Micro-Reactors

Regulatory Topics

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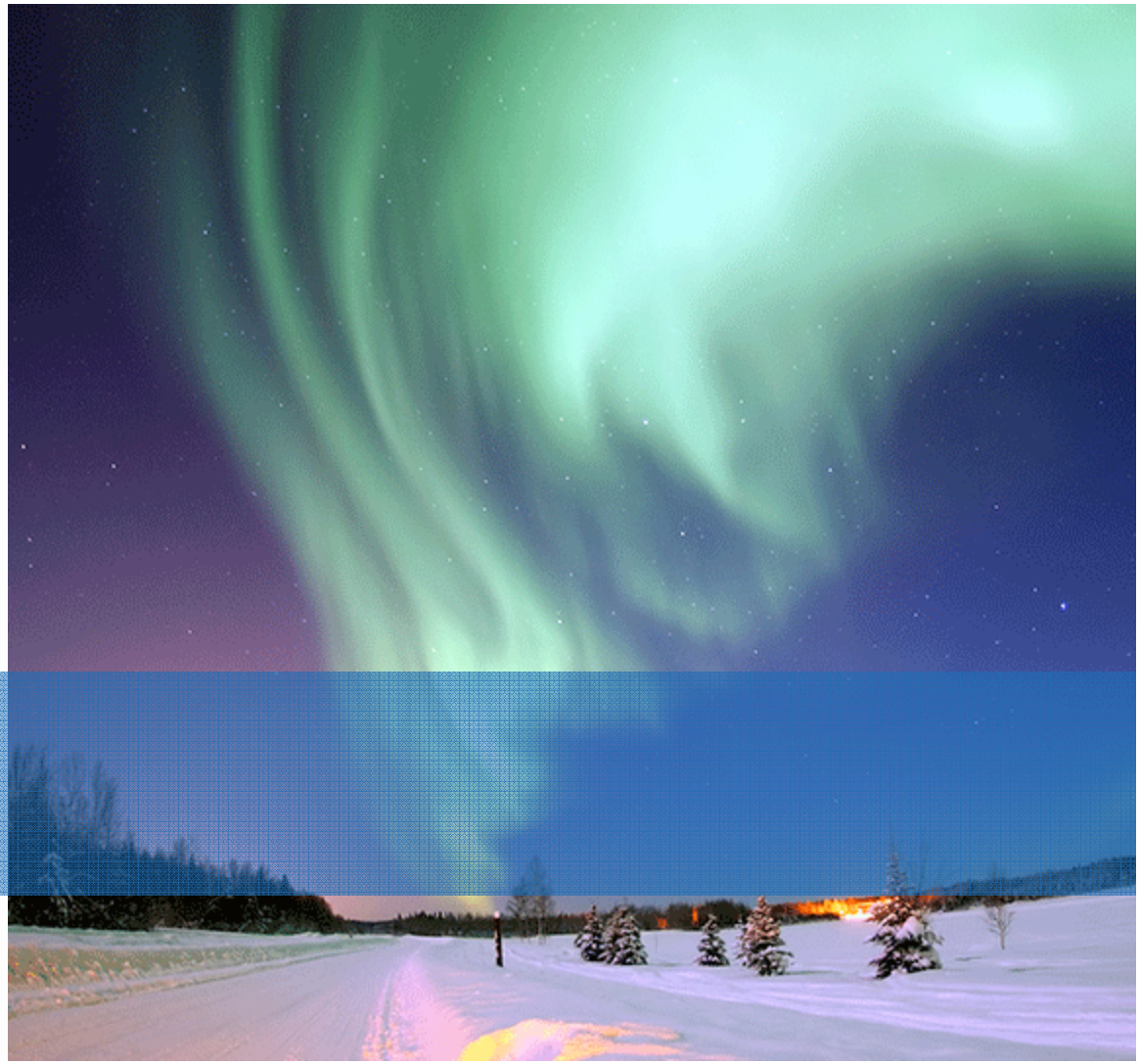

Overview of Micro-Reactors

- Typically 1 MWe to 10 MWe (2 MWth to 40 MWth)
- Very small size
  - Site as small as 0.1 acres, building ~size of a house
  - Reactor is road shippable, minimal site work
- Non-traditional uses and locations
  - Remote villages (e.g., arctic and islands)
  - Mining operations
  - Defense and other mission critical installations
  - Micro-grids – in populated areas
- Rapidly maturing technology
  - First licensing applications expected in 2020

Intended Micro-Reactor Capabilities*

- Resilience – ability to withstand, mitigate or quickly recover from
  - Extreme natural events
  - Man-made physical and cyber threats
  - Electro-magnetic pulses
- Operations
  - Island mode and black-start
  - Automatic operations with minimal or no operator action required
  - Flexible operation – e.g., integration with renewables
  - Hybrid energy – (e.g., electricity, heat, hydrogen, water desalination/purification)

*General description, all capabilities may not be applicable to all designs

Micro-Reactor Safety Features*

- Very small potential consequences
  - Radionuclide inventory significantly lower than large LWRs
  - Fail-safe, shuts itself off, long term passive cooling
  - No credible event that could result in unacceptable off-site doses
- Features that result in very low potential consequences
  - Safety relies on passive or inherent functions (natural forces)
  - Reactor can be contained completely below ground
  - Natural forces sufficient to transfer decay heat indefinitely without damaging fuel
  - Proliferation resistant fuel and enrichments below 20% U-235
  - Safety does not rely on any operator action
  - Operational simplicity: very few instruments and controls

*General description, all features may not be applicable to all designs

Micro-Reactor Regulatory Considerations

- Safety profile of micro-reactors fundamentally differ from other power reactors
  - Existing regulations and proposed rule changes are often not well suited to micro-reactors (e.g., Security, Aircraft Impact, some GDC)
  - Near term should look at using alternative approaches or exemptions, but in future rulemaking could facilitate more efficient micro-reactor licensing
- Micro-reactors are more similar to research and test reactors (RTR)
  - Similar in power level and potential consequences
- Some differences between micro-reactors and RTRs
  - Micro-reactors typically operate nearly constantly at full power, have balance of plant
  - Micro-reactors have more inherent safety features (e.g., loss of coolant and loss of electrical power may not be relevant accidents)
  - Micro-reactors rely less on human actions
  - RTRs can be open pool, typically perform tests and experiments

Framing the Regulation of Micro-Reactors

- NUREG-1537 is a more appropriate guidance document
  - Use as starting point, adjust based on features of micro-reactors
  - Accommodate different approaches (e.g., MCA, MHA, LMP)
  - Dose criteria for accidents from 50.34(a)(1) / 100.11
  - NRC recent success in adapting to other technologies (e.g., SHINE)
- "Minimum amount of regulation…to protect public health and safety"
  - Policy of Section 104c 42 USC 2134c
  - Embodied in NRC Principles of Good Regulation
- Additional considerations
  - Performance based, consequence oriented
  - Graded approach to address differences in designs

Micro-Reactor Regulatory Issues

Priority Issues	Addressed in Broader Efforts	Other Potential Issues
1. Review Scope, Duration, Level of Effort 2. Operations (auto/remote) 3. Inspections 4. Physical Security 5. Emergency Preparedness 6. Aircraft Impact	• Siting • Environmental Reviews • Fuel Qualification	• Annual Licensee Fees • Generic License • PRA • QA • Liability Insurance • Decommissioning Funding • Transportation

Review Scope, Duration, Level of Effort

- Schedule and cost related to complexity and safety margin

Notional	Micro-reactor	Typical Reactor
Manhours to develop design to maturity needed for NRC review	~ <25,000 to 50,000	~1 million
Number of pages in an application	~ <500 to 1,000	~10,000
Number of pages in supporting documents	~ <1,000 to 2,000	~50,000

- Recommended NRC targets for micro-reactor review (including environmental)
  - **Schedule**: 6 to 12 months (from Acceptance to Final Safety Evaluation)
  - **Cost**: $2M to $5M, roughly 7,000 to 18,000 man hours

Automatic / Remote Operations*

- Features of micro-reactors with automatic / remote operations
  - Will not require human actions to maintain safety
  - May not require human action for power adjustment, shutdown, or startup
  - Have very few controls
- Applicant evaluation to determine whether there is need for operator actions
  - Exemptions from Part 50.54 and Part 55 may be needed
- If no human action needed to protect public health and safety
  - No licensed operators required (numbers, presence, training, requal, simulator)
  - Plant is likely to have at least one individual on-site or remote to monitor reactor
- If some actions needed to protect public health and safety
  - Applicant propose licensed operator scheme (number, presence, training)
  - Ability to return within an acceptable time could be credited for presence

*Assumes that requirements for licensing automatic/remote operations are adequate

Instrumentation and Controls

- Traditional control room may not be necessary
- If safety can be assured without operator action, and if unauthorized individual cannot compromise safety through manipulating controls:
  - No need for requirements relating to the control room (e.g., GDC-19)
  - No need to require capability for operator initiated shutdown
  - No need for instruments and controls to be in a restricted area

NRC Inspection and Oversight

- Licensee is responsible for safety and regulatory compliance
- NRC independently verifies licensee's compliance through inspection
  - Performance based, focused on activities important to safety
  - Emphasis on observing activities over reviewing documents
- Micro-reactors have very few activities
- Recommended NRC inspection paradigm
  - Inspection frequency – once every one or two years
  - No need or requirement for resident inspectors
  - Construction inspection program emphasize manufacturing/supplier inspections
  - Significance determination process and performance indicators not needed
- Need for NRC inspection manual and procedures for micro-reactors
  - Model after IMC-2545 and related procedures (for RTR)
  - Screen out irrelevant procedures (e.g., IP-69005 on experiments)

Emergency Preparedness

- EP rulemaking for SMRs and other nuclear technologies
  - Performance based, technology inclusive, consequence oriented
  - Do no explicitly refer to micro-reactors
- Draft rule 10 CFR 50.60
  - Appears flexible enough for micro-reactors
- DG-1530
  - Does not contemplate extremely low potential consequences of micro-reactors
- Need guidance on emergency plans for micro-reactors
  - Model after NUREG-0849 (for RTRs)

Physical Security

- Security rulemaking for SMRs and other nuclear technologies
  - Not very performance based, technology inclusive, consequence oriented
  - Results in excessive burden on micro-reactors
- Requirements appropriate for micro-reactor security
  - Principally focused on theft and diversion
  - Access control
  - Intrusion detection
  - Communications with law enforcement
  - Human actions are not needed to meet security requirements
  - If personnel perform security function, may be outside site boundary, have other duties, be unarmed

Aircraft Impact Assessment

- Impact of large aircraft is beyond-design-basis-event
  - Requirements on design, construction, testing, ops and maintenance for design-basis events do not apply
- Aircraft impact on micro-reactors are highly unlikely
  - Not high-value target: could not cause mass casualties
  - Not easily impacted: building is small in size, some may be below grade
  - Impact does not pose hazard to public: very little radionuclide inventory
- Micro-reactors do not need to meet Part 50.150 requirements
  - Reactor core remaining cool, or containment remaining intact, and
  - Maintaining spent fuel cooling or spent fuel pool integrity;
  - Not needed to protect public health and safety

Potential Generic Acceptance Criteria

Do not rely on any active functions from systems or components to remain functional during or following a design basis event to prevent or mitigate the consequences of accidents that could result in the potential offsite exposures comparable to the applicable guideline exposures set for in 10 CFR 50.34(a)(1) or 10 CFR 100.11.

- Micro-reactors that meet acceptance criteria can
  - Apply an adjusted NUREG-1537 approach
  - Apply approaches for key micro-reactor policy and technical issues

Conclusions

- First micro-reactor application expected in 2020
- NUREG-1537 is appropriate starting point for guidance for micro-reactors
  - Micro-reactors are similar to RTRs in terms of power level and potential consequences
  - Differences in operations and safety features should be considered
- Key Policy and Technical issues to address promptly
  - Review duration and level of effort
  - Automatic / remote operations
  - NRC Inspection
  - Emergency Preparedness
  - Physical Security
  - Aircraft Impact

