Introduction to ASME Section XI, Division 2 Reliability and Integrity Management (RIM)

MAY 26, 2023

ANS

Risk-informed, Performance-based Principles and Policy Committee (RP3C)

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Today's Speaker

A. Thomas Roberts
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Chairman of ASME Section XI Division 2
Reliability Integrity Management (RIM)

BIO

Mr. Roberts’ career summary spans over forty-five years’ experience, starting with the construction of several nuclear plant sites, then transitioning to management roles at three operating plants involving both pressurized water and boiling light water reactor technologies.

He has held direct responsibilities for:
Project and Construction Management, Nondestructive Examination, Welding Engineering, Engineering Program Management, and the responsibility for American Society of Mechanical Engineering (ASME) Code implementation during various plant construction sites and three operating units.

His involvement in nuclear industry related Codes and Standards development is diverse and includes:

- Current Co-Vice Chair of ASME Section XI Standards Committee
- Current Member of ASME Section XI Executive Committee
- Current Chair of the ASME XI Inquires Committee
- Current Chair of ASME Section XI Division 2 - Sub Group Reliability Integrity Management (RIM)
- Current Member of ASME/JSME Task Group on System Based Codes
- Current Member of the Nuclear Energy Institute Codes and Standards Task Force

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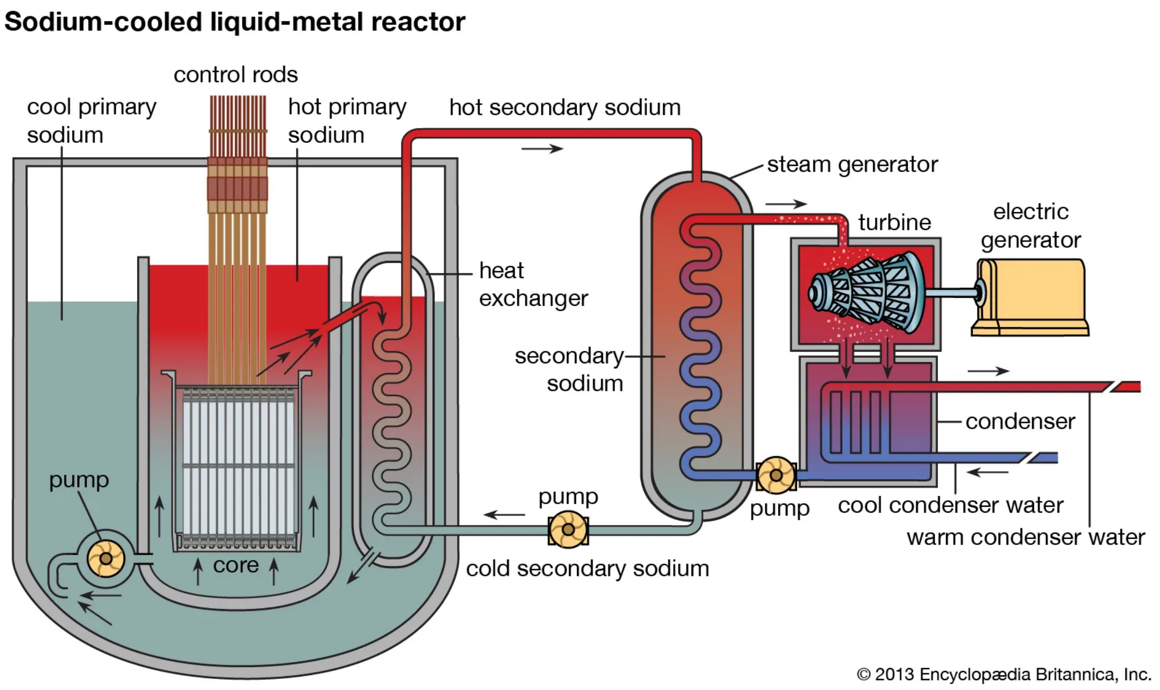
Agenda

- Outline the process of Reliability Integrity Management (RIM)
  - What is RIM and why it is needed for advanced reactors?
- RIM process concepts
- Operational (monitoring) inspection challenges for advanced reactor designs
- RIM use & MANDE example

Outline of RIM

- Section XI, Division 2 Reliability Integrity Management (RIM) overview.
- What is RIM?
- Why is RIM essential to AR*, SMR* and MR* **designers** and not just to future Owners/Operators?
- What is important about RIM that AR, SMR & MR **designers** should consider throughout the design phase?
- How does Risk Informed Performance Based approaches integrate into RIM?



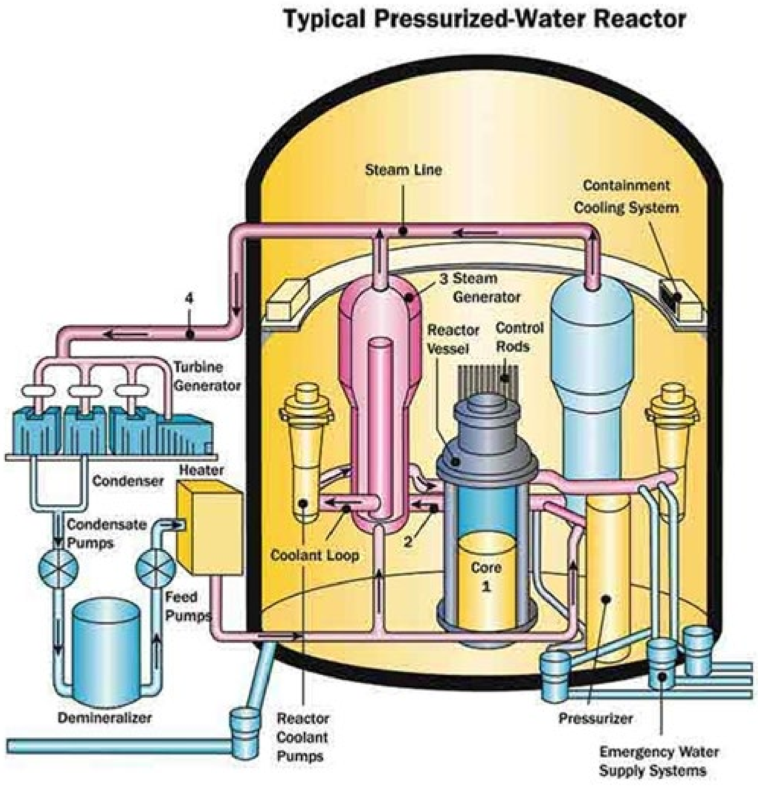
*
- AR = Advanced Reactors.
- SMR = Small Modular Reactors (i.e., <=300 MWe per unit) independent of technology
- MR = Micro Reactors (Info Link) https://www.energy.gov/ne/articles/what-nuclear-microreactor

Challenges for Advanced Design Reactors

- ASME Section XI Division 1, and similar international inservice inspection standards (e.g., KTA), are **<u>not well suited</u>** for most advanced design reactors currently in development.

- ASME Division 1 was developed primarily for light water reactor technology (e.g., BWRs & PWRs).

- ASME XI Division 1 tends to be "weld centric" in terms of what is inspected.



Reliability Integrity Management (RIM)

An ASME Section XI Sub-Group – developed the new ASME XI Division 2 Reliability Integrity Management (RIM)

- RIM is a detailed process to establish operational monitoring criteria for expected degradation mechanisms that are expected to occur, regardless of the reactor technology, (e.g., Molten Salt, HTGR, Liquid Metal, etc.)
  - RIM is "technology neutral“ process – applicable to all reactor designs and technologies.
  - RIM criteria may be established by deterministic or probabilistic methods
  - RIM requires Monitoring and NDE **(MANDE)** to be assigned to SSC, based on expected credible degradation mechanisms in concert with an individual SSC’s contribution to risk for safe plant operation.

LINK TO WEBPAGE

https://aris.iaea.org/

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Reliability Integrity Management Basic Process Overview Concepts

During design and operations → **1. RIM scope definition and SSC selection based on PRA**

INPUTS:
- Licensing & Safety Requirements
- Plant Level PRA
- SSC Level PRA Contribution to Risk

During design and operations → **2. Degradation Mechanism Assessment**

INPUTS:
- Assess Damage Mechanisms (DMs) relevant to the specific technology.
- Examples - creep, corrosive coolants, deterioration of non-metallics, such as graphite.

During design and operations → **3. Plant and SSC Reliability Target Allocation**

INPUTS:
- Selected SSC Reliability Target value feeds into the required System and Plant Required Reliability needed to meet safety objectives.
- Established by Frequency/Consequence Curve

During design and operations → **4. Identification and establishment of RIM strategies and MANDE**

INPUTS:
- MANDE is selected to monitor or inspect for DMs that are relevant to the specific reactor technology.

Reliability Integrity Management Basic Process Overview Concepts

During design and operations

5. Evaluation of Uncertainties

INPUTS:

- Both PRA models as well as selected MANDE have associated uncertainties.

- These uncertainties must be accounted for to assure the fidelity of the required reliability of an SSC to meet its performance objectives,

During operations

6. RIM Program implementation

INPUTS:

- Program is initially implemented based on initial PRA, assigned RT values and selected MANDE.

During operations

7. Continuous monitoring and RIM Program and MANDE updates

INPUTS:

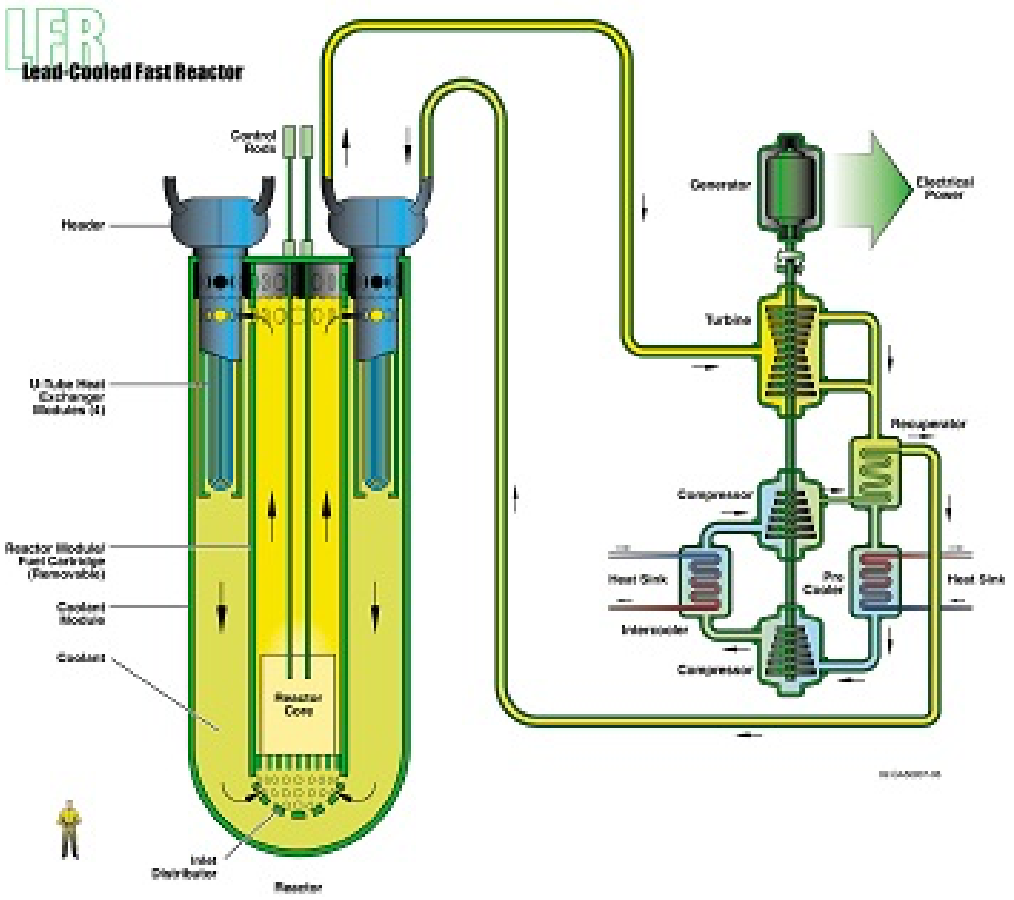
- As the plant is operated, the RIM program is continuously updated, modified, adjusted using the same processes as were employed during the initial development of the RIM Program but using newly gained insights from OE.

RIM Process Description: Part I

- **<u>Any SSC</u>** that could affect plant reliability must be scoped into the RIM program.

  - Non-Safety Related SSC* classified under historic SSC classification guidance as Non-Safety Related, but that are **<u>deemed risk significant</u>**, are required for inclusion in the RIM programs.

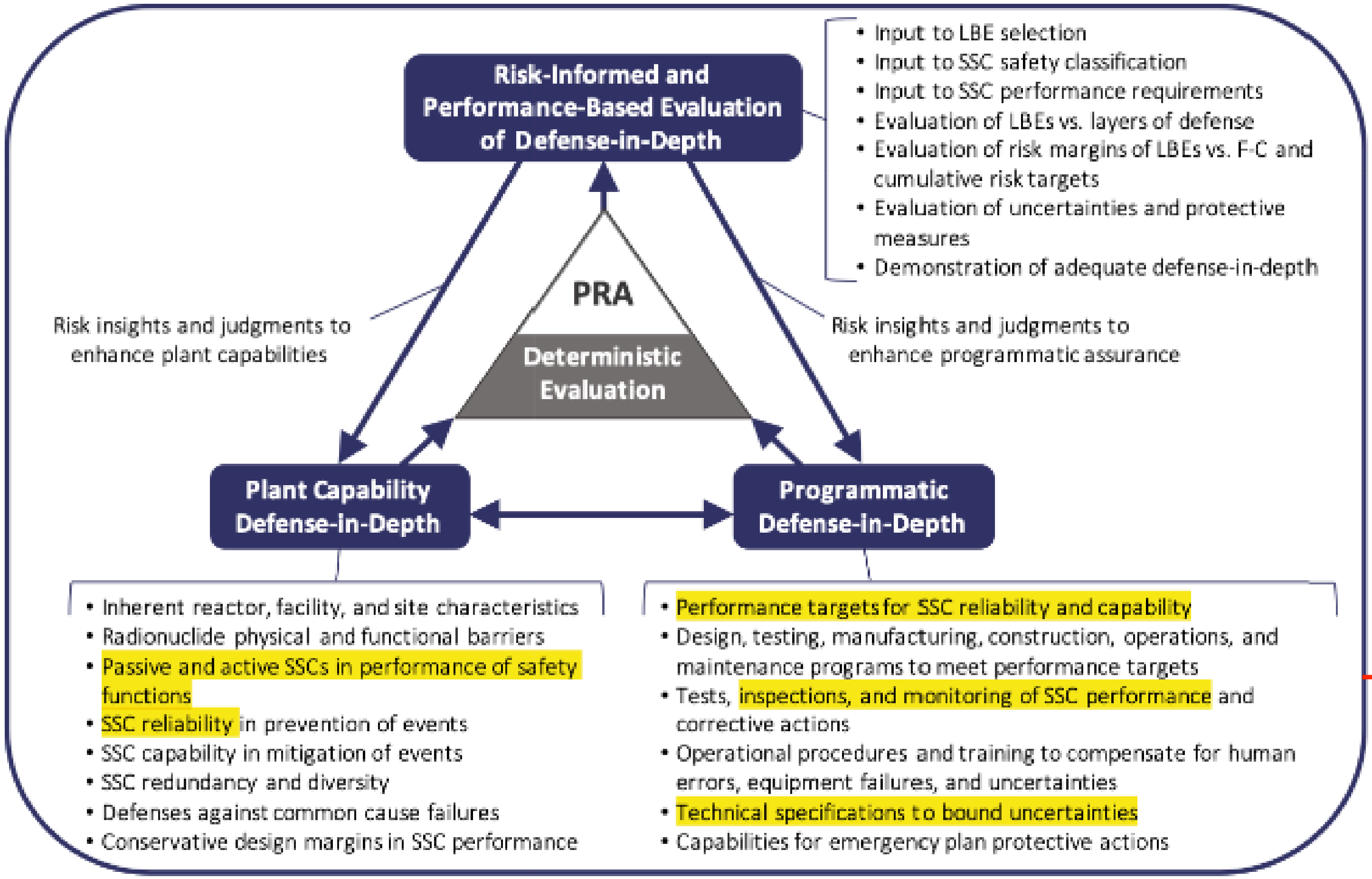
- This contrasts with the existing ASME XI Div. 1 Class 1, Class 2, Class 3, Class MC, Class CC, etc. ISI approach, with each class having different graduated criteria based on the Class of an SSC, rather than its risk significance.

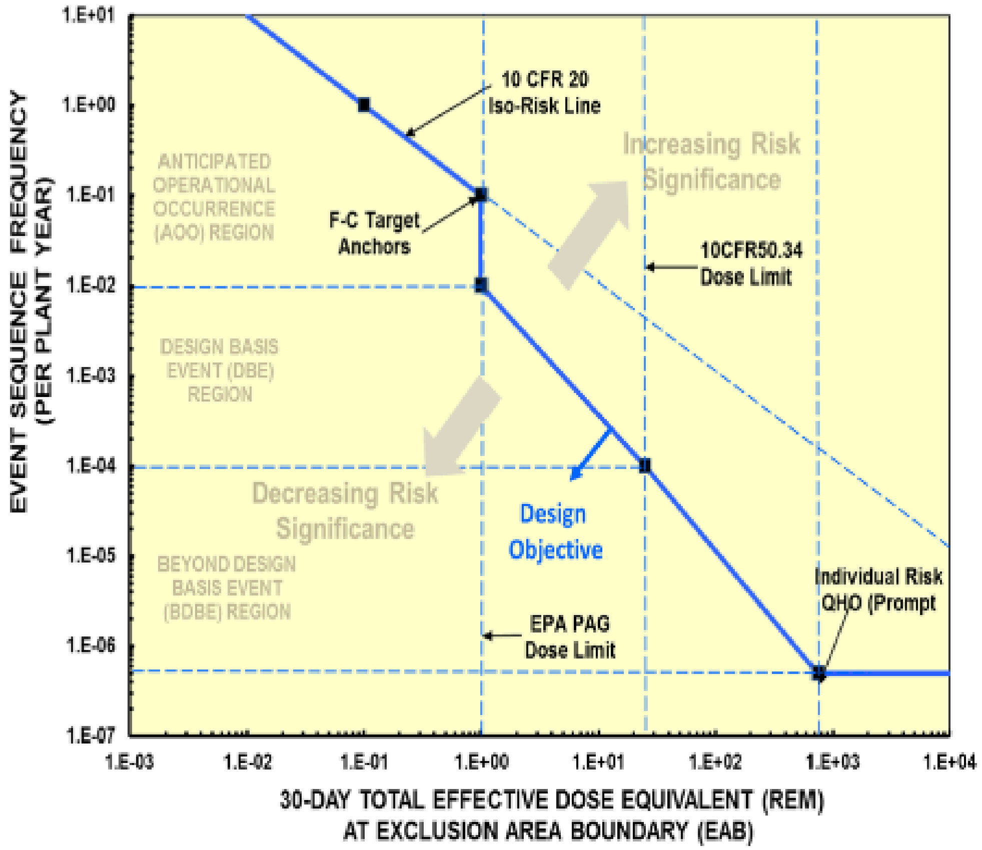


* Using NEI 18-04 guidance such SSC would be classified as Non-Safety Related with Special Treatment (NSRST)

RIM Process Description: Part I

A ranking for risk contribution, known as a **Reliability Target Value**, is assigned to each SSC.





Figures from NEI 18-04

RIM Process Description: Part I

- As part of initial design as well as during operations, SSCs that are deemed risk significant are scoped into the RIM Program.
    - This determination is established by the RIM Expert Panel (RIMEP)
    - RIMEP must use accepted PRA criteria to make this determination at the plant, system and SSC level.
    - This applies to passive components that would not normally be considered in traditional PRA evaluations.
- A ranking of relative risk, known as a **Reliability Target Value**, is assigned to each SSC.

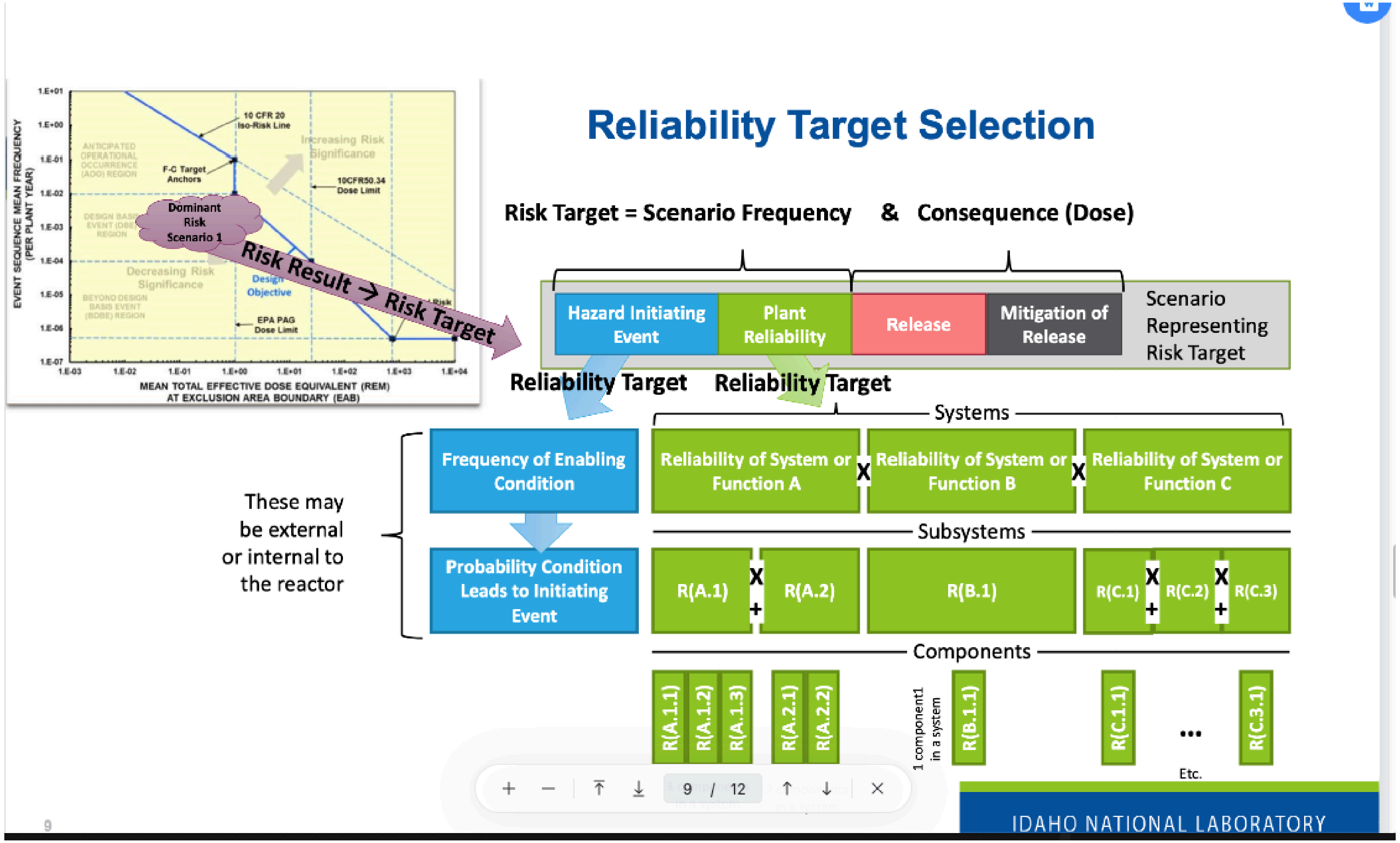


Figure from INL Report INL/PT-22-68899 Link: https://inldigitallibrary.inl.gov/sites/sti/sti/Sort_64127.pdf

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RIM Process Description: Part I

- An SSC's **Reliability Target** value is the assigned numerical index that must be maintained for an SSC within the program to assure it will:
  - Perform its required function over its expected life cycle
  - Not challenge safe plant operation or reduce overall Plant or System Reliability criteria

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RIM Process Description: Part I

- As part of the RIM process, the RIMEP and a second RIM prescribed expert panel called the MANDE Expert Panel (MANDEEP) are required to perform an SSC Degradation Mechanism Assessment (DMA)

  - The DMA establishes what credible degradation mechanisms might apply to an SSC for a specific reactor technology over the life of the SSC (e.g., Creep, Stress Corrosion Cracking, Flow Induced Vibration, coolant chemistry excursions, etc.).

Table VII-1.2-1 Degradation Mechanism Attributes and Attribute Criteria (LWR) (Cont'd)

Degradation Mechanism		Attribute Criteria	Degradation Features and Susceptible Regions	Table VII-1.3.3-1 Examination Category (as appropriate)
FS (cont'd)	FAC	– Carbon or low alloy steel piping with Cr <0.5% (some literature indicates 0.1%) and – Wet steam environment (i.e., two-phase flow) or – Any high-purity water environment coupled with – Low levels of dissolved oxygen – And flow (there is no known practical threshold velocity below which FAC will not occur) [reference: T. M. Laronge, M. A. Ward, "The Basics and Not so Basics of Water Corrosion Processes Altered by Flow Changes," CORROSION/99, paper 99345, NACE International, Houston, TX (1999)] – Accelerated further by turns in the flow path and – Low or very high pH – Fluid flow present >100 hr/yr	wall thinning can initiate in welds, HAZ, and base metal at the component inner surface affected locations can include regions where the potential for FAC degradation has been identified FAC can occur over extensive portions of the component inner surface Degradation growth is relatively slow, and through-wall degradation is not expected within an inspection period	A, B, D, F, J, O
	PE	– Solid Particle Erosion (SPE) is damage caused by particles transported by the fluid stream rather than by liquid water or collapsing bubbles. In contrast to liquid impingement erosion, the necessary velocities for SPE are low, approximately 3 ft/sec. SPE also requires the presence of particles of sufficient size, typically >0.004 in. (100 microns). – Erosion rate decreases in ductile materials rapidly with decreasing particle size below 0.004 in. (100 microns).	Wall thinning can initiate in welds, HAZ, and base metal at the component inner surface. "Hard materials" (e.g., Stellite) offered only modest improvement over carbon steel. The Inconel alloys offered only a very modest improvement over carbon steel. Unless exotic materials are used (i.e., ceramics), there is no material solution to SPE. Susceptible regions include valve internals, nozzles, and the steam turbine. Degradation growth is relatively slow, and through-wall degradation is not expected within an inspection period.	B, D, F, J

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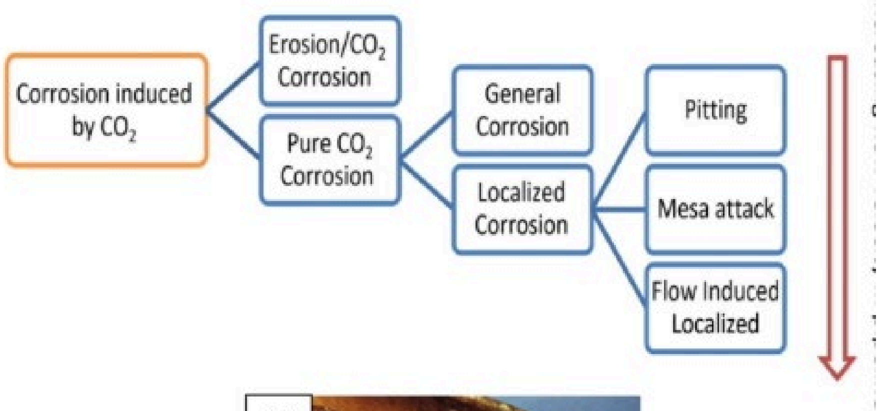
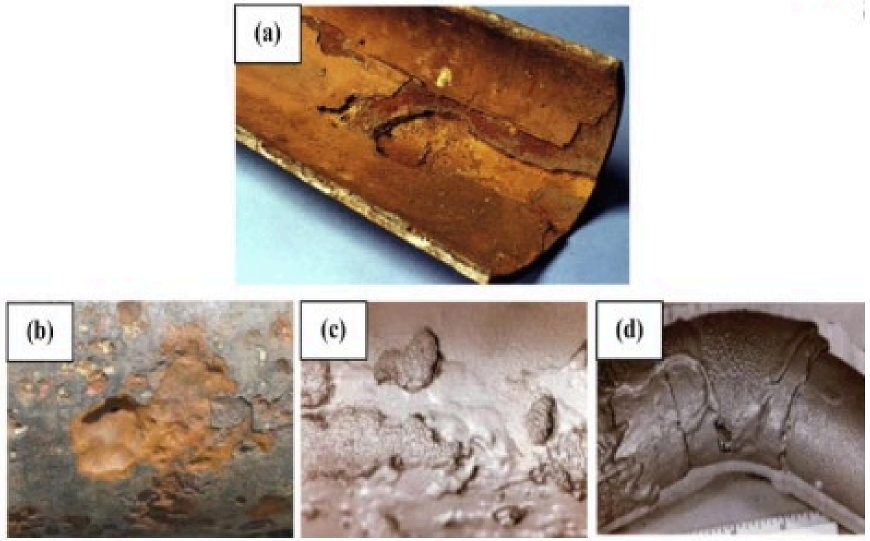
RIM Process Description: Part I

- The RIMEP and MANDEEP are responsible for determining and assigning MANDE
- Any MANDE selected must be **<u>“performance demonstrated”</u>** before being employed
- This assures that any MANDE selected is effective in detecting the degradation mechanism
- RIM is **<u>not focused exclusively on weld examinations</u>**. Any credible degradation mechanism must be accounted for in MANDE selection (e.g., general corrosion).





NOTE: Some AR intend on using CO2 as a coolant

RIM Process Description: Part I

- The MANDE that is selected is chosen for the purpose of being able to detect credible degradation mechanisms that are expected to apply to a particular reactor technology.

- Because DMs may not be limited to just weld locations, MANDE needs to be accounted for in the design of an AR to be able to employ RIM.

- Based on the previous example of corrosion phenomena in a CO_2 environment, a system may need to be outfitted with installed transducers to be able to detect changes in wall loss due to general corrosion effects.
- Regardless of the method of MANDE selected, a provision of RIM is that MANDE must be performance demonstrated.

  - That is to say, what is the “confidence level” of the MANDE chosen to be able to reliably detect changes in wall thickness of any SCC exposed to CO_2 as might be necessary for the noted example.

RIM Process Description: Part II

- RIM is an on-going "Living Program".
- It applies over the entire plant life cycle for risk significant SSC:
  - The periodicity for any prescribed MANDE is based on SSC's:
    - Active degradation mechanisms
    - Required Reliability Target value of an SSC and
    - Operating conditions (e.g., longer fuel cycles than PWR or BWR)
  - As operating experience is gained, the RIM Program must be updated
    - RIM can therefore be thought of as an ongoing age management program.

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Advanced Reactor Designer Considerations:

- Integrating RIM considerations during conceptual and detailed design efforts is essential and should include:
  - Establishing what the population of risk significant SSCs are for inclusion of the RIM Program, design specific considerations, and the plant level PRA
  - Determining credible degradation mechanisms for RIM scoped SSCs
  - Defining Reliability Target values for SSC
  - Demonstrating MANDE selected for SSC within the RIM Program
  - Working with ASME XI Division 2 committees to update and revise RIM, in order to best address specific or unique reactor design considerations and accommodate various reactor designs as they evolve.

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Summary

- Advanced nuclear reactors have varied designs and purposes
  - Alternative approaches to current ISI activities are needed to accommodate new technologies.
  - Technology is moving to designs other than traditional LWRs
  - Some proposed reactors are for applications other than power production (e.g., medical isotope production, desalination, experimental test reactors, etc.)
  - RIM was developed to address and accommodate these new designs.

Summary

- RIM is a process that can be used:
  - For any reactor design or application.
  - It provides targeted MANDE criteria for all unique designs.
  - It serves as a living program to monitor aging effects on risk significant SSC
- Nuclear reactor applications are moving toward new designs, miniaturization, etc. but reactor safety and long-term reliability remains paramount.
- RIM can accommodate these changes while maintaining long term safety and reliability.

Questions & Answers

- RIM itself is a living document and the work has just started!

- Interested in learning more about the BPVC-XI-2 Standards or how to get involved with the Committee?

- Contact presenter:

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