

Multi-Module Topics

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Agenda

- Purpose and outcome objectives
- NuScale design overview
- Regulatory background and guidance
- Multi-module topics
- Next steps

Purpose and Outcome Objectives

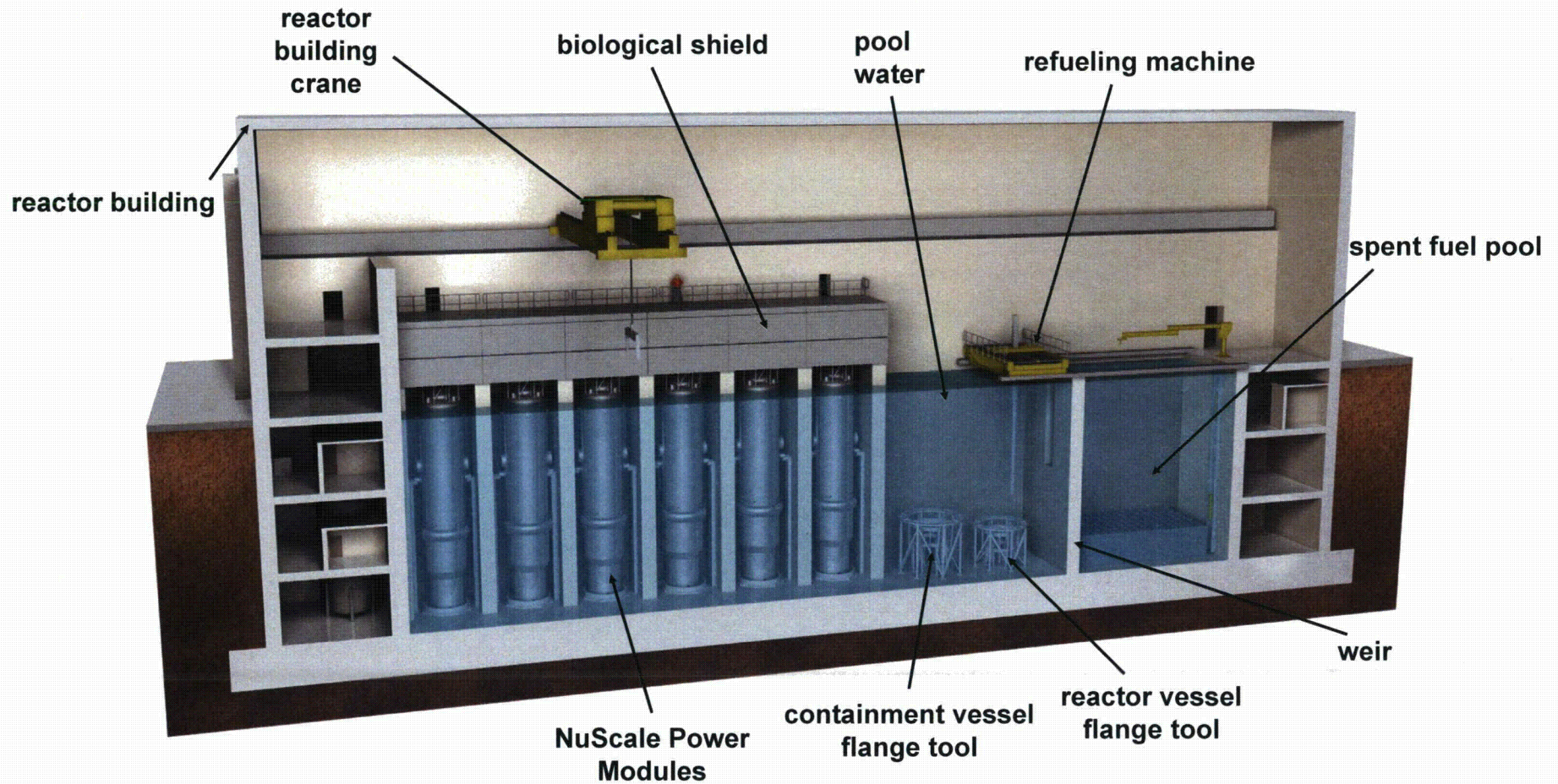
- Purpose
 - Present and discuss NuScale’s plan to address potential multi-module technical and regulatory topics in the DCA
- Outcome objectives
 - Describe NuScale’s plant design and deployment strategy
 - Introduce unique multi-module topics
 - Discuss technical aspects and licensing engagement for each specific multi-module topic
 - Align on the appropriate guidance and policy documents for each multi-module topic
 - Align on identification of the complete set of multi-module topics for the NuScale design
 - Align on the topics needing additional interactions with NRC

Definitions

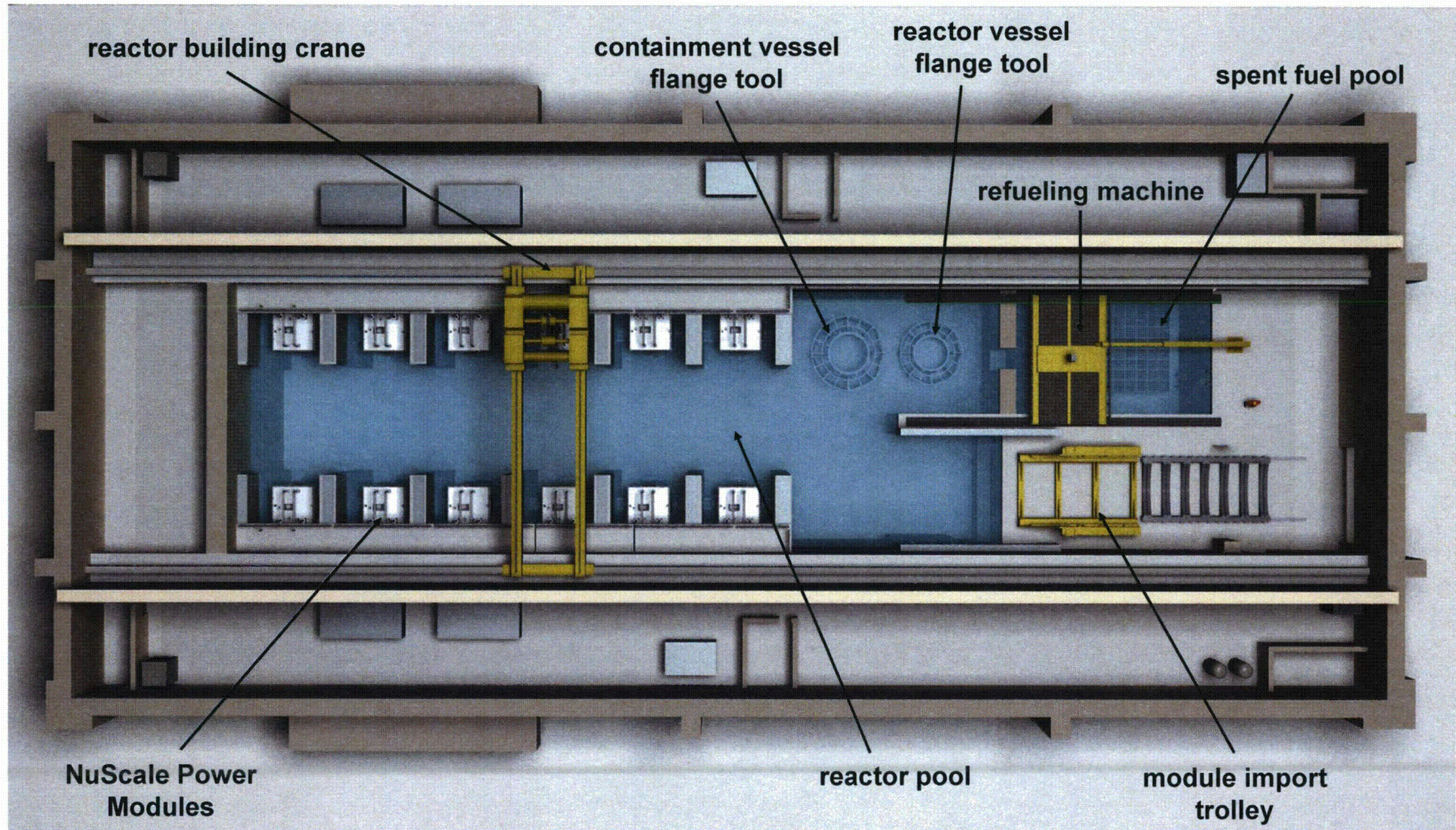
Term	Definition
CES	containment evacuation system
DHR	decay heat removal
DHRS	decay heat removal system
ECCS	emergency core cooling system
EP	emergency planning
EPZ	emergency planning zone
LOCA	loss-of-coolant accident
PWR	pressurized-water reactor
PRA	probabilistic risk assessment
RCS	reactor coolant system
RPV	reactor pressure vessel
SMR	small modular reactor
SSC	structure, system, and component

Reactor Building Cross-Section

Reactor building houses reactor modules, spent fuel pool, and reactor pool



Reactor Building Overhead View



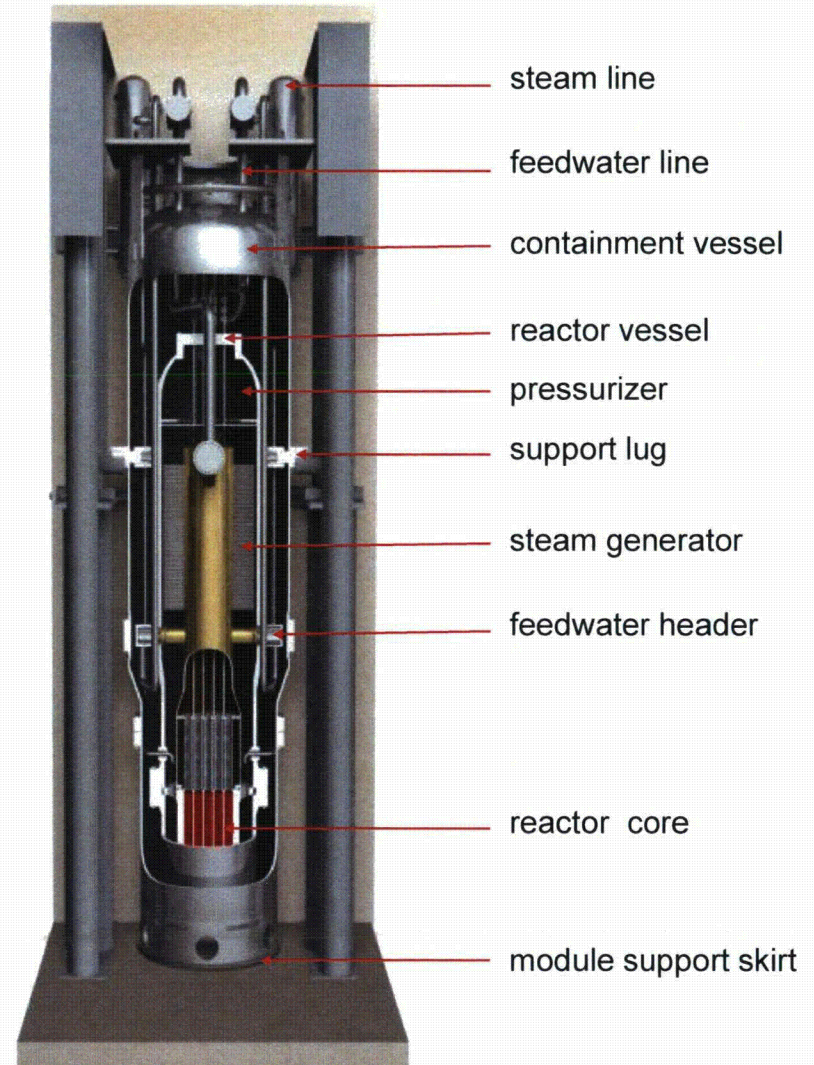
Reactor Module Overview

Natural convection for cooling

- passively safe, driven by gravity, natural circulation of water over the fuel
- no safety-related pumps, no need for emergency generators

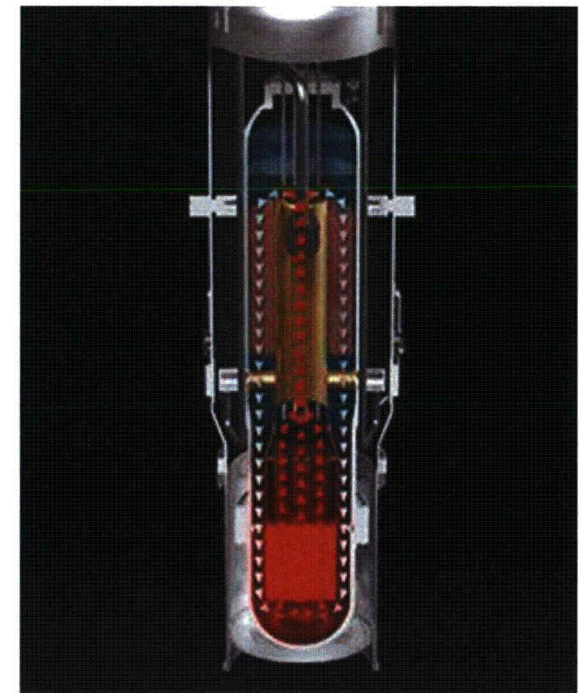
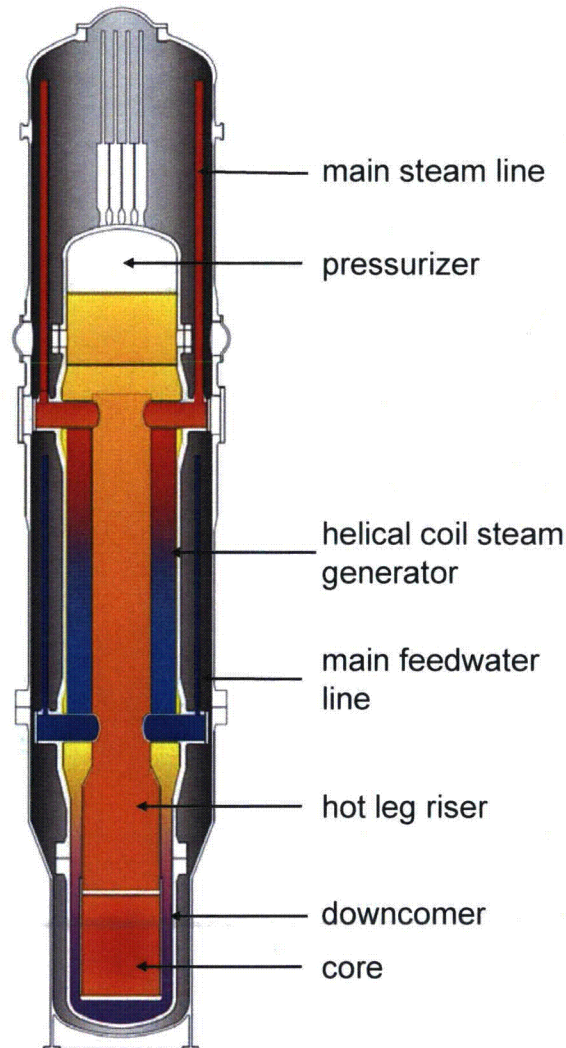
Simple and small

- reactor is 1/20th the size of large reactors
- integrated reactor design, no large-break loss-of-coolant accidents



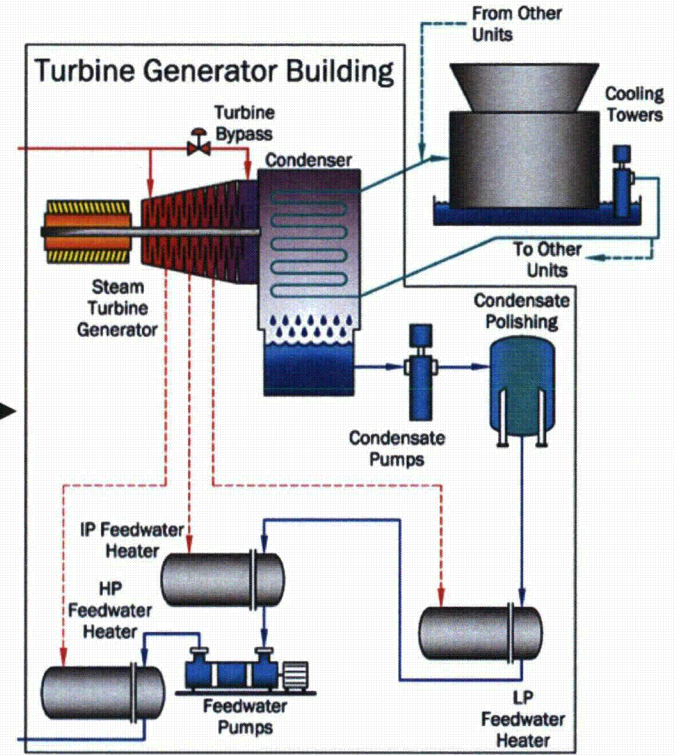
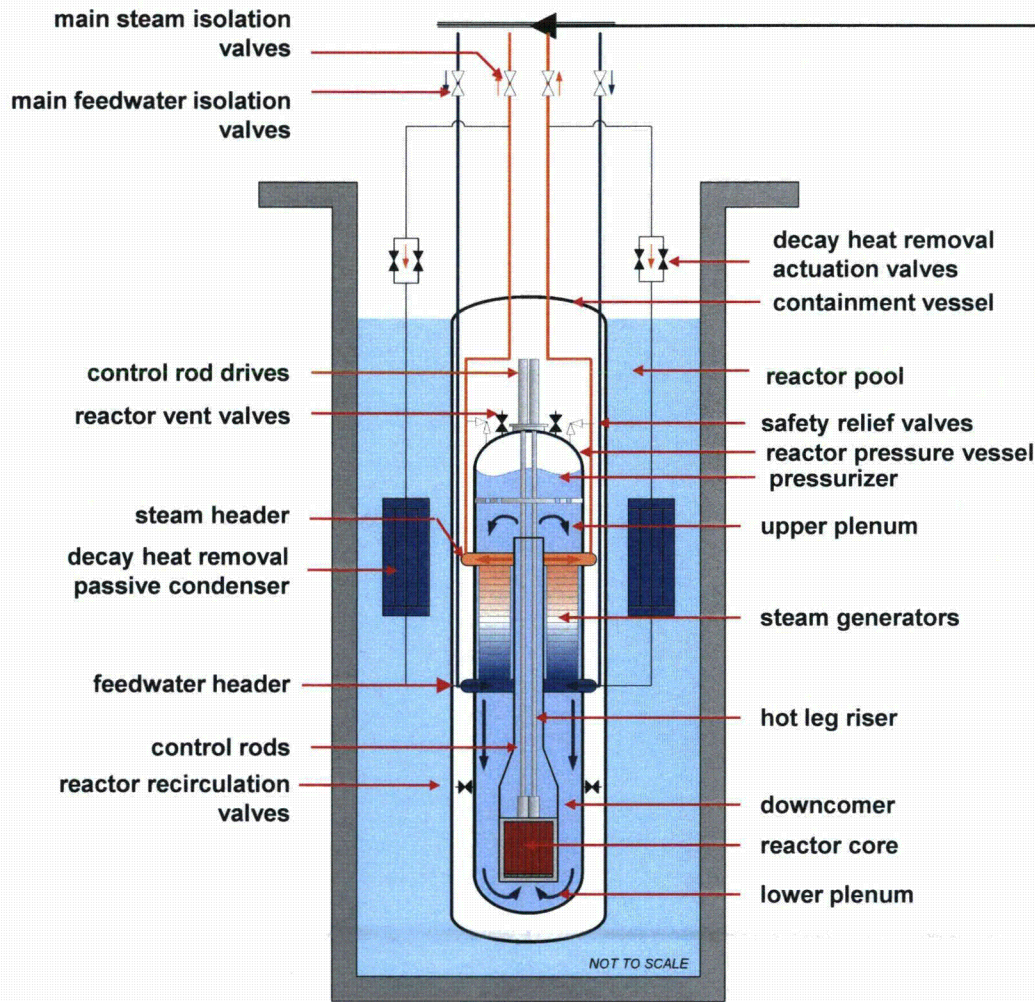
Module Normal Operation

- Primary side
 - natural circulation
 - integral pressurizer
- Secondary side
 - feedwater plenums
 - two helical steam generators
 - steam plenums



primary coolant flow path

NuScale Power Train

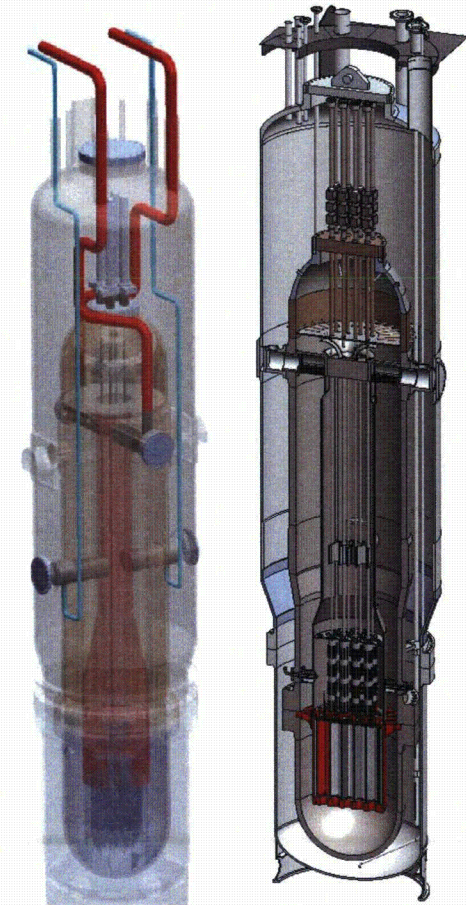


- Each reactor module feeds one turbine-generator (T-G) train eliminating single-shaft risk
- Small, simple components support short simple refueling outages

Containment Design

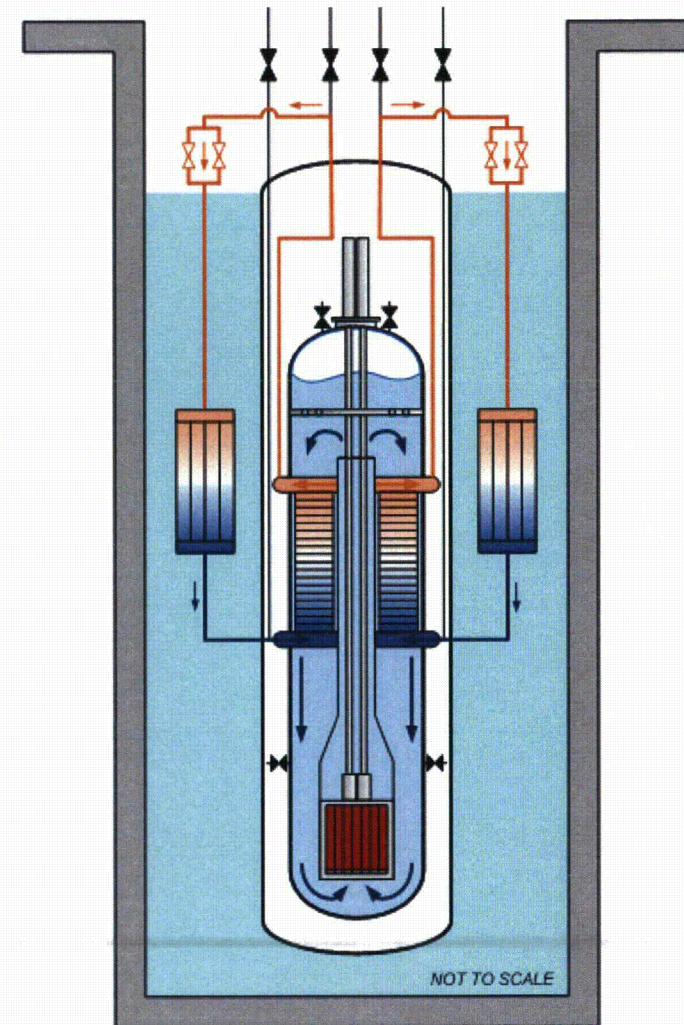
Evacuated Containment—Enhanced Safety

- **Containment volume sized so that core does not uncover following a LOCA**
- **Large reactor pool keeps containment shell cool and promotes efficient post-LOCA steam condensation**
- **Insulating vacuum**
 - significantly reduces conduction and convection heat transfer during normal operation
 - eliminates requirement for insulation on the reactor vessel, therefore, no sump screen blockage issue (GSI-191)
 - improves LOCA steam condensation rates by eliminating air
 - prevents combustible hydrogen mixture in the unlikely event of a severe accident (i.e., little or no oxygen)
 - reduces corrosion and humidity problems inside containment



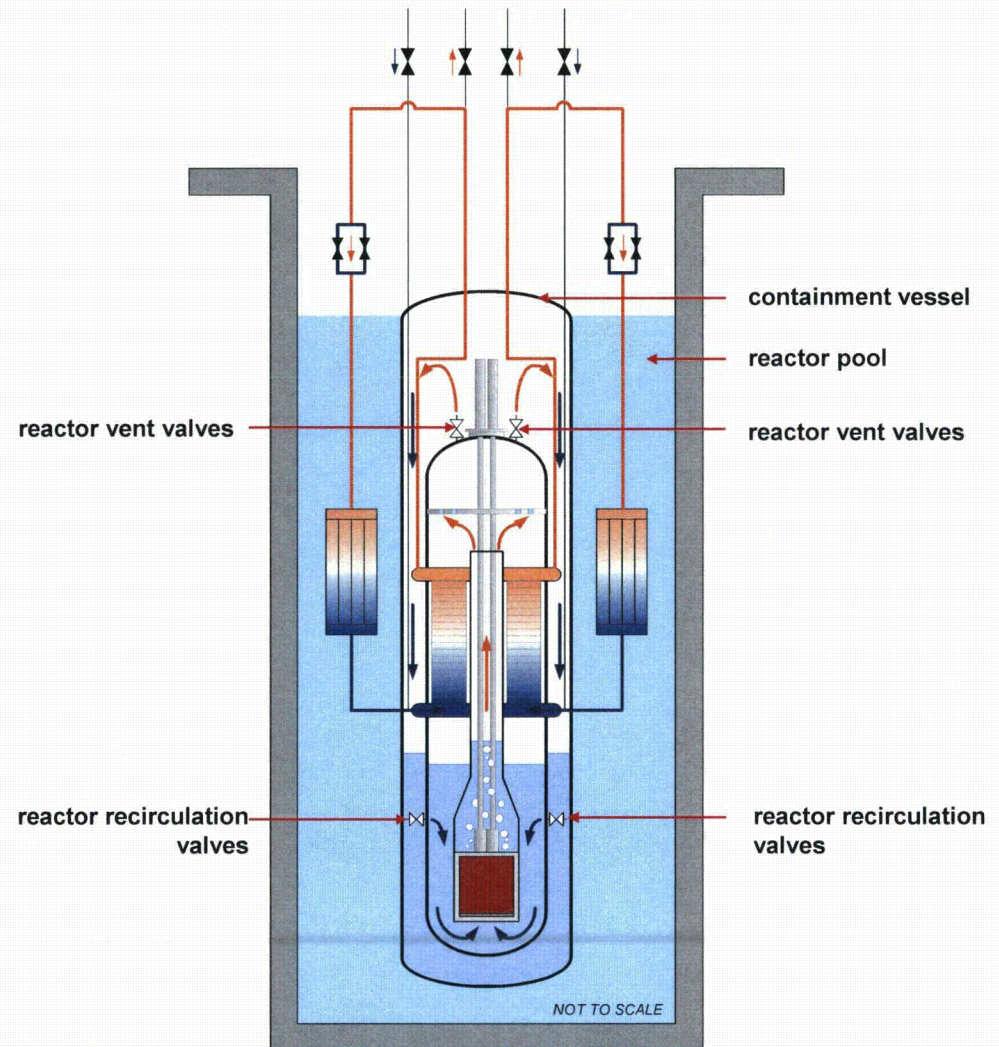
Passive Decay Heat Removal System

- Main steam and main feedwater isolated
- Decay heat removal (DHR) valves opened
- Decay heat passively removed via the steam generators and DHR heat condensers to the reactor pool
- DHR system is composed of two independent single failure proof trains (1 of 2 trains needed)

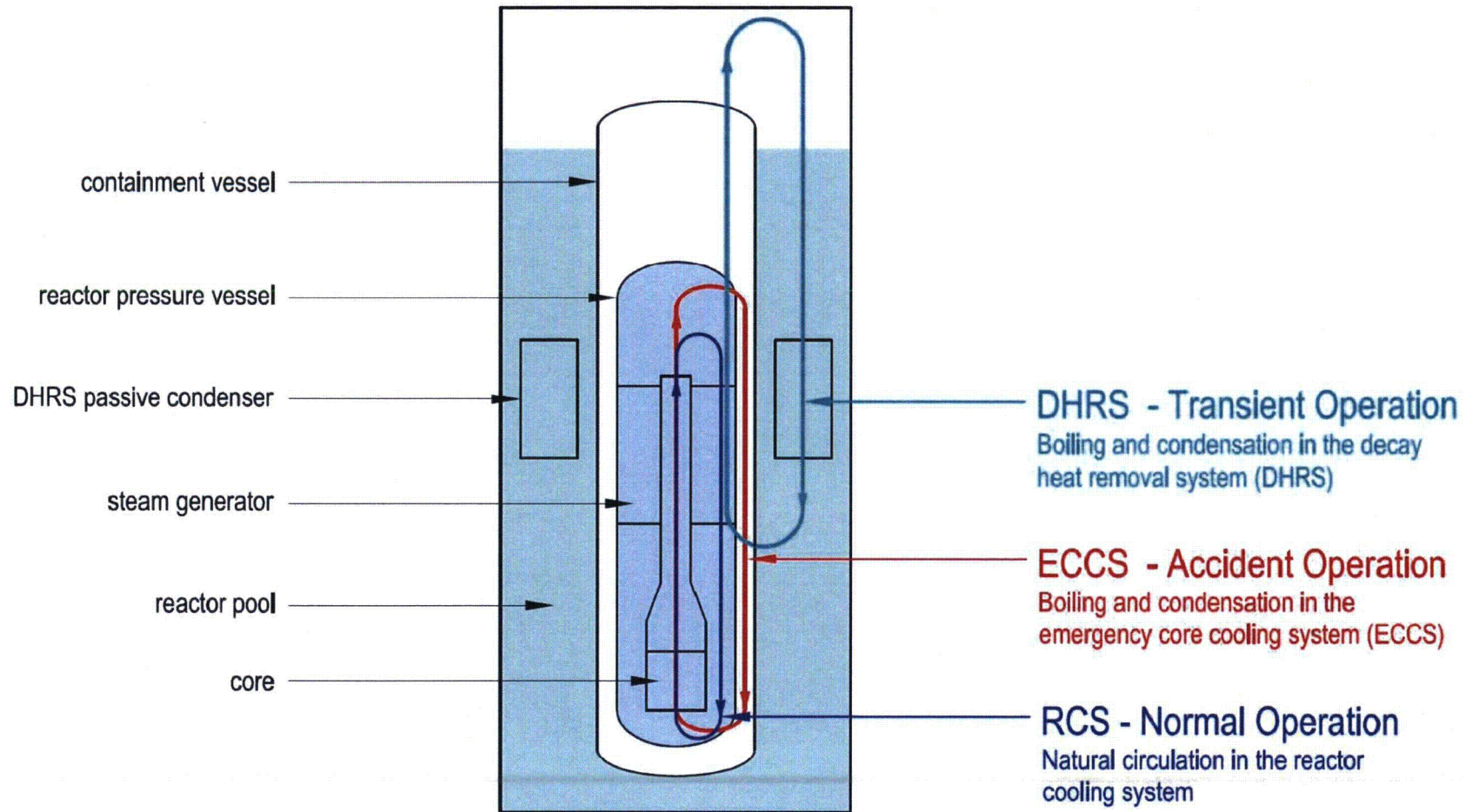


Emergency Core Cooling System and Containment Heat Removal

- Adequate core cooling is provided without the need for safety-related injection
- Reactor vent valves opened on safety signal
- Reactor recirculation valves open when containment liquid level is high enough
- Decay heat removed
 - condensing steam on inside surface of containment vessel
 - convection and conduction through liquid and both vessel walls



Passive Cooling Systems



Design Simplification

- **New system**

- containment evacuation
- containment flooding

- **Eliminated systems**

- containment spray
- containment fan cooler
- auxiliary feedwater
- ECCS injection and recirculation
- steam generator blowdown
- electrical generator hydrogen supply
- safety-related electrical systems

- **Eliminated components**

- reactor coolant pumps
- ECCS pumps, tanks, and RPV injection lines
- containment sumps and tanks
- refueling water storage tank
- reactor coolant hot leg and cold leg piping
- pressurizer surge line and relief tank
- reactor vessel and primary coolant system insulation
- safety-related emergency diesel generators

NuScale Safety Case and Defense-in-Depth

IAEA DiD Level	Current Operating LWR	NuScale
1 – Prevent abnormal operation and failures	<ul style="list-style-type: none"> • ~20 safety-related systems • Historical set of design basis events • Active safety systems that require electrical power • Core damage frequency (CDF) $\sim 1 \times 10^{-5}$ 	<ul style="list-style-type: none"> • Only ~8 safety-related systems • Reduction in design basis events due to simplified design • Passive safety systems* • CDF $< 1 \times 10^{-7}$*
2 – Control of abnormal operation and detection of failures	<ul style="list-style-type: none"> • Multiple active systems required to protect critical assets 	<ul style="list-style-type: none"> • Simple, passive systems to protect assets*
3 – Control of accidents within the design basis	<ul style="list-style-type: none"> • Several design basis events lead to core damage 	<ul style="list-style-type: none"> • No design basis events lead to core damage *
4 – Control of severe accident conditions	<ul style="list-style-type: none"> • Conditional Core Damage Probability (CCDP) for loss of all AC/DC power = 1 (core damage every occurrence) 	<ul style="list-style-type: none"> • SBO CCDP $\sim 2.5 \times 10^{-9}$ (1 core damage every 400 million occurrences) • Containment can withstand H2 deflagration*
5 – Mitigation of consequences of significant radiological releases	<ul style="list-style-type: none"> • Large early releases • EPZ = 10 mi 	<ul style="list-style-type: none"> • Small late releases* • EPZ < 10 mi*

**IAEA DiD improvement recommendation (INSAG-12, Basic Safety Principles for Nuclear Power Plants)*

Regulatory Background and Guidance

- Price-Anderson Act Amendments made as part of the Energy Policy Act of 2005 recognize modular reactors as a potential configuration in the future
- 10 CFR recognizes several different attributes of small modular reactors and how to address them, including
 - 10 CFR 52.47(c)(3): An application for certification of a modular nuclear power reactor design must describe and analyze the possible operating configurations of the reactor modules with common systems, interface requirements, and system interactions. The final safety analysis must also account for differences among the configurations, including any restrictions that will be necessary during the construction and startup of a given module to ensure the safe operation of any module already operating.
 - 10 CFR 52.157(f)(25): If the reactor is to be used in modular plant design, a description of the possible operating configurations of the reactor modules with common systems, interface requirements, and system interactions. The final safety analysis must also account for differences among the configurations, including any restrictions that will be necessary during the construction and startup of a given module to ensure the safe operation of any module already operating.

Regulatory Background and Guidance

- In addition to requirements codified in the 10 CFR and regulatory guidance provided in NUREG-0800, Regulatory Guides, Draft Regulatory Guides, Interim Staff Guidelines, and NRC Generic Communications, NRC and industry continue to work on developing the regulatory framework for the certification of multi-module small modular reactor designs
- NRC, NEI, and industry stakeholder papers currently contain the regulatory guidance on the multi-module specific issues
- A representative list of multi-module regulatory and industry guidance documents identified by NuScale as relevant are presented within the “Multi-Module Topics for DCA” discussed below

Multi-Module Topic Identification

Multi-module topics are identified through periodic and continuous evaluation processes. Key issues are evaluated holistically and translated into potential DCA risks. These potential risks are then tracked and managed under the NuScale risk management program.

- Relevant processes, programs, and evaluations for addressing multi-module topics

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Multi-Module Topics for DCA

- SSC failures and impact on multiple modules
- Multi-module risk
- Seismic analysis
- Other external and beyond-design-basis events
- Normal operation and accident source term
- Operations
- ITAAC
- *Module installation while plant is operating**
- *Startup testing while modules are operating**
- DCD structure

****Plans under development and to be discussed in future DCA pre-application meetings.***

Multi-Module Topics for COLA

- Operator staffing
- Physical security
- License structure
- Emergency planning and response
- Decommissioning

These topics will be discussed at a later time with the NRC outside of the DCA.

SSC Failures and Impact on Multiple Modules

Definition

Final safety analysis must account for differences among the configurations, including any restrictions that will be necessary during the construction and startup of a given module to ensure the safe operation of any module already operating.

Multi-module guidance documents include

- 10 CFR 52.47(c)(3)
- 10 CFR 52.157(f)(25)
- SECY-11-0156, “Feasibility of Including Risk Information in Categorizing Structures, Systems, and Components as Safety-Related or Nonsafety-Related”
- SECY-11-0024, “Use of Risk Insights to Enhance the Safety Focus of Small Modular Reactor Reviews”
- SECY-95-0132, “Policy and Technical Issues Associated with Regulatory Treatment of Nonsafety Systems (RTNSS) in Passive Plant Designs”

SSC Failures and Impact on Multiple Modules

NuScale implementation

- Chapter 15 Transient and Accident Analysis will consider failures in shared SSCs that could affect reactor safety
- Chapter 19 PRA and Severe Accident Analysis will evaluate adequacy of defense-in-depth of the NuScale plant by considering SSC failures that could impact more than one module
- Reactor modules are designed for maximum independence from an engineered safety feature perspective
- Each reactor module has its own dedicated
 - reactor protection system
 - emergency core cooling system
 - decay heat removal system
- Ultimate heat sink (e.g., reactor pool) is the only shared safety system from a core and containment cooling perspective. Reactor building is a shared structure.
- ***Address through DSRS process; primarily DCA Chapter 15***
- ***Planned Topical Report on multi-module risk methodology***

NuScale Plant Shared Systems Supporting Reactor Module Operation

- Shared systems are being designed to enhance plant performance while maintaining safe operation in the event of a failure
- Human factors team reviews shared system designs to support human-machine interface design, operation, construction, testing, and maintenance plans

NuScale Plant Shared Systems Supporting Reactor Module Operation

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NuScale Plant Shared Systems Supporting Reactor Module Operation

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NuScale Plant Shared Systems Supporting Reactor Module Operation

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Multi-Module Risk

Definition

Multi-module risk associated with potential radionuclide release from more than one module as a result of a single initiating event

Multi-module guidance documents include

- NUREG-0800, SRP 19.0, Draft Revision 3, “Probabilistic Risk Assessment and Severe Accident Evaluation for New Reactors”
- SECY-13-0137, “Recommendations for Risk-Informing the Reactor Oversight Process for New Reactors”
- SECY-12-0081, “Risk-Informed Regulatory Framework for New Reactors”
- NUREG-1635, Vol. 10, “Review and Evaluation of the Nuclear Regulatory Commission Safety Research Program”
- NRC draft technical guidance on multi-module risk
 - use systematic process to identify potential multi-module core damage or large release scenarios (including human errors)
 - assess design features, systems, and operationally-focused strategies to prevent/mitigate scenarios and demonstrate they are not significant risk contributors

Multi-Module Risk

NuScale implementation

- Potential multi-module events can arise from three basic categories of events
 - initiating events that affect multiple modules
 - failures of common support systems, structures, and components (including human actions) that are relied upon by multiple modules
 - common cause failures that span multiple modules
- NuScale will develop an approach for addressing multi-module risk that will be included in the DCA
- Based on preliminary NRC guidance, only a single-module large release frequency (based on relative size of NuScale core) is expected in Chapter 19 to provide a basis for multi-module qualitative evaluation
- ***Planned Topical Report on multi-module risk methodology***

Seismic Analysis

Definition

Potential for a design-basis seismic event to induce failure of equipment in multiple modules or in a common structure

Multi-module guidance documents include

- BNL-V6096-15455-20111221, “Seismic Performance of Multiple Reactors on a Common Foundation”

Seismic Analysis

NuScale implementation

- May 2012 Seismic Design Methodology Workshop pre-application meeting with the NRC

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- ***Address through DSRS process; primarily DCA Sections 3.7 and 3.8***
- ***No Topical Reports planned in this area***

Other External and Beyond-Design-Basis Events

- The following other external and beyond-design-basis events are not considered multi-module topics since their impact on plant safety is largely related to the reactor building itself, not potential multi-module interactions
 - aircraft impact
 - high wind
 - flood
 - fire
- ***No Topical Reports currently planned in this area***

Normal Operation Source Term

Definition

Source term from simultaneous operation and maintenance of multiple modules (e.g., during refueling)

Multi-module guidance documents include

- SECY-13-0107, “Status of the Accident Sequence Precursor Program and the Standardized Plant Analysis Risk Models”
- SECY-10-0034, “Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs”
- NRC Memorandum, “Status of Mechanistic Source Term Policy Issue for Small Modular Reactors”

Normal Operation Source Term

NuScale implementation

- White paper in review internally at NuScale
- Alternative to PWR-GALE86 for normal operation and AOOs
- NuScale methodology includes a number of modifications, for example

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- ***Address through DSRS process; primarily DCA Section 11.1***
- ***Planned Topical Report on normal operation source term in 2015***

Accident Source Term

Definition

Potential for multi-module release during design basis events

Multi-module guidance documents include

- SECY-10-0034, “Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs”
- SECY-13-0107, “Status of the Accident Sequence Precursor Program and the Standardized Plant Analysis Risk Models”
- NEI 94-01, “Industry Guideline for Implementing Performance-Based Option of 10 CFR Part 50, Appendix J”
- NEI Position Paper, “Small Modular Reactor Source Terms”
- NRC Memorandum, “Status of Mechanistic Source Term Policy Issue for Small Modular Reactors”

Accident Source Term

NuScale implementation

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- Pre-application meeting held to discuss comments on report
- ***No specific multi-module issues identified for this topic, but still evaluating***
- ***Address through DSRS process; primarily DCA Sections 15.0.1 and 15.0.3***
- ***Planned Topical Report on accident source term in 2015***

Operations

Multi-module guidance documents include

- SECY-11-0098, “Operating Staffing for Small or Multi-Module Nuclear Power Plant Facilities”
- SECY-10-0034, “Potential Policy, Licensing, and Key Technical Issues for Small Modular Nuclear Reactor Designs”
- NUREG-1791, “Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m)”
- NUREG-0711, “Human Factors Engineering Program Review Model”
- NUREG/CR-7126, “Human-Performance Issues Related to the Design and Operation of Small Modular Reactors”

Operations

NuScale implementation

Maintenance activities requiring module movement

- Definition: Refueling and maintenance activities involving movement of one module while other modules are operating simultaneously in the same reactor building

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- *No Topical Reports planned in this area*
- *Related Topical Report on normal operation source term*

Operations

ALARA

- Definition: Personnel radiation exposure evaluations with consideration of different operating modes for each module and various combinations of simultaneous module operations
- Shielding is being designed with consideration of source terms based on various plant configurations (e.g., 10 modules at full power, one module in refueling mode, and one module in startup mode)
- ***No Topical Reports planned in this area***
- ***Related Topical Report on normal operation source term***

Operations

Technical specifications (TS)

- Definition: TS for facility with multiple reactors in a single building using shared systems

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- ***Address through DSRS process; primarily DCA Chapter 16***
- ***No Topical Reports planned in this area***

ITAAC

Definition

ITAAC for multi-module facility in which modules may be installed over an extended time period

Multi-module guidance documents include

- NEI White Paper, “Proposed Improvements to Tier 1 and the Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) for Small Modular Reactors”

ITAAC

NuScale implementation

- ITAAC for multi-module facility in which modules may be installed over an extended time period
- July 2012 pre-application with the NRC

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- A thorough review of the systems that share equipment will enable the design team to provide the ability to properly test oncoming modules
- ***Working closely with NEI on ITAAC initiatives***
- ***Address through DSRS process; primarily DCA Section 14.3***
- ***No Topical Reports planned in this area***

DCD Structure

- Additional DCD chapter containing multi-module safety basis summary in one location
- Pointers to appropriate DCD sections for supporting information

Next Steps

- **Submittal of Topical Reports**

- Letter sent to NRC on May 30, 2014 (LO-0514-7037) with list of 21 topical reports and schedule by NRC fiscal year through FY 2016
- Planned multi-module related Topical Reports to support DCA

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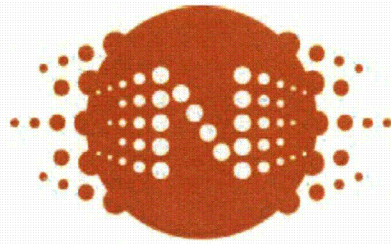
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- **Continued pre-application interactions**

- Meetings scheduled based on technical topics
- To be planned over the next five quarters (fall 2014 through FY 2015) to support DCA submittal schedule
- DSRS review and comment (TBD)

- **Industry initiatives**

- NEI ITAAC 2014 meetings: September 18, October 9, and November 6



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