCore power main complex – courtesy StarCore Nuclear

<table>
<thead>
<tr>
<th>Service agreement under development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical capacity (MW)</td>
</tr>
<tr>
<td>Fissile content (fuel particles in coated particles embedded in carbon moderator matrix)</td>
</tr>
<tr>
<td>Design life of each core module</td>
</tr>
<tr>
<td>Spent core storage</td>
</tr>
</tbody>
</table>
1) Control rods  
2) Heat exchanger  
3) Reactor Core  
4) Pump  
5) Reactor vessel  
6) Concrete  
7) Human scale

Cross section of core module – courtesy ARC Nuclear

### Review in-progress

<p>| | |</p>
<table>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Capacity (MW)</td>
<td>100</td>
</tr>
<tr>
<td>Fissile Content</td>
<td>Low enriched U-235 (&lt;20% enriched) metallic allow</td>
</tr>
<tr>
<td>Moderator</td>
<td>None – fast neutron spectrum</td>
</tr>
<tr>
<td>Design Life of each core module</td>
<td>20 years (refuellable core)</td>
</tr>
<tr>
<td>Spent Core Storage</td>
<td>On-site</td>
</tr>
</tbody>
</table>
Understanding the Implications of New Reactor Technologies for Regulators
According to the *Nuclear Safety and Control Act*, no licence shall be issued unless, in the opinion of the Commission, the applicant:

(a) is qualified to carry on the activity that the licence will authorize the licensee to carry on and

(b) will, in carrying on that activity, make adequate provision for the protection of the environment, the health and safety of persons and the maintenance of national security and measures required to implement international obligations to which Canada has agreed.
Credible Science and Technology
Information in Support of Safety Claims

Many safety claims are being made by developers and proponents:

- Most designs still conceptual (5-20% complete) – no Preliminary Safety Analysis Report yet
- Evidence to support these claims has not yet been reviewed by regulators
  - adequacy of R&D, safety analysis, safety classification approach etc.
  - are requirements being addressed in a satisfactory manner (including application of graded approach)?
Key Considerations in the Licensing Process

- Operating Performance
- Safety Analysis
- Physical Design
- Fitness for Service
- Siting and EA
- Informing the Public
- Packaging & Transport
- Safeguards & Non-proliferation
- Security
- Waste Management
- Emergency Mgmt & Fire Protection
- Environmental Protection
- Conventional OHS
- Radiation Protection
- Management System
- Human Performance Management
- Licensing Basis

Licensing Basis
Technical Challenges Associated With Novel Features/Approaches

<table>
<thead>
<tr>
<th>Examples of Novel Features/Approaches</th>
<th>Examples of Challenges</th>
</tr>
</thead>
</table>
| Passive and inherent features        | Failure modes difficult to predict  
                                        | This impacts PSA results |
| New operator and maintenance         | Human factors considerations:  
                                        | interface approaches     |  
                                        | ➢ human machine interface issues  | | ➢ more automation equates to  
                                        |                        | additional failure modes to model |
| New materials, fuels                 | Aging management, in-service  
                                        | inspection, fuel performance,  | | chemistry considerations,  
                                        |                        | understanding of accident  | | progressions, impacts of external | | hazards |
| Alternative equipment arrangements    |                        |
Understanding What ‘Proven’ Means

For novel features/approaches:

- What is the status and quality of available R&D information?
- What Operating Experience (OPEX) is available?
- How is R&D/OPEX relevant to the specific technology application being proposed?
Determination of ‘Proven’ may be Challenging

Regulators reviewing SMRs and Gen IV technologies are asking the question “what level of evidence is necessary to make the determination of ‘proven enough’ for”:

<table>
<thead>
<tr>
<th>Stage Description</th>
<th>Evidence Needed</th>
<th>State of Proven-ness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prototypical experiments</td>
<td>To collect specific scientific/engineering information on proof of concept</td>
<td>Low state of proven-ness – risks and uncertainties are higher – additional safety &amp; control measures may be needed</td>
</tr>
<tr>
<td>Demonstration reactor / First-of-a Kind</td>
<td>Demonstration of integrated components/systems and collection of OPEX to refine design for nth of a kind</td>
<td>Varying amounts of OPEX – proving in progress- varying risks and uncertainties to be addressed – some additional safety &amp; control measures needed where uncertainties are high</td>
</tr>
<tr>
<td>“Nth”-of-a-Kind</td>
<td>Commercial operation – information used to improve operational performance</td>
<td>High state of proven-ness – uncertainties generally well understood and ongoing R&amp;D supports management of uncertainties</td>
</tr>
</tbody>
</table>
Impacts on a Regulator’s Licensing and Compliance Activities:

- Need to interpret requirements & guidance in the face of new approaches
- Need to understand how much evidence is needed to support staged deployment of new technologies (demonstration, First-of-a-Kind, nth-of-a-Kind?)
- Need processes on how to use results from other regulators
Projected licensing timelines need to take into account time for both an applicant and the regulator to:

- Understand implications of new features/approaches to key areas such as engineering, procurement, construction and conduct of operations
- Ensure information supporting safety claims is sufficient in the face of uncertainties that may arise from the new technologies/approaches
- For specific cases, develop specific review criteria to confirm ‘proven enough’
- Engage with stakeholders about the technological approaches and demonstration of safety claims
A regulatory framework informs decision-making

- provides sound decision-making approaches/processes
- considers levels of acceptable risk from licensed activities
- is informed by science as well as regulatory policy
Addressing Challenges Using the Regulatory Framework (2)

- Requirements are generally based on technology neutral nuclear safety principles
- Guidance supports requirements by permitting a regulatory discussion on their intent
- Regulator identifies scope and depth of information needed in a licensee’s programs to support their licensing basis

Outreach programs should be used to promote an understanding of how the regulatory framework functions
Conclusions

- New technological approaches will challenge the conduct of technical reviews
  - claims need to be well supported and uncertainties well understood
  - this impacts when and how professional judgement can be used
- Licensing timelines need to be realistic in consideration of uncertainties presented by new technologies/approaches
- A well structured regulatory framework and regulator’s management systems will enable flexibility around addressing new technological approaches in decision-making without compromising safety
We Will Never Compromise Safety...

... It’s In Our DNA!

nuclearsafety.gc.ca
Questions?

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