Materials Risk Guidance Development Efforts
Risk-Informed Materials Assessment

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ACRS Meeting

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Topics

- Purpose and Applicability of RIMA Project
- Defense-in-Depth
- Safety Margin
- Risk Impacts (use of risk insights)
- Performance Monitoring
- Tier List
- Sampling Considerations
- Sampling Analysis

RIMA - Purpose

Risk-Informed Materials Assessment Project

A risk-informed materials engineering forward guidance development project

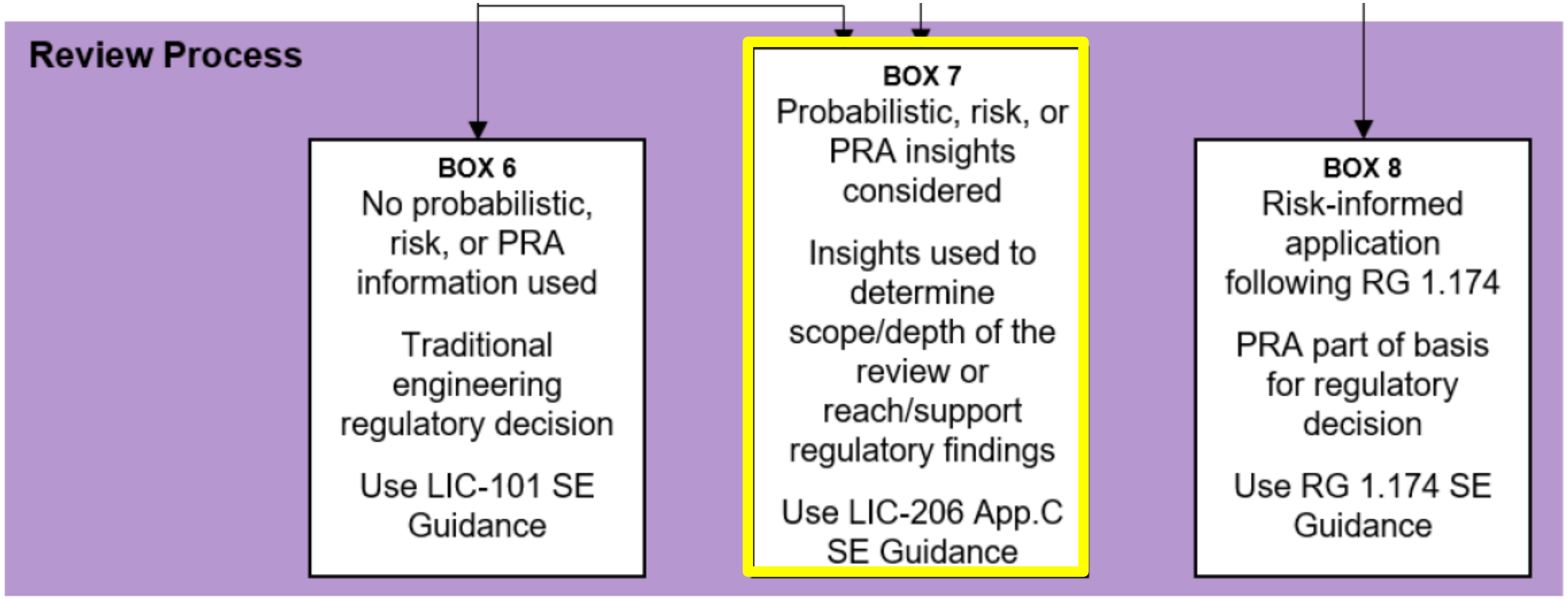
Leveraging the processes and guidance of RG 1.174, RG 1.200, LIC-206, RG 1.245, etc. to enable more efficient and effective reviews

Providing applicants and reviewers guidance in utilizing risk-informed decision making for non-integrated reviews

RIMA - Applicability

Target submittals:

LIC-206 Box 7 Type applications and reviews with non-integrated teams (e.g., materials engineers and counterparts only)



RIMA – Preliminary Concepts

Staff has been generating a preliminary set of RIMA concepts to support potential guidance document development

What it is (will be):

- Clearer/broader guidance in the language of materials engineers
- Applicant guidance to enable high quality submittals and efficient staff review

What it is not (will not be):

- New policy
- Deviation from RG 1.174

The following slides detail current preliminary concepts

RIMA – Defense in Depth

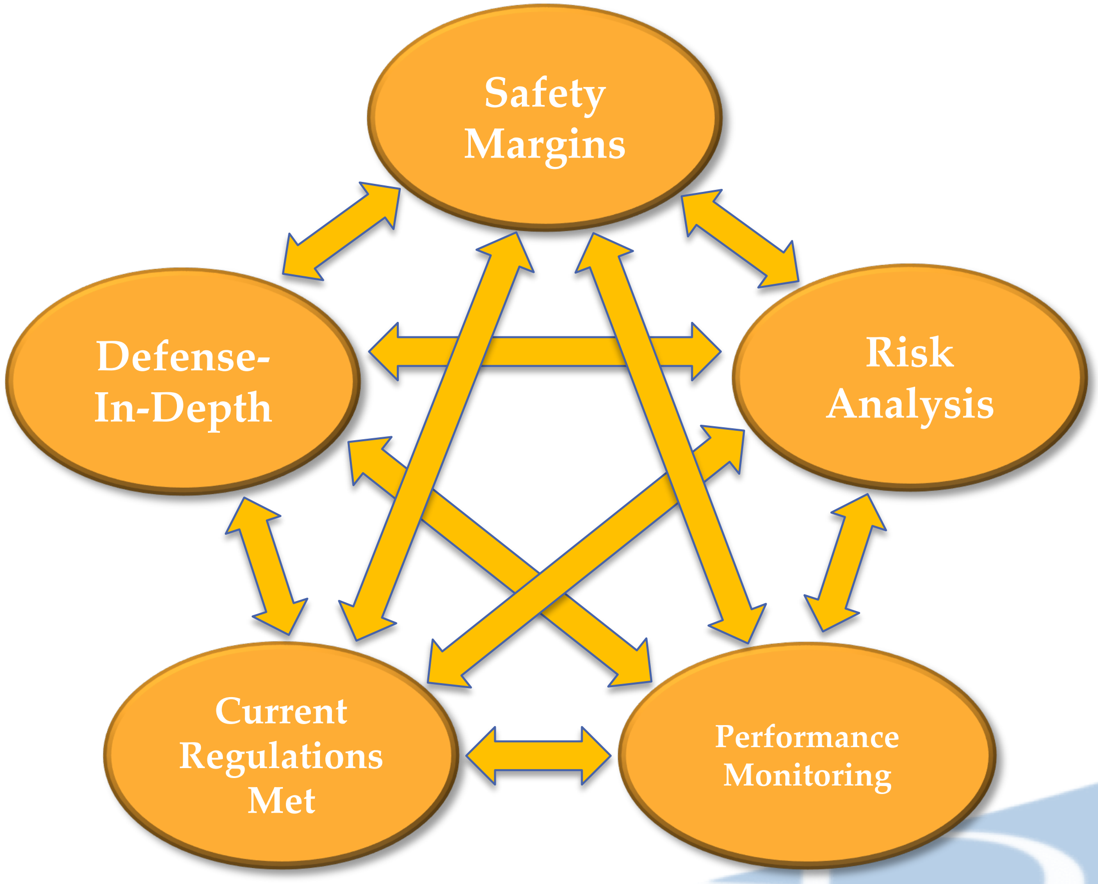
Further clarify the relationship between materials engineering topics and defense-in-depth considerations.

Typically, materials engineering reviews do not establish defense-in-depth characterizations, rather materials engineering supports commensurate level of assurance based on characterization.

Is treatment of subject systems commensurate with defense-in-depth functions of subject systems.

Key consideration:

Is there enough "assurance" from other four Principles of RIDM to credit subject system for defense in depth?

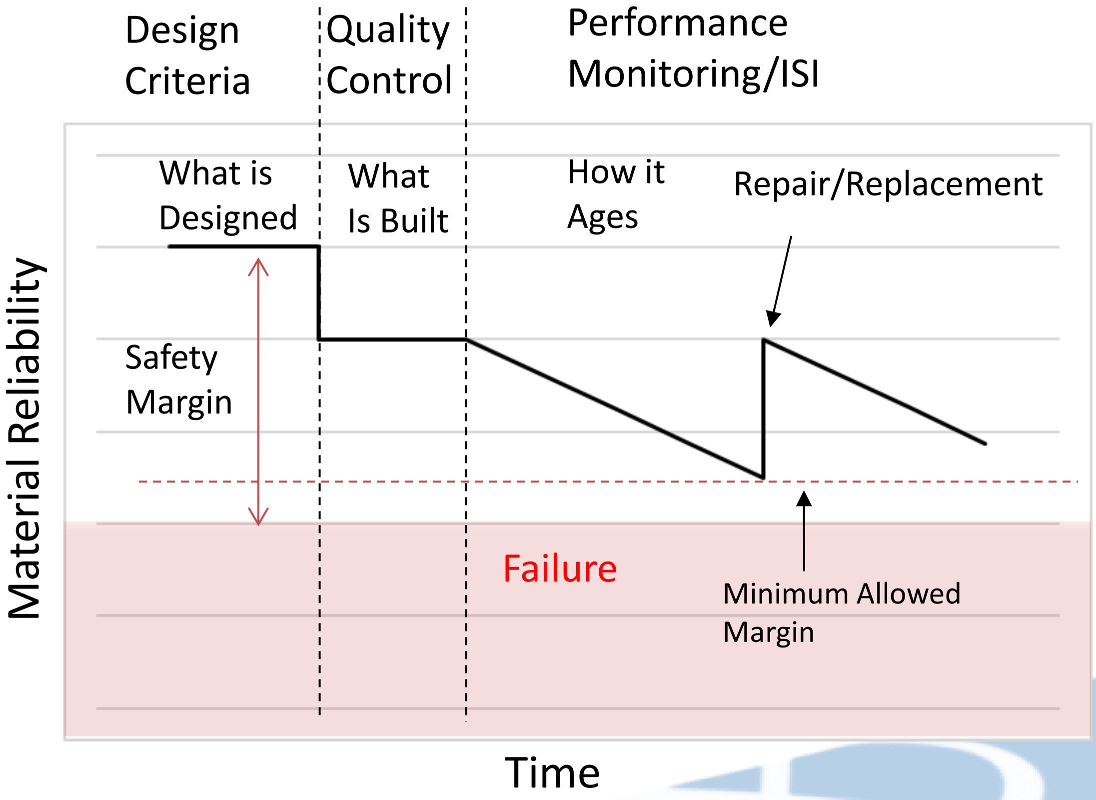


RIMA – Safety Margins

Further clarify the relationship between materials engineering topics and safety margin considerations.

Key consideration:

Are safety margins large enough, in concert with other Principles of RIDM, to manage uncertainties?



RIMA – Risk Impacts

Clarification and discussion of risk insights derived from qualitative or non-PRA modeling (e.g., PFM).

How insights related to one or more elements of the Risk Triplet (i.e., what can go wrong, how often, and what are the consequences?) can be leveraged.

(More in a few slides.)

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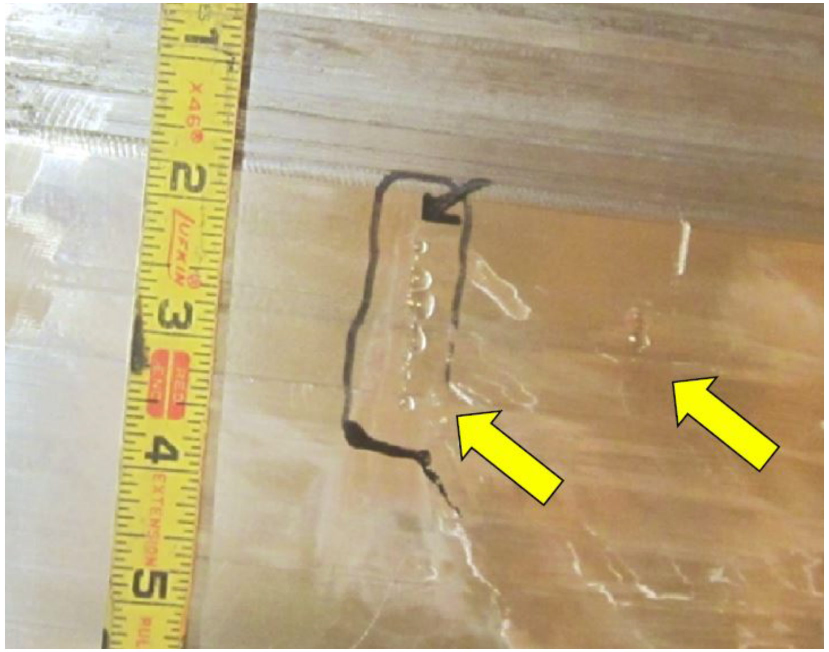
PFM is often a Risk Impact insight:

Risk Triplet

- What can go wrong?
- ***How often?***
- What are the consequences?

Frequency of potential initiating event such as LOCA



RIMA

Further clarify the relationship between materials engineering performance monitoring and the other Principles of RIDM.

Expanded discussion of performance monitoring and bathtub curve relationship.

Discussion of management of novel performance monitoring results.

RIMA – Performance Monitoring

Performance monitoring adequacy rests on several pillars.

- How much monitoring?
- What kind of monitoring?
- How often?
- Are there triggers for more or less monitoring within program?

Answers to these questions must be judged in context of other Principles of RIDM (e.g., how does subject system support defense-in-depth?)

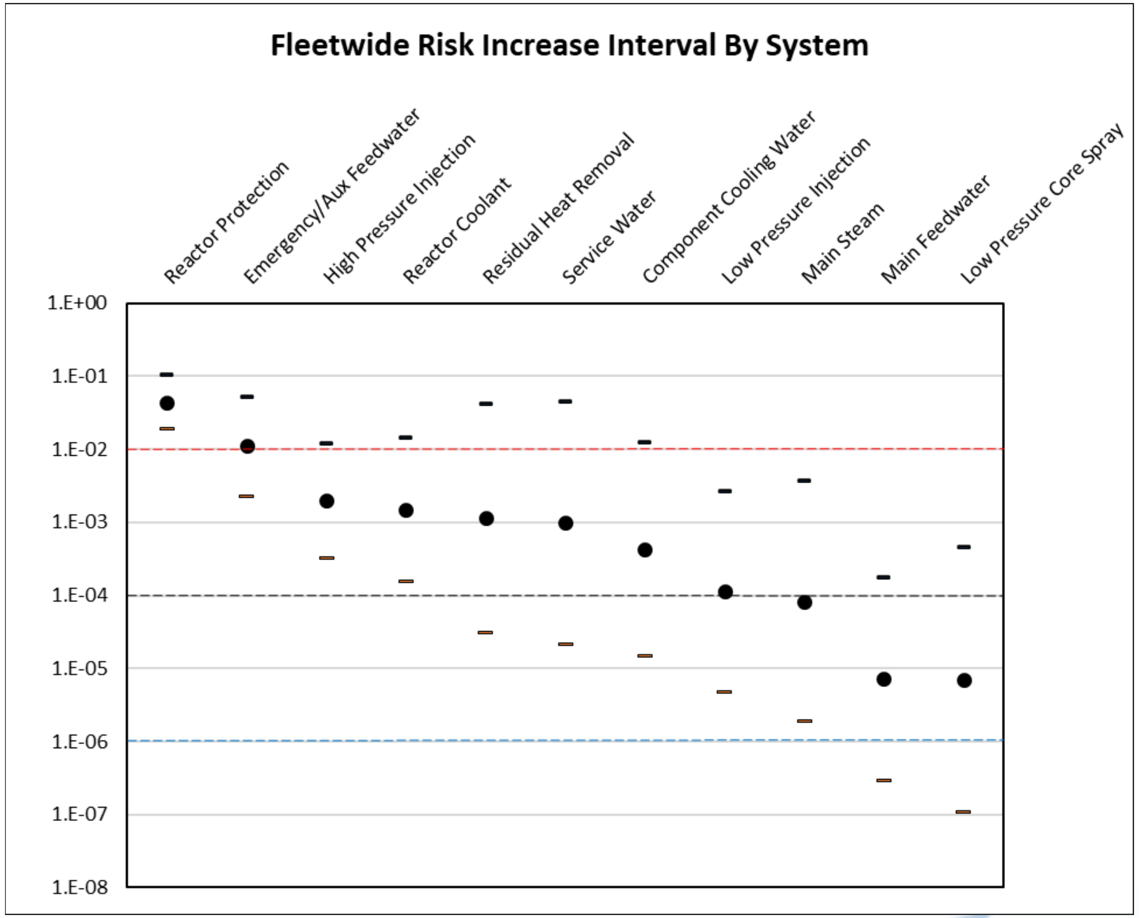
RIMA – Tier List

The materials staff wanted a risk ranking of important systems to help risk-inform materials reviews.

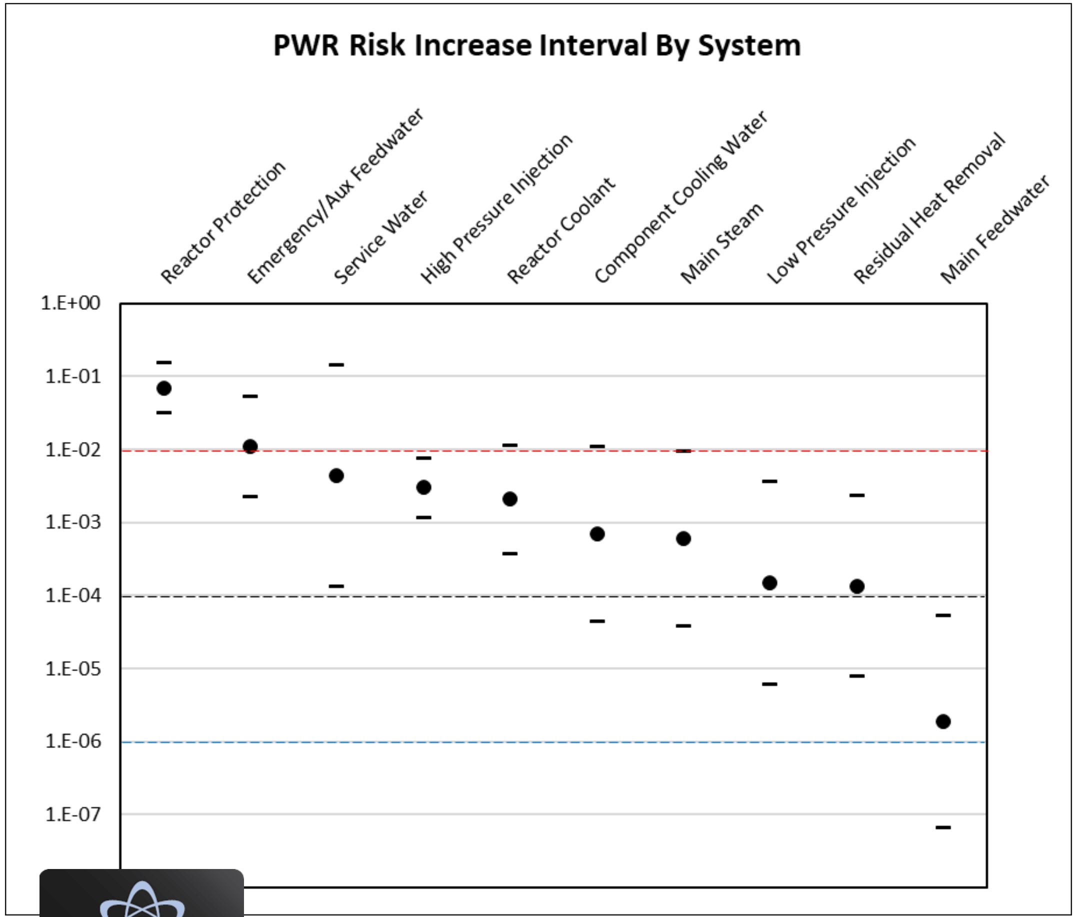
The NRC Staff used the SPAR-Dash tool to rank important systems.

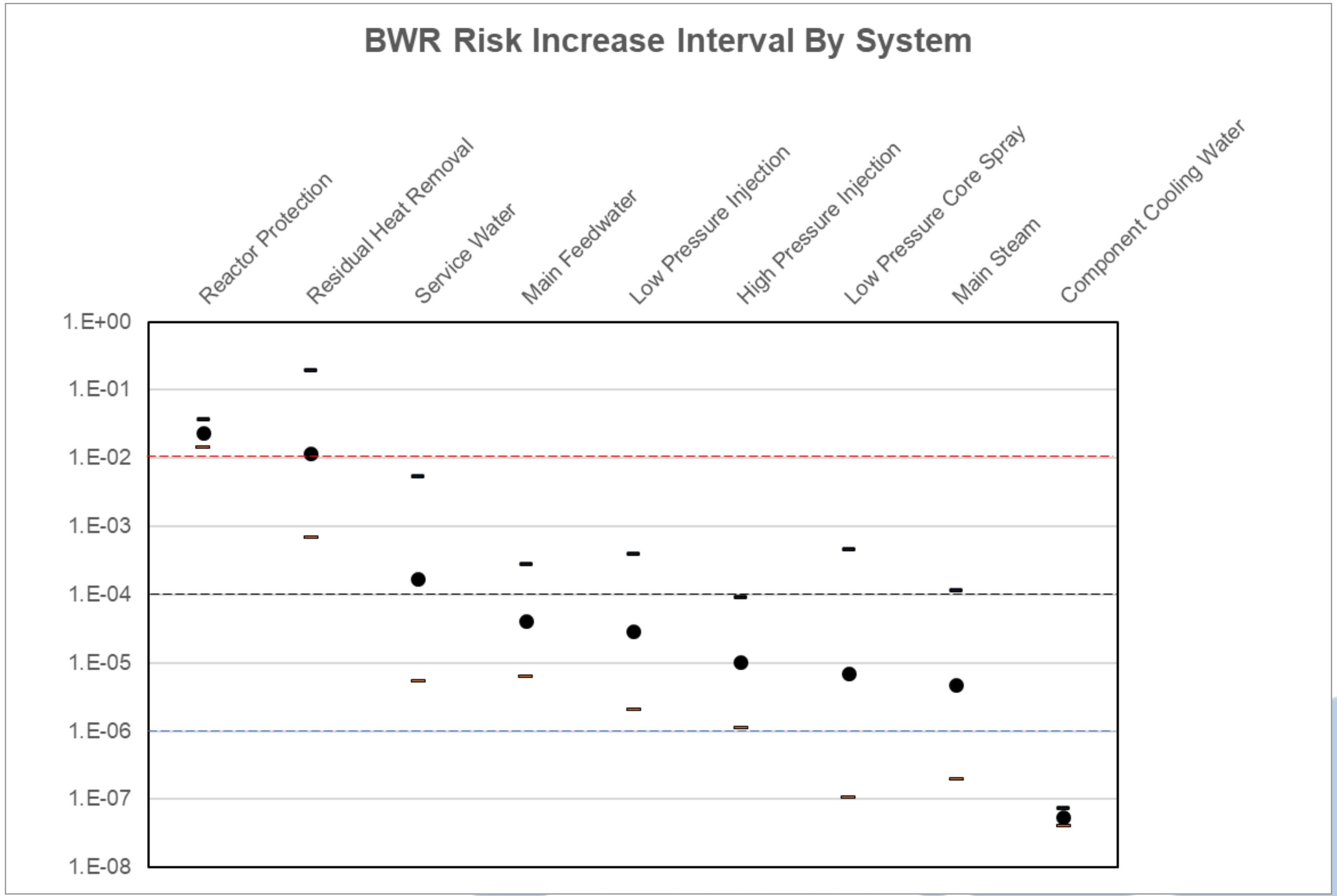
For this work we have decided to focus on broad systems rather than components.

Tier List – Fleetwide System Importance



Tier List – PWR and BWR System Importance





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Tier List – Final Tier List

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Fleetwide

Tier X	Reactor Protection Emergency/Aux Feedwater
Tier 1	High Pressure Injection Reactor Coolant Residual Heat Removal Service Water Component Cooling Water
Tier 2	Low Pressure Injection Main Steam
Tier 3	Main Feedwater Low Pressure Core Spray

PWR

Tier X	Reactor Protection Emergency/Aux Feedwater
Tier 1	Service Water High Pressure Injection Reactor Coolant Component Cooling Water Main Steam
Tier 2	Low Pressure Injection Residual Heat Removal
Tier 3	Main Feedwater

BWR

Tier X	Reactor Protection Residual Heat Removal
Tier 1	Service Water
Tier 2	Main Feedwater Low Pressure Injection
Tier 3	High Pressure Injection Low Pressure Core Spray Main Steam Component Cooling Water

* Reactor protection is not a focus for materials assessment

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Tier List – Takeaways

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The Tier List is not directly applicable to individual plant reviews as there is large variability in risk significance from plant to plant for the same systems.

The risk rankings are helpful to focus attention when looking at fleet-wide issues.

The list is a tool to teach new staff about the importance of different systems.

The list does not consider internal flooding.

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RIMA – Sampling Considerations

Expanded discussion of performance monitoring including framework to help identify target concepts supporting optimization of performance monitoring

Includes discussion of qualitative factors as well as an example statistically driven sampling calculation

Leverage bathtub curve terminology to create common language for discussion

RIMA – Sampling Considerations

The following tables are initial thoughts regarding the impact of various considerations on necessary sampling.

✓ - Means a consideration likely indicates a particular column applies

↑ - Means a consideration increases emphasis

↓ - Means a consideration decreases emphasis

Color ↓ vs. ↓ implies a stronger or weaker association between a consideration and a particular column.

Generic life-stage determination table

	Burn-in	Maturity	Wear-out
Novel material, process, or design	✓		
Novel repair	✓		
Repair	✓	✓	
Novel degradation mechanism identified	✓		✓
Novel degradation parameters (CGR, etc.)	✓		✓
Degradation threatening function			✓
PSI only	✓		
PSI + 1 interval of ISI	✓		
PSI + more than 1 intervals of ISI	✓	✓	

* Checks in multiple columns are "ors"

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Qualitative factors affecting sampling intensity table

	Component level sampling	Population Level sampling
Burn-in	✓	✓
Maturity period	✓	✓
Wear-out	✓	✓
Safety related	↑	↑
RISC-2 (50.69 approved designation, system designation)	↑	↑
Consequence significant	↑	↑
Aging management program	↑	↑
Failure tolerant (LBB, etc.)	↓	
Low impact on other safety significant systems	↓	
Redundant	↓	
Isolable	↓	

* Gray marks indicate that column should be considered but is not a priori necessary

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Sampling Considerations – Emergent Events

Qualitative factors affecting sampling due to emerging events table

	Component level sampling	Population level sampling	Site sampling expansion	Population sampling expansion
Site-specific event or chemistry issue		↑	↑	
Novel indications identified at a single site			↑	↑ (gray)
Novel indications identified at multiple sites			↑	↑
OE limitations (e.g. low coverages or other issues)	↑ (gray)	↑		
Extensive OE demonstrating no degradation	↓	✓		
Extensive OE demonstrating limited degradation	↓	✓		
Extensive OE demonstrating unmodeled degradation	✓	✓	↑	↑
Extensive OE demonstrating modeled degradation	✓ (gray)	✓		

* Marks in multiple columns are all applicable or should be considered (if gray)

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RIMA – Sampling Analysis

Quantitative sampling calculation can be derived from statistical calculations

For example, NRC staff leveraged this in support of review of PROMISE Code submittals

Detailed discussion of approach in PVP2023-105203, *Statistical Approach to Developing a Performance Monitoring Program*

Binomial Distribution

- The binomial distribution is frequently used to model the number of successes in a sample of size n drawn with replacement from a population of size N
- Can be used to find number of inspections needed to find a crack
- Only a function of the number of inspections and the percentage cracked
- Very easy to use (beware of limitations)

$$f(k,n,p) = \binom{n}{k} p^k (1-p)^{n-k}$$

$$\binom{n}{k} = \frac{n!}{k!\,(n-k)!}$$

k= number of successes (cracks found)
n=number of trials (inspections)
p= probability of success on an individual trial (percentage of population cracked)
If k=0 then this is the probability of no successes is:

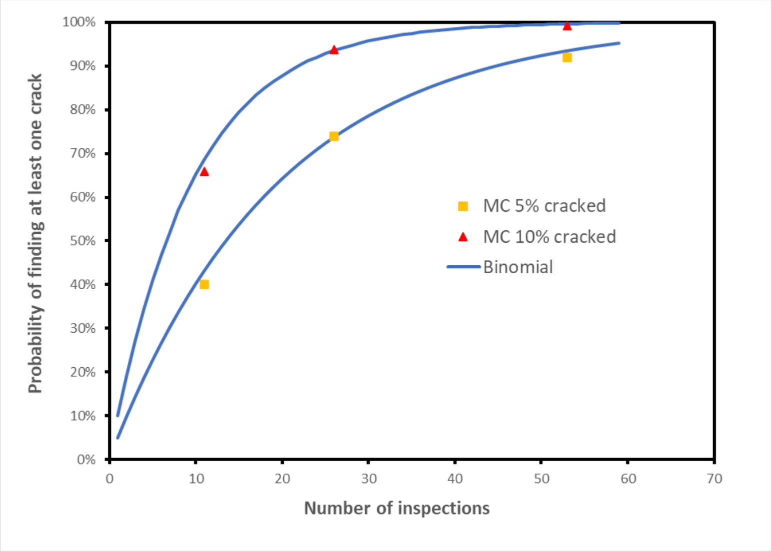
$$f(n,p) = (1-p)^n$$

and therefore, the probability of at least one success is:

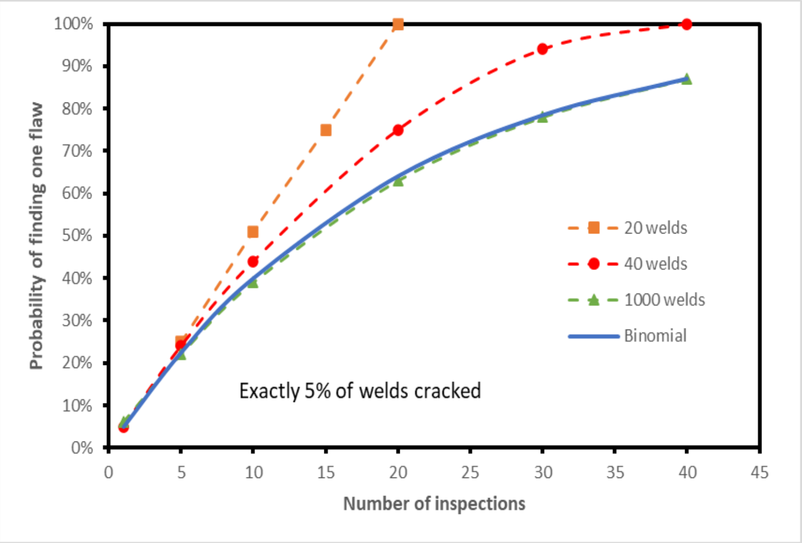
$$1 - f(n,p)$$

Monte Carlo Analysis

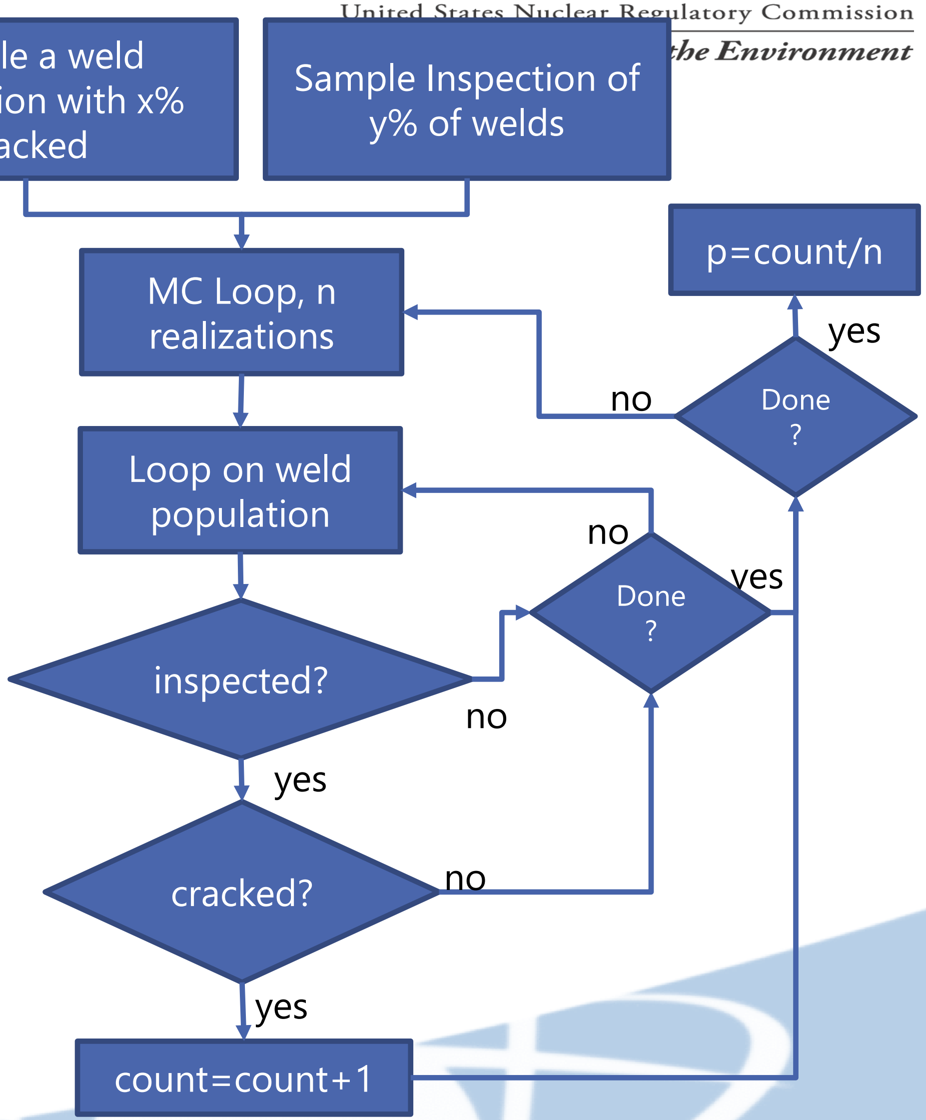
- Same idea can be developed through a MC analysis
- Allows maximum flexibility in analysis
- Binomial response can be recreated



For large populations



For small populations



Combining insights from Sampling Consideration slides with Sampling Analysis approaches allows for high quality proposals in performance monitoring space

Take Aways

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- RIMA Project aims to build forward from RG 1.174 and similar guidance in materials engineering specific language
- Focus is on non-integrated (e.g., NRC materials engineer reviewer only) submittals
- Guidance on all five Principles of RIDM to be translated and extended
- Tier List and Sampling Considerations provide increased domain specific granularity of guidance

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