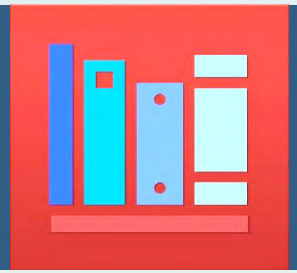
Codes & Standards Initiatives for New & Advanced Reactors



- **Session Chair:** Christian Araguas, Director, Division of Engineering, Office of Nuclear Regulatory Research; NRC Standards Executive

- **Speakers:**
  - Jason Christensen (INL)
  - Christian Araguas (NRC)
  - Kate Hyam (ARCSC)
  - John Richards (EPRI)

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Protecting People and the Environment

September 25, 2024

Jason Christensen
Sr. Regulatory Engineer

NRC-INL Collaboration on Codes & Standards

NRC Standards Forum

Purpose of the Collaborative Effort

- Project was born from a discussion between Nuclear Regulatory Commission (NRC) Chair Hanson and Idaho National Laboratory (INL) Director John Wagner in an effort to enhance communications and technical exchanges between NRC and INL
- The purpose of this project between INL and NRC was to review and assess the effectiveness and timeliness of codes and standards activities associated with development and licensing of advanced nuclear reactors
  - Specifically, are there new and/or novel ways to endorse codes and standards more efficiently?
- The scope of this effort includes external communication with stakeholders and an evaluation of publicly available reports to identify the most critical codes and standards needed to successfully deploy advanced reactors

Public Meeting

- NRC Office of Nuclear Regulatory Research and INL Regulatory Support Group held a public meeting on April 4, 2024 at NRC headquarters in Rockville, MD
  - The attendees and participant organizations included the NRC, the Department of Energy (DOE) and other Federal Agencies, DOE National Laboratories, advanced reactor vendors, microreactor vendors, academic institutions, current reactor licensees, researchers, industry consultants, and international regulators
  - The meeting was hybrid, with approximately 45 in-person participants and over 300 virtual participants
  - The meeting consisted of presentations as well as facilitated two-way engagement via polls, questions, surveys as well as Q&A sessions

Public Meeting Introduction

- Introductions included remarks from:
  - Michele Sampson, NRC's Standards Executive and Director of the Division of Engineering in the Office of Nuclear Regulatory Research
  - Curtis Smith, Director of the Nuclear Safety and Regulatory Research Division at INL
- Opening Remarks were provided by:
  - The Honorable Christopher T. Hanson, Chair of the NRC
  - Dr. Jess Gehin, Associate Laboratory Director for the Nuclear Science and Technology Directorate at INL
- Highlights of the opening remarks included
  - Doubling nuclear capacity by 2050 and the challenges associated with that
  - Reduction of over-conservatisms in C&S by leveraging new technology and better risk characterizations
  - Expanding codes and standards activities to better include non-light water reactor (non-LWR) and the use of more risk-informed and performance-based thinking

Public Meeting Themes

- What Codes & Standards are Needed to Foster Efficiencies (and their Timeline)?
  - DOE Office of Nuclear Energy C&S activities
  - DOE National Laboratory studies on the needs of advanced reactors
  - Advanced Reactor Codes and Standards Committee (ARCSC)
- How can NRC's Codes and Standards Program be Enhanced?
  - NRC support to standards organizations and preparations for future reactors
  - Canadian Nuclear Safety Commission (CNSC) support to standards organizations and preparations for future reactors
  - National Reactor Innovation Center's (NRIC) role in preparing for future reactors
  - Standards Development Organizations (SDOs) activities to prepare for future reactors
  - Perspectives from reactor vendors

Common Themes to Polls and Questions

- Need to improve timeliness of the development, updating, and endorsement of codes and standards (C&S) to support new and advanced reactor designs. Challenges include the need for consensus, while relying on volunteers that may not be funded by their employer
- The NRC may need to consider a broad range of licensing and rulemaking tools to provide regulatory certainty, while not inhibiting innovation
- Current standards specific to light-water reactors (LWRs) may be overly prescriptive and are not applicable to many advanced reactor designs, and first-of-a-kind and Nth-of-a-kind applications may require different approaches
- There are significant gaps in C&S for certain technologies and material qualification. This is especially true in graphite and high-temperature materials

Common Themes to Polls and Questions (continued)

- There is also a need for risk informed and performance-based standards which cover, among other things, passive designs
- Existing material standards do not cover the higher temperature ranges and the new materials needed for several advanced reactor designs. In addition, existing graphite qualification standards are overly restrictive and grade-specific which make it harder for new vendors to enter the industry
- Consider clarification of roles between vendors, DOE, and SDOs to avoid duplication of effort and ensure that we address all existing gaps
- International code and standard inclusion is essential to utilizing foreign vendors as current efforts are focused heavily on North America
- Current codes and standards tend to be overly prescriptive, which can hinder risk-informed and performance-based development and licensing

INL Capabilities

- Through this collaboration, INL brings a plethora of resources to NRC's R&D and endorsement of codes and standards
  - This also allows access to the national laboratory complex as a whole

Path Forward

- NRC and INL prepared and issued the final meeting summary
- NRC developed an action plan for the path forward in the area of codes and standards efficiencies
- INL is currently reviewing the NRC Action Plan to determine next steps
  - This path forward will continue collaborative efforts with the NRC and will likely include coordination with industry and other organizations
  - Collaboration will open access to INL resources as well as access to the national laboratory complex as a whole
- DOE-NE Regulatory Development Program will be continuing work in FY25 to revise and support NRC endorsement of the sodium fire consensus standard ANS 54.8, which was previously endorsed in 1988 and withdrawn in 2000.
  - This could be used as a test case for the NRC-INL Collaboration
- For input or observations, please contact:
  - Jason Christensen, INL Sr. Regulatory Engineer, Jason.Christensen@inl.gov

IDAHO NATIONAL LABORATORY

75TH ANNIVERSARY

Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development, and also performs research in each of DOE's strategic goal areas: energy, national security, science and the environment.

INL Idaho National Laboratory | www.inl.gov

Idaho National Laboratory

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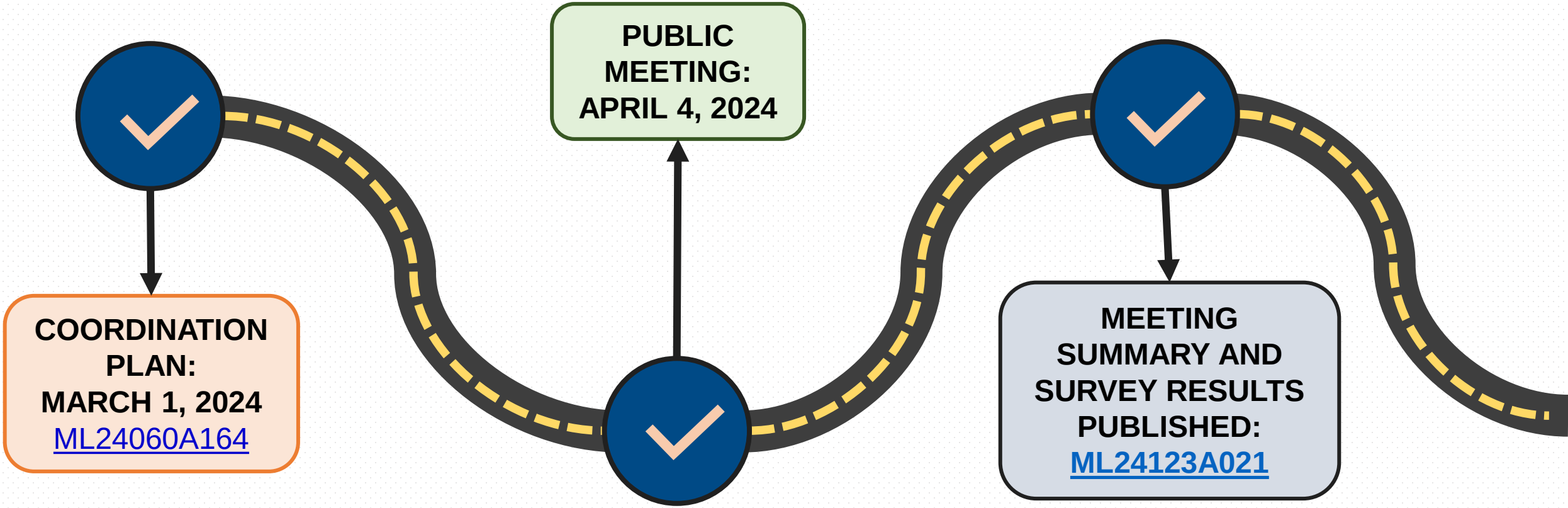
Codes & Standards Initiatives for New & Advanced Reactors

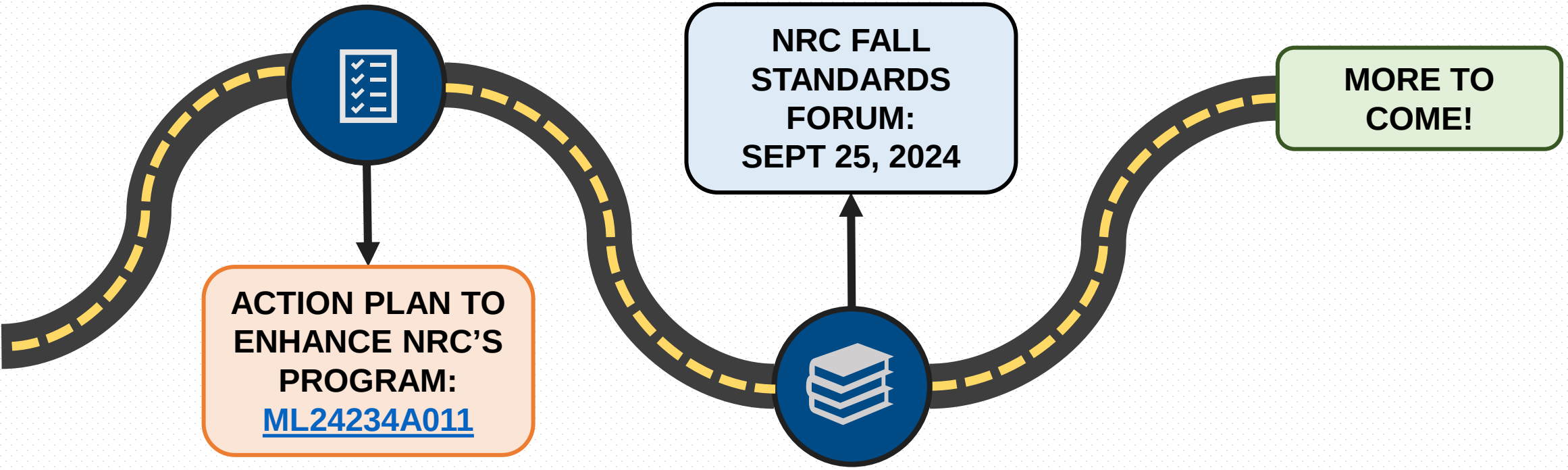
Christian Araguas

***Standards Executive &* Director of the Division of Engineering in the Office of Nuclear Regulatory Research**

New and Advanced Reactors Codes and Standards Program Initiative



New and Advanced Reactors Codes and Standards Program Initiative

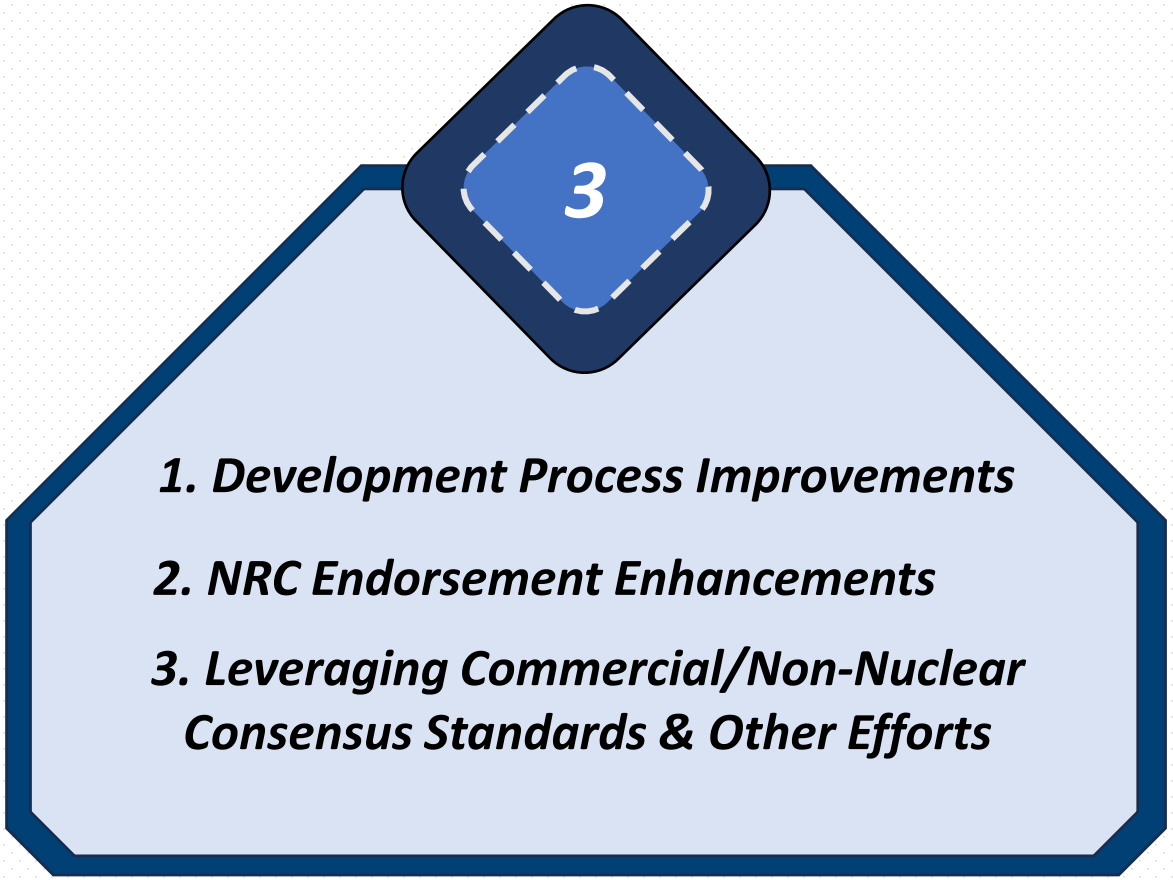


Goal of the NRC Action Plan

Provide a set of actions with the following attributes to facilitate timeliness of new or different consensus standards for new and advance reactors

- Flexible and adaptable
- Risk-and performance-based approach
- Uses expedited processes

ACTION PLAN



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ACTION PLAN

1. Development Process Improvements

Swift Actions

1.1 **Publish a list** of **prioritized** consensus standards, committees, and working groups for enhanced NRC staff engagement.

1.2 **Identify** NRC staff **experts** to **support attendance** at prioritized committee and working group meetings.

Intermediate Activities

1.3 Identify opportunities to **promote** the inclusion of **risk- and performance-based insights** within existing or new consensus standards.

Program Enhancements

1.4 Periodically conduct **public meetings** to **solicit information** on approaches for deployment of new, non-code, materials or use of **materials outside existing parameter ranges** (e.g., temperature, pressure, etc.).

1.5 Conduct **public meetings** in-between consensus standards working group meetings to allow NRC staff opportunities to provide prompt, independent, regulatory feedback when **significant technical issues of concern** to the NRC have been identified.

ACTION PLAN

2. NRC Endorsement Enhancements

Swift Actions

2.1 Expedite staff's **endorsement review** of the 2023 edition of **ASME** Section III, Rules for Construction of Nuclear Facility Components, **Division 5, High-Temperature Reactors**.

2.2 **Develop** potential **efficiencies for the endorsement process**, such as the augmented use of Interim Staff Guidance, Trial Use Regulatory Guides, Standard Review Plans, White Papers, and expanded opportunities for public engagement.

Intermediate Activities

2.3 **Update Management Directive (MD) 6.5**, "NRC Participation in the Development and Use of Consensus Standards," to incorporate identified enhancements for early deployment and flexibility.

2.4 Identify a **test case** to pilot one or more of the identified enhancements to **facilitate endorsement** of a consensus standard for use by new and advanced reactors.

ACTION PLAN

2. NRC Endorsement Enhancements

identified enhancements for early deployment and flexibility.

2.4 Identify a **test case** to pilot one or more of the identified enhancements to **facilitate endorsement** of a consensus standard for use by new and advanced reactors.

Program Enhancements

2.5 Evaluate potential **use of artificial intelligence**, such as Large Language Models, for **updating** NRC's **RG 1.84**, "*Design, Fabrication, and Materials Code Case Acceptability, ASME Section III*," **RG 1.147**, "*Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1*," **RG 1.192**, "*Operation and Maintenance Code Case Acceptability, ASME OM Code,*" and **RG 1.193**, "*ASME Code Case Not Approved for Use,*" with the latest ASME code cases, more efficiently. The **goal would be to update more frequently and with significantly less staff resources** than the current process.

ACTION PLAN

3. Leveraging Commercial/Non-Nuclear Consensus Standards & Other Efforts

Swift Actions

3.1 Solicit public input and **identify potential commercial standards** for NRC staff consideration and review, including a **public meeting**, to solicit input on the use by **Advanced Reactor vendors and applicants** of existing: (1) commercial standards, (2) guidance from research organizations, and (3) guidance from nuclear-focused non-standards organizations.

3.2 **Identify** NRC **staff** to **observe and/or participate** in select **commercial standards** revisions and/or development.

3.3 Maintain **support** of **ongoing efforts** by industry and other organizations to develop approaches for **advanced deployment** of new, non-code, materials or **materials outside existing parameters** for advanced reactors.

3.4 Pilot a **test case** consensus **standard not developed** for use by **nuclear** power reactors for review and **potential endorsement** for a nuclear reactor application

Intermediate Activities

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ACTION PLAN

3. Leveraging Commercial/Non-Nuclear Consensus Standards & Other Efforts

Program Enhancements

3.5 For **commercial** standards that are identified as appropriate for potential nuclear facility use, **develop a regulatory guide specific to these standards for endorsement**.

3.6 **Support efforts** by **consensus standard organizations** to create **risk-informed and performance-based standards**. Recognizing that risk-informed and performance-based standards may be inherently less detailed than more deterministic, prescriptive standards, **identify approaches for NRC endorsement** that provide an appropriate level of regulatory efficiency, certainty, and stability.

3.7 Participate as an **observer in the Advanced Reactor Codes and Standards Collaboration** working group to maintain awareness of industry efforts.

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Thank You

Current Progress, Future Actions Advanced Reactor Codes and Standards Collaborative (ARCSC)

Kate Hyam
ASME
Director of Nuclear, Clean Energy, and Standardization Codes and Standards
ARCSC Co-Chair

NRC Standards Forum
September 25, 2024

Presentation Objectives

- **Brief History**
- **North American Advanced Reactor Roadmap**
- **ARCSC Charter and Goals**
- **2023-2024 Accomplishments, 2024-2025 Projected Activities**
- **Standards Development Process/Assessment/Survey**
- **Future Actions**
- **Closing Remarks**

Brief History: Advanced Reactor Codes & Standards Collaborative (ARCSC) - What is it?

- **Primary Objectives: (Early 2022)**

  Create an Industry Nuclear Standards Collaborative - a “centralized industry led team” - to ensure coordination and collaboration among standards development organizations (SDOs) to support reactor designers, regulators, other stakeholders to develop codes, standards and/or guidelines to support advanced reactor designs.

  Develop interrogatories, agendas, other actions necessary to facilitate strategies and action plans that support development of codes, standards and foster licensing, design, construction, operation of advanced reactors.

- **Collaborative to parallel focus of NRC’s Forums:**

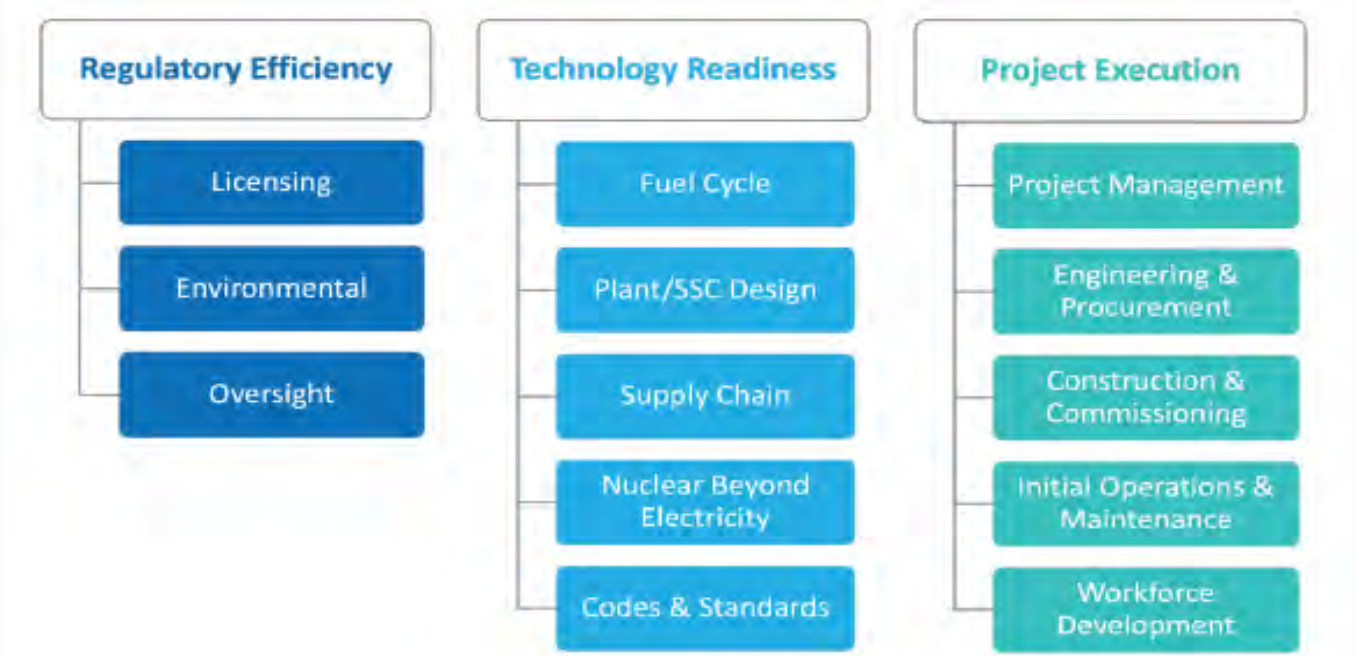
  “… aims to identify standards needs for the nuclear industry that are not currently being addressed by standards development organizations (SDOs) such as ASTM, ASME, AISC, ANS, IEEE, etc.”

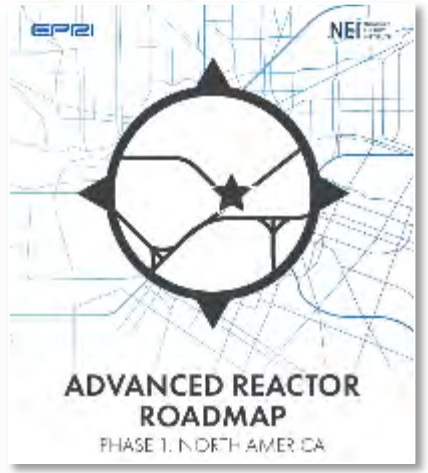
North American Advanced Reactor Roadmap

Achieve successful deployment of advanced reactors through a shared industry strategy

Align organizations and foster collaboration to implement the strategy

Serve government, academic, industrial, and public stakeholders

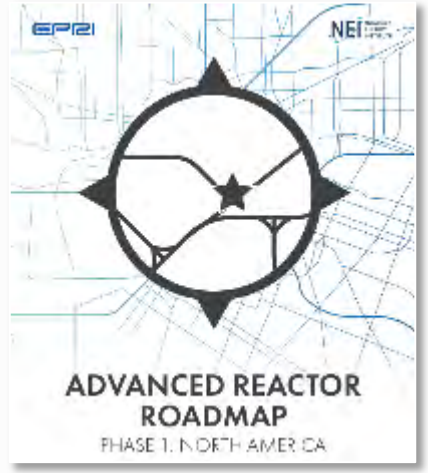




ARCSC and its constituent SDOs and stakeholders interface with the Roadmap through the Codes & Standards element.

NEI and EPRI Support ARCSC Formation

- Need for ARCSC came out of the NEI/EPRI North American Advanced Reactors Roadmap to enable and expedite commercialization of advanced reactors.
- ANS, ASME, and CSA Group are founding members of ARCSC with support from NEI and EPRI.
- ARCSC has grown considerably and now includes representatives from ASCE, IEEE, AISC, NRC, DOE, ISO, INPO, COG, WNA, CNSC, IAEA, IEC/ISA.



ARCSC Current Membership

Name	Member/ Observer	Employer	C&S Affiliation
Don Eggett	Co-Chair/RIB	Eggett Consulting, LLC	ANS
Kate Hyam	Co-Chair	ASME	ASME
Mark Richter	Lead	Nuclear Energy Institute	ASME
Andrew Sowder	Lead	EPRI	ANS
Frankie Pimentel	Lead/RIB	Nuclear Energy Institute	ANS
Pat Schroeder	Secretary	American Nuclear Society	ANS staff
Todd Anselmi	Member	INL	ANS
Sonia Iqbal	Member	CANDU Owners Group	CSA
Ron Janowiak	Member	Self-employed	AISC
Christopher Jones	Member	Kansas State University	ASME
Larisa Logan (Vanessa Mitchell-alternate)	Member	CSA Group	CSA
Carlos Lorencez	Member	CANDU Owners Group	CSA
Maury Pressburger	Member	Sargent & Lundy LLC	ASME
Sam Sham	Member	NRC	
Richard Stattel	Member	General Electric	NPEC IEEE (alternate)
Ronan Tanguy	Member	World Nuclear Association	
Beth Vary	Member	CNSC	CSA

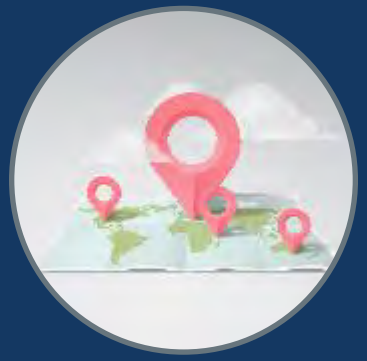
ARCSC Current Membership (Cont'd)

Name	Member/ Observer	Employer	C&S Affiliation
Thomas Vogan	Member	Sargent & Lundy – Retired	ASME
Andrew Whittaker	Member	University at Buffalo	ASCE
Richard Wood	Member	University of Knoxville	IEEE NPEC
Ashley Ferguson Shawn Simon Joe White Greg Kanda	Observer Observer Observer Observer	INPO	
Lyndsey Fyffe	Observer	DOE	
Ted Quinn	Observer	Paragon Energy Solutions	IEC/ISA
Tom Basso	Observer	NEI	
Julie McCallum	Observer	NEI	
Jim Herrold	Observer	US NTAG Chair	ISO TC 85
Christian Araguas David Rudland Robert Roche-Rivera	Observer Observer Observer	NRC	
Jon Facemire	Guest	NEI	
Chris Wax Hasan Charkas John Richards Craig Stover	Guest Guest Guest Guest	EPRI	

ARCSC Charter and Goals

Share information
on AR standards development among SDOs and stakeholders

Identify needs
gather stakeholder input; identify gaps being addressed by SDOs; assess remaining gaps and identify actions and resources needed



Inform and complement
relevant international & national efforts (e.g., IAEA NHSI, WNA CORDEL)

Align actions
with NEI/EPRI North American Advanced Reactor Roadmap Implementation Board

Objectives

Mission: To ensure the development, alignment and timely availability of U.S., Canadian, and international codes and standards needed to support large-scale advanced reactor deployment.

Advanced Reactor International Activities

- International participants (WNA, IAEA, SDO Convergence Board)
- Presentations on standards and harmonization approaches
- Charter Goal: Inform and complement international and national C&S efforts
  - ✓ IAEA Nuclear Harmonization Standards Initiative – Pekka PYY
  - ✓ SDO Convergence Board – Dr. Seiji Asada
  - ✓ WNA international activities – Ronan Tanguy
- ARCSC focus: Continual engagement with these international efforts, not duplicating efforts where possible

ARCSC's Definition of Harmonization

ARCSC considers harmonization to be the process of increasing alignment and consistency in requirements in codes and standards to enable their acceptance across jurisdictions.

Harmonization should support equivalency and convergence towards alignment of common outcomes and safety objectives, but it does not necessarily mean that all requirements or means to achieve those outcomes must be made identical.

Advanced Reactor International Activities

Pros and Cons of Harmonizations

Considerations	Pros	Cons
International standards	Broad harmonization and reduction of trade barriers	Challenges may exist with consensus, each country having its own national perspectives and priorities
	Collaboration among countries in application and harmonization of standards	Intangibles: higher-level requirements become a challenge among countries – may need to provide guidance on how to address requirements
Regional Standards	Use of more efficient and effective technology and supply chain among participating stakeholders	Misalignment with other regions or international requirements
	Leverages national expertise while including regional requirements	Coordination and consensus challenges
National Standards	Allows greater control and customization of requirements to address national needs	Possible misalignment with international requirements
	Development can be faster	
Adoption of International Standards with National Standards	Promotes harmonization	Deviations from national may impact harmonization
Industry Specific Standards	Drives harmonization among countries through “sharing”	Proprietary nature of some sources of information
	Mitigates isolationism among Standard Development Organizations	
	Improves working relationship between countries	

ARCSC Website – Launched in February 2024

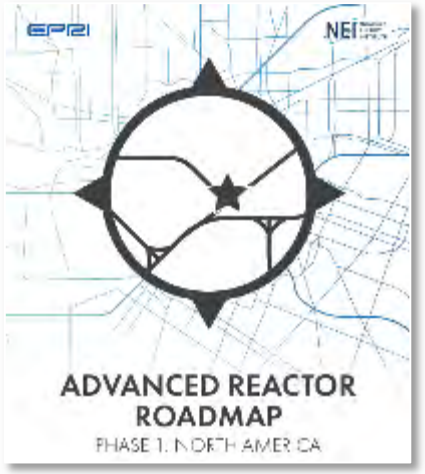
http://arcsc.nei.org

NEI/EPRI North American Advanced Reactor Roadmap Assigned Actions to ARCSC

- **TR-CS-01: Alignment and Improvement of Codes and Standards ACTION for 2024: Identify additional gaps in, and any adjusted timelines for, advanced reactor codes and standards**

  - ✓ Consolidate and update prior advanced reactor codes and standards gap analysis
  - ✓ Define development timelines for commercial relevance
  - ✓ Prioritize gaps and associated actions
  - ✓ Secure resources to address gaps in and timelines for advanced reactor codes and standards development

- Action Owners: ARCSC, SDOs, NEI, EPRI, AR Vendors
- **Need Date: Gaps identified by end of 2024**



NEI/EPRI North American Advanced Reactor Roadmap Assigned Actions to ARCSC

- **TR-CS-02 Risk-Informed and Performance-Based Approach**

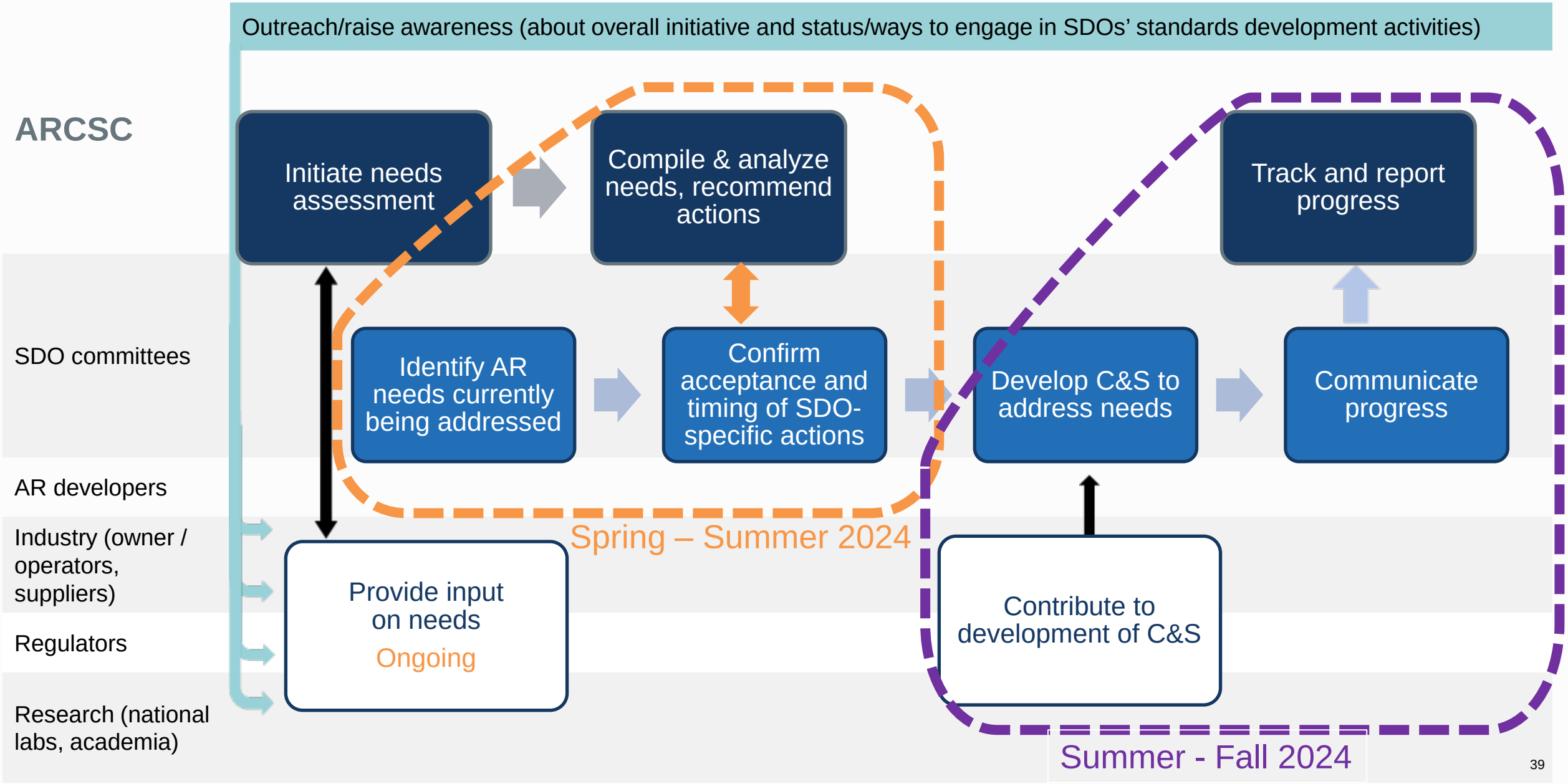
  - ✓ Demonstrate Risk-Informed and Performance-Based Approach Standard
  - ✓ Develop and execute a pilot project that applies Risk-Informed and Performance-Based (RIPB) methods in development of a new AR standard jointly with US and Canada-based SDOs (potential cross-cut with International Harmonization actions).

- Action Owners: ARCSC
- **Need Date: 2025**

ARCSC Activities to Date

Fall 2022	December 1, 2022	Mar – Oct 2023	November 30, 2023	Winter/Spring 2024	Summer 2024
• Formation of ARCSC	• Kickoff Workshop	• Charter Developed • Process Developed • Collection of relevant standards • Survey initiated • Survey Data Collected	• Annual Workshop to share preliminary survey results	• ARCSC Website deployed in February https://arcsc.nei.org/ • SDOs received Survey results and evaluate survey data.	• Survey feedback from SDO members collected including identification of research needs.

Identify C&S Needs: Next steps - SDO committee(s) disposition of survey results



Process to Translate SDO Committee Responses of Master Spreadsheet

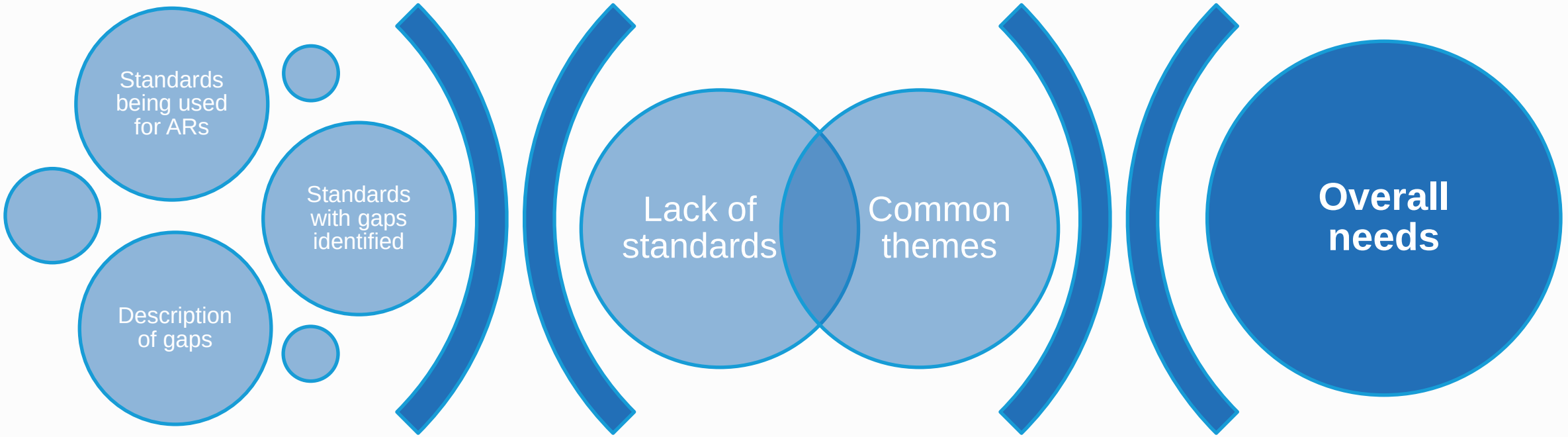
SDO committee questions:

1. Is there a **gap identified**? Y/N
2. [If Y] **Committee disposition of gap**: Persuasive (P) | Non-persuasive (NP) | Non-germane (NG) | Needs more investigation (NMI)
3. [If Persuasive] **Proposed action** to address gap: New standard | Update | Other solution
4. [Optional] **Anticipated timeline** for action to address gap: Start date | Completion date
5. [Optional] **Anticipated resources** needed for action to address gap: Liaisons |Technical basis | Funding

SDO	Designation	Title	Status	Applicable to ARs?	Relevant topical area	Gap identified from survey?	SDO input: gap disposition (P, NP, NG, NMI)	SDO input: proposed action to address gap	SDO input: timeline to address	SDO input: resources needed (liaisons/input from other SDOs, R&D, RIB, funding)

Survey and Workshop Results

Types of Insights



SDO-specific responses:
Action on SDOs

Cross-cutting responses:
Analysis by ARCSC

Cross-Cutting / Common Themes

Topic	Relevant SDOs	Next steps
Risk Informed Performance Based Standards including safety significance*	All	Addressed as part of TR-CS-02 Risk-Informed and Performance-Based Approach; add discussion of public workshop to explain RIPB methods and how to incorporate them into standards to be added to Nov/Dec ARCSC agenda.
Digitalization*	CSA, IEEE -- ALL	Each SDO should consider the impact of digitalization on their standards. Charters should be reviewed.
Advanced Manufacturing; material fabrication *	ASTM, ASM, ASME, AWS, CSA, AISC	Need to identify, accelerate, and align
Functional Containment (fuel)*	CSA, ASCE, ASME	Engage high-temperature reactor designers
Code Classification*	All	
Concrete Containment*	AISC, ASCE, CSA, ASME	ASME researching.
Seismic Analysis*	CSA, ASME, ANS, ASCE, IEEE	Aligning definitions, improve standards ability to work together.
Remote Reactors (microreactors)– autonomous reactors*	All SDOs, EPRI, INPO	Follow what NEI and NRC are doing. Mitigate regulatory burden (SECY-20-0093, SECY-24-0008). Standards will be needed in future.

**high priority*

ARCSC Activities

August 1, 2024

- Meeting held to discuss status of SDO feedback and process for prioritization
- ARCSC evaluated overarching topics
- Each SDO prioritization due August 31st

Fall 2024

- Survey results posted to the website
- NEA September 2024
- SDO prioritization with C&S with highest ranking provided to NAAR Roadmap Implementation Board
- Feedback from designers, stakeholders, on SDOs' "highest ranking" C&S. Requesting H/M/L independent determination.

Future

- Virtual/hybrid event later in 2024
- Move forward with risk-informed and performance-based (RIPB) approaches including pilot project
- Continue outreach efforts to collect C&S needs including cross cutting themes and those independently determined having significance by the ARs.

Concluding Remarks: Recap of ARCSC Actions and Requests of Designers

- Recap of ARCSC actions
  - ✓ Determined “highest ranking” C&S from gap analysis survey using NEI 19-03.
  - ✓ Determined “cross-cutting/common themes.”
  - ✓ NEA & NRC Forum presentation updates.
  - ✓ Present C&S priorities to RIB, Oct 2024.
- Requests of designers/industry stakeholders
  - ✓ Feedback from designers, stakeholders, on SDOs’ “highest ranking” C&S. Requesting H/M/L independent determination.
  - ✓ ARs to determine other C&S having significance not identified in 2023 ARCSC gap survey.

ARCSC: Needs Prioritization Survey

ANS-54.8

ANS-54.8: Liquid Metal Fire Protection in LMR Plants

ARCSC Proposed Prioritization:

HIGH

Identified Gap:

Need current version of 54.8

Reinstate 54.8-1988

22. Please check the following criteria that ANS-54.8 meets.

- [ ] (1) Supports design efforts
- [ ] (2) Supports licensing review
- [ ] (3) Reduces component fabrication time and costs
- [ ] (4) Reduces facility construction time and costs
- [ ] (5) Reduces O&M costs

23. Do you agree that the following are gaps in ANS-54.8?

	High Priority	Medium Priority	Low Priority
Need current version of 54.8	○	○	○
Reinstate 54.8-1988	○	○	○

24. Comments on the gaps (if none, please write N/A)

Enter your answer

25. By when would your organization need changes to ANS-54.8?

- ○ Within 1 year (2025)
- ○ Within 3 years (2027)
- ○ Within 5 years (2029)
- ○ Within 8 years (2032)

Thank you!

Contacts

Don Eggett, ARCSC Co-Chair and RIB member don.eggett@gmail.com

Kate Hyam, ARCSC Co-Chair hyamk@asme.org

Larisa Logan, recent past ARCSC Co-Chair

Pat Schroeder, ARCSC Secretary pschroeder@ans.org

Mark Richter, NEI mar@nei.org

Andrew Sowder, EPRI asowder@epri.com

Frankie Pimentel, NEI & Alt ARCSC RIB member fap@nei.org

Use of Risk Insights in Selecting Code or Standards for Advanced Reactor SSCs

Application of the Licensing Modernization Project Criteria

John Richards
Senior Technical Executive
Risk & Safety Management, EPRI

NRC Standards Forum
September 25, 2024

LMP Risk-Informed Design

- NEI 18-04, Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development
  - Uses a RI-PB process for selection of Licensing Basis Events (LBEs), safety classification of structures, systems, and components (SSCs), and associated risk-informed special treatments
  - A key tool in that process is the Frequency-Consequence Target
- EPRI performed research to explore use of the criteria for external hazards, using seismic hazard as an example
- Selection of SSC codes and standards was integral to establishing the seismic performance base, in terms of fragilities

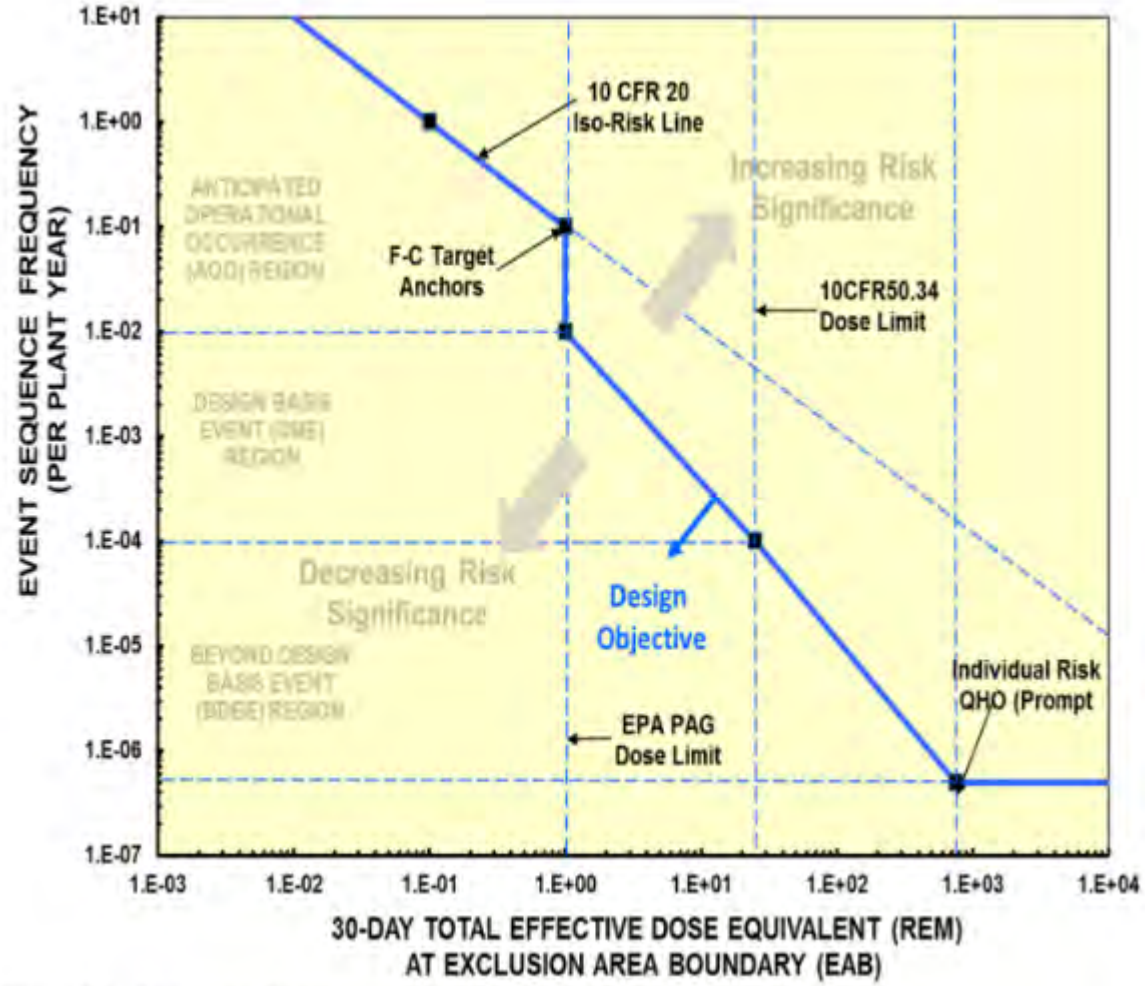
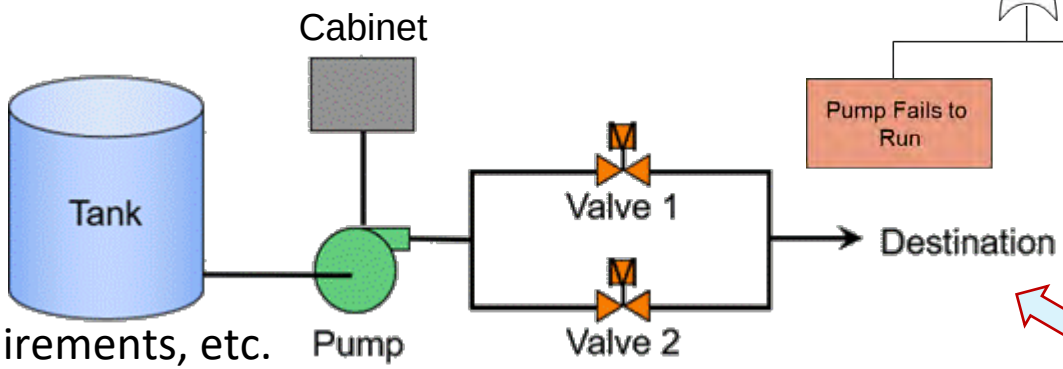


Figure 3-1. Frequency-Consequence Target

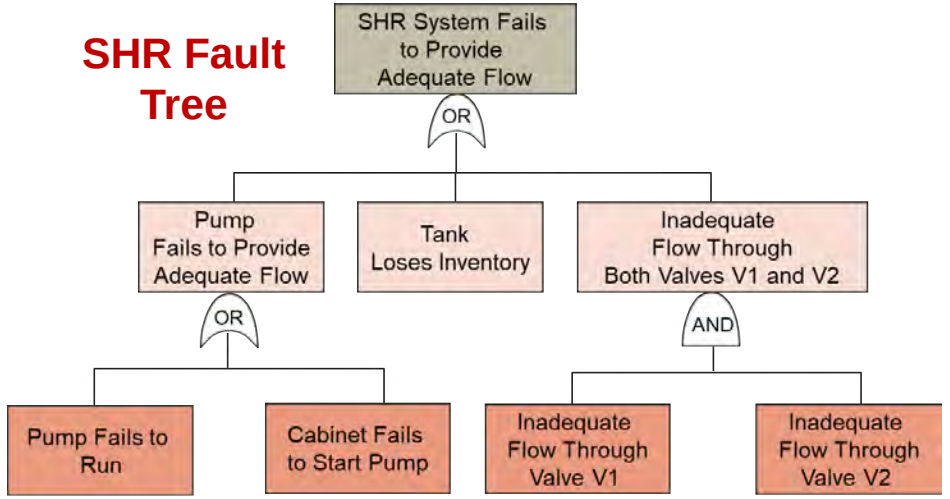
Example System Model

- Example model is general and relevant to multiple AR designs
- For each item in the model, establish initial design assumptions:
  - Safety-Related
    - Safety-Related design standards, factors of safety, performance requirements, etc.
  - Non-Safety-Related with Special Treatment
    - Commercial standards with special treatment necessary to achieve the performance target
  - Non-Safety-Related
    - Commercial standards, factors of safety, performance requirements, QA, etc.
- Each of these choices establishes the performance basis, and the resulting seismic fragility

System for Heat Removal (SHR)



SHR Fault Tree



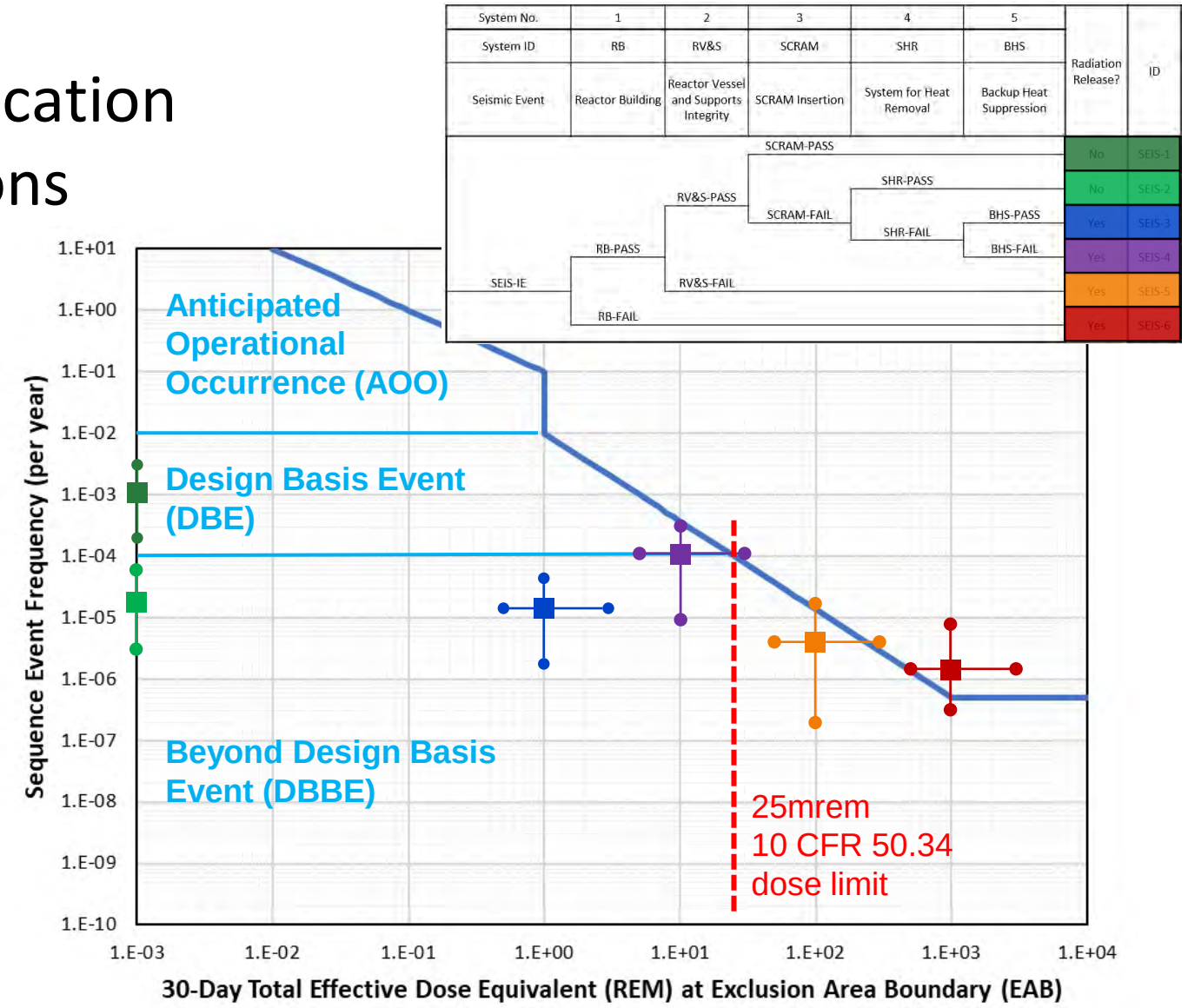
Event Tree

System No.	1	2	3	4	5	Radiation Release?	ID
System ID	RB	RV&S	SCRAM	SHR	BHS		
Seismic Event	Reactor Building	Reactor Vessel and Supports Integrity	SCRAM Insertion	System for Heat Removal	Backup Heat Suppression		
SEIS-IE	RB-PASS	RV&S-PASS	SCRAM-PASS	SHR-PASS	BHS-PASS	No	SEIS-1
					BHS-FAIL	No	SEIS-2
				SHR-FAIL		Yes	SEIS-3
			SCRAM-FAIL			Yes	SEIS-4
		RV&S-FAIL				Yes	SEIS-5
	RB-FAIL					Yes	SEIS-6

Frequency-Consequence – Initial Design

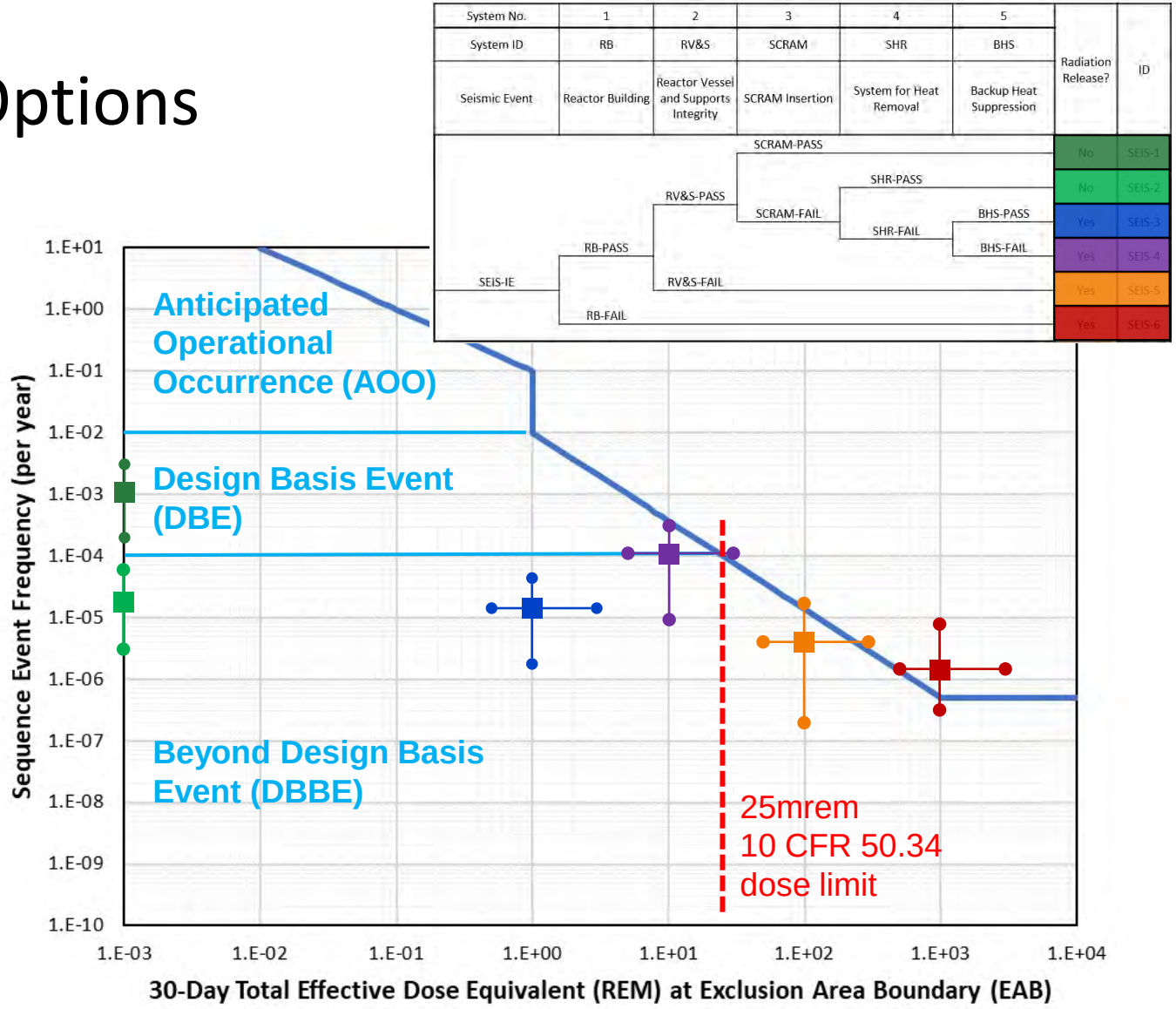
Key Results from Risk Quantification Using Initial Design Assumptions

- Several event sequences exceed the F-C Target (*Not favorable*)
- DBA defined based on DBEs does not meet the 25mrem dose regulatory limit in 10 CFR 50.34
  ➔*Design revision is necessary*



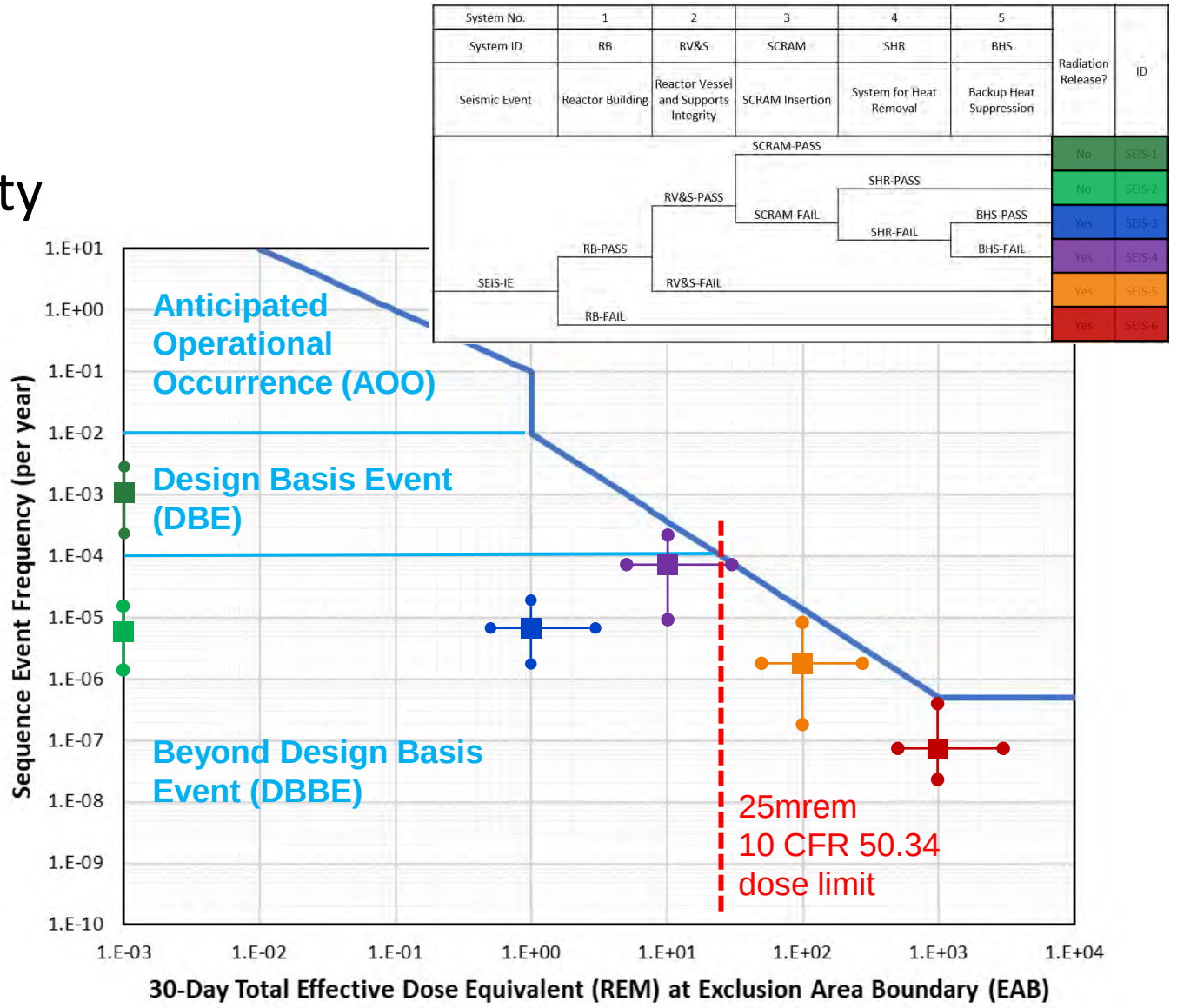
Frequency-Consequence – Revise Design

- Potential Design Revision Options
  - Reconsider the seismic design basis selected for SSCs
  - Impose additional or special requirements on SSC designs
  - Reclassify SSCs
  - Limit dose consequences by introducing barriers
  - A combination of the above options



Frequency-Consequence – Revised Design

- Selected Design Revisions
  - Limiting the demand-to-capacity ratio for RB, RV&S, and SCRAM
  - Best cost-benefit of several options considered
- Key Takeaway
  - LMP allows optimizing design for cost-benefit purposes as it progresses



LMP and RI Design for External Hazards – Insights

- Challenges
  - An initial PRA is needed at early RIPB design stages, which can be challenging since there is limited site-specific data and the early PRA insights may have high uncertainty
  - Implementing RIPB/LMP framework requires close collaboration between multiple technical disciplines in design and PRA teams
- Benefits
  - Risk-informed external hazards design can be used to risk-inform design requirements and holds potential to make plant designs more cost-effective, while maintaining high levels of safety
  - Risk-informed performance-based design considerations can inform the selection of codes and standards
- Follow-up research
  - Criteria for risk-informed codes & standards for structural design
  - Treatment of very rare seismic events in RIPB design

Selection of Codes and Standards for Structural Design

- Some Civil Standards already include performance-based criteria
  - ASCE/SEI 7-22, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*
  - ASCE/SEI 43-05, *Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities*
- For non-safety related (NSR) SSCs and non-safety related with special treatment (NSRST) SSCs, Commercial Standards could be used for structural design
- For safety related (SR) SSCs, Nuclear Standards could be used for structural design for loadings associated with functions associated with Design Basis Events, and Commercial Standards for other loadings
  - For example, if the AR operates at atmospheric pressure, the reactor building safety function might be to provide shielding and avoid collapsing in a seismic or high wind event

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