Enhancing Risk-Informed and Performance-Based Used Fuel Storage

What Can We Glean from Recent Advances in Seismic Design Concepts for Nuclear Power Plants

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June 7, 2023

What do We Mean By Risk-Informed

Let's see what ChatGPT says:

Risk-Informed: The risk-informed approach involves using risk assessments and analysis to inform decision-making processes. It recognizes that all activities carry some degree of risk and aims to understand and manage those risks effectively. **Instead of relying solely on prescriptive rules and regulations, risk-informed approaches consider the probability and consequences of potential hazards or failures to make informed decisions**.

By utilizing risk assessments, organizations can identify, prioritize, and allocate resources based on the level of risk associated with different scenarios. Risk-informed approaches allow for **a more nuanced understanding of risks, enabling stakeholders to make informed choices that balance safety, cost-effectiveness, and other factors.**

What do We Mean By Performance-Based

<u>Performance-Based:</u> Performance-based approaches **focus on achieving desired outcomes or objectives rather than prescribing specific methods or requirements.** Rather than dictating how to achieve a goal, performance-based approaches provide flexibility, allowing stakeholders to choose the best means to meet the specified performance criteria.

In a performance-based approach, **the emphasis is on defining clear objectives, performance measures, and performance criteria**. This allows for innovation and adaptation, as different strategies can be employed to meet the desired performance level. It encourages a more efficient use of resources and fostering continuous improvement.

How Do They Work Together

When combined, risk-informed and performance-based **(RIPB)** approaches offer **a framework for decision-making** that considers both the level of risk associated with different options and the desired performance outcomes of these options.

➢ **This requires a change in approach**

- **Move away** from overly prescriptive requirements (*make it this thick, this high, this deep, this hard, use this material, maintain it according to this schedule)*

- **Move toward** arrangements that focus on the decision-making process itself (*holistic views*, *cost-benefit analyses, adaptability, negotiation, consensus, safety envelopes).*

How To Get There

Develop and implement a **structured and formal assessment process** that integrates the requisite constituents (e.g., **design, construction, safety, cost, operation, maintenance, community, regulator**) into RIPB decisions that are objective, robust, and transparent.

Take a practical approach that (mostly) **uses existing risk assessment and performance analysis tools** that help us categorize and simplify these assessments.

Outline

1. Describe some **examples of established formalized decision-making processes** that have been successfully implemented in the commercial nuclear power plant world.

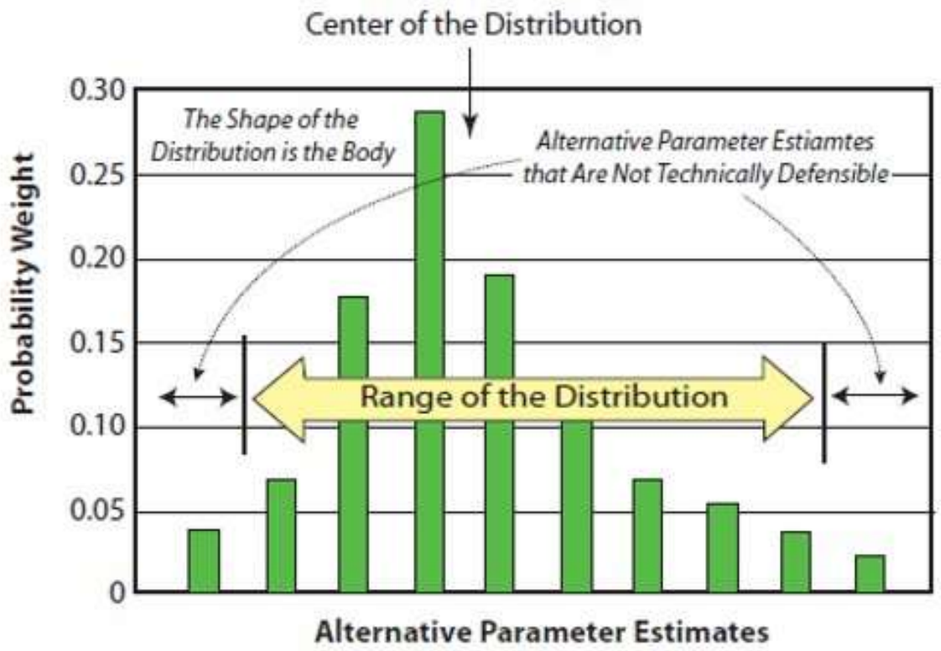
2. **Summarize the proposed RIPB processes** for seismic design of advanced reactors described in Stamatakos et al., (2022).

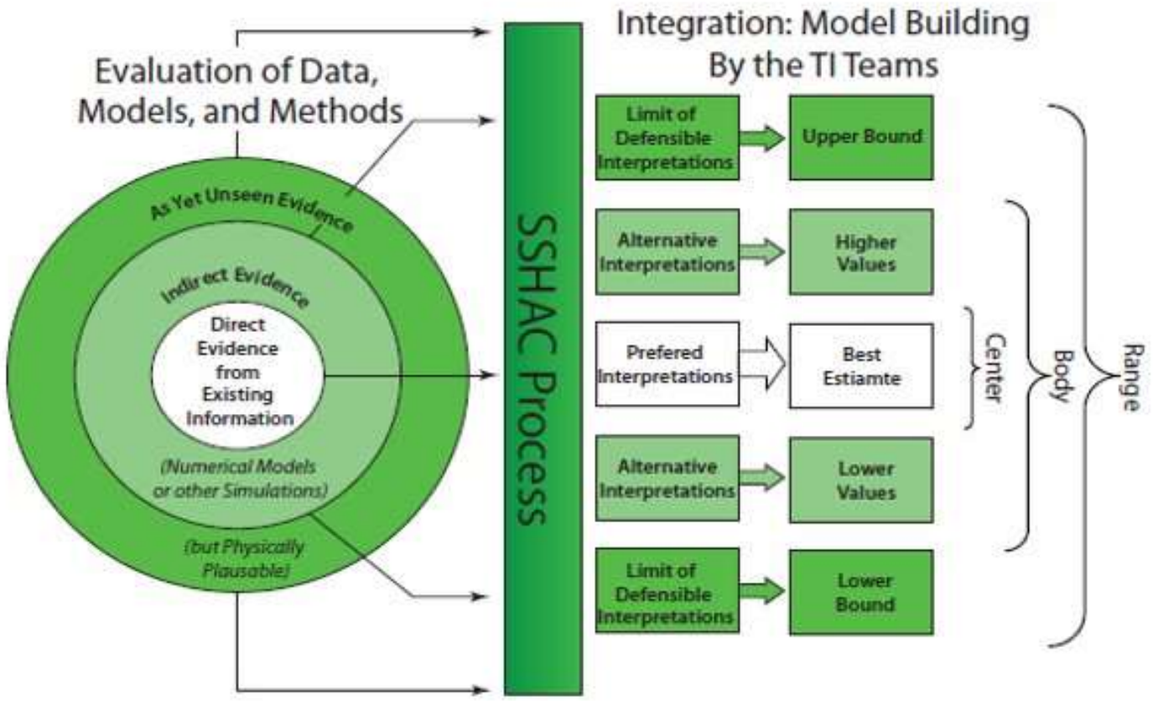
3. Have a **discussion with all y'all** on how we can leverage these ideas and concepts into an enhanced RIPB approach for used fuel storage.

(*Stamatakos et al., 2022, Proposed Enhancements to the Risk-Informed and Performance-Based Regulatory Framework for Seismic Hazard Design at NRC-Regulated Nuclear Power Plants. Nuclear Science and Engineering, https://doi.org/10.1080/00295639.2022.2158701*

Senior Seismic Hazard Analysis Committee (SSHAC)

SSHAC is a formal and structured process to elicit expert judgement and reach consensus among experts. It is designed to achieve a well-documented hazard study that captures the center, body, and range of technically defensible interpretations.



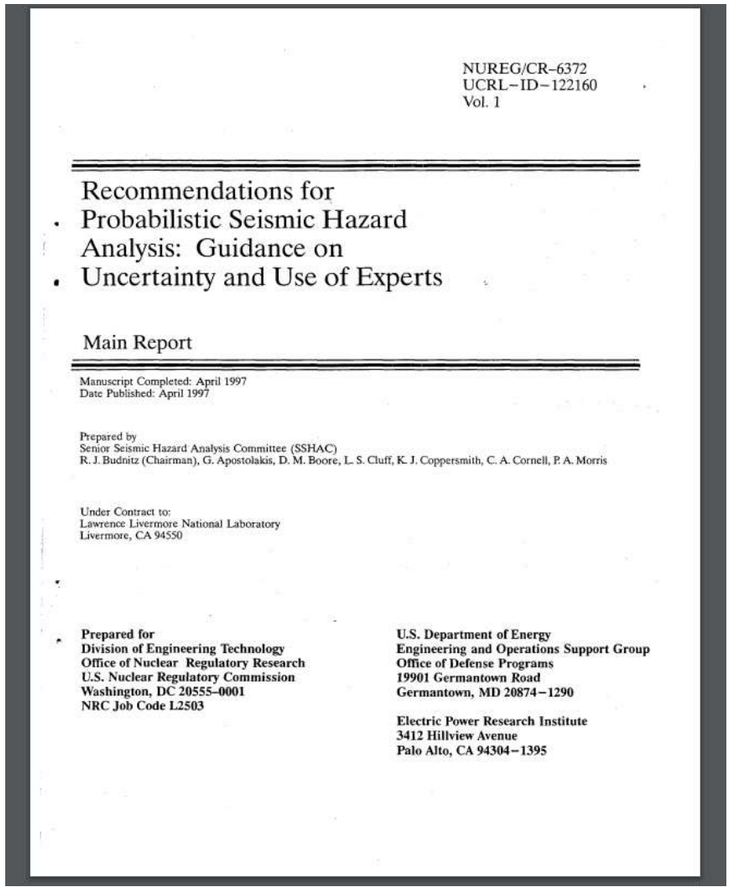


Why was SSHAC Developed

- SSHAC arose because of significant differences in Probabilistic Seismic Hazard Analysis (PSHA) results from two separate studies in the 1980s.
  - Electric Power Research Institute-Seismicity Owners Group (*EPRI-SOG, 1988, 1989*).
  - Lawrence Livermore National Laboratory (LLNL) (*Bernreuter et al., 1989*).

- The specific goals of the original SSHAC were to ensure that:
  - The PSHA is based on **unbiased interpretations** of available data, models, and methods.
  - The study explicitly identifies and evaluates **uncertainties and variabilities**.
  - The PSHA incorporate these uncertainties and variabilities in the **composite measure of uncertainty in the results**.

SSHAC Documentation



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Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on Uncertainty and Use of Experts

Main Report

Manuscript Completed: April 1997
Date Published: April 1997

Prepared by
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U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

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Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies

Manuscript Completed: May 2011
Date Published: April 2012

Prepared by:
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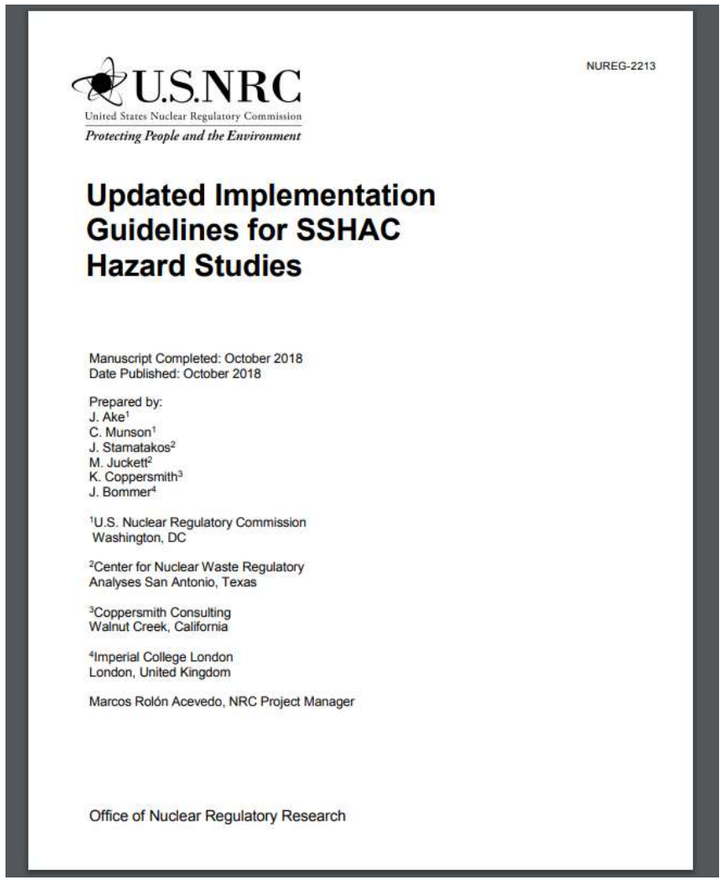

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Protecting People and the Environment

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Updated Implementation Guidelines for SSHAC Hazard Studies

Manuscript Completed: October 2018
Date Published: October 2018

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NUREG-2117

NUREG-2213

Five Essential Elements of SSHAC

1. **Clearly Defined Roles** for all participants.
2. **Objective Evaluation** of all available data, models, and methods that could be relevant to the characterization of the hazard at the site.
3. **Integration** of the outcome of the evaluation process into models that reflect both the best estimate of each element of the hazard input with the current state of knowledge and the associated uncertainty.
4. **Documentation** of the study with sufficient detail to allow reproduction of the hazard analyses.
5. **Independent Participatory Peer Review** to confirm that the evaluation considered relevant data, models, and methods, and that the evaluation was conducted objectively and without bias.
6. **Recognition of Cognitive Bias** that is inherent in all expert judgment processes in which there is significant uncertainty.

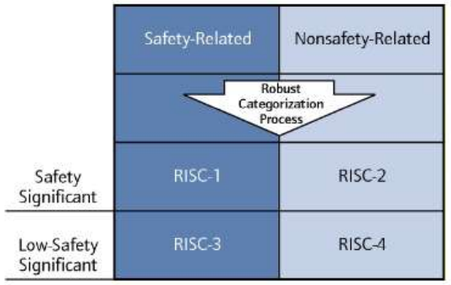
Other Examples of Structured Decision-Making Processes

Nuclear Services/Engineering Services

NRC 50.69 Rule Improves Safety and Saves Millions in O&M Costs

Background

On November 22, 2004, the U.S. Nuclear Regulatory Commission (NRC) amended its regulations by adding a new section to 10CFR50. Section 50.69, Risk-informed categorization and treatment of structures, systems and components for nuclear power reactors, provides an alternative approach for establishing the requirements for treating structures, systems and components (SSCs) for nuclear power reactors using a riskinformed method of categorizing SSCs according to their safety significance. This regulation relaxes requirements with respect to "special treatment" for safety-related SSCs that are low-safety significant. Special treatment requirements are those plant design and operational features that are required by regulations and that provide increased assurance (beyond normal industrial practices) that SSCs perform their design basis functions.



Risk Informed Safety Classification (RISC) Groupings

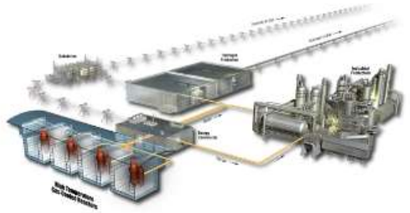
Integrated risk informed decision making

IAEA
International Atomic Energy Agency

INL/EXT-18-46151

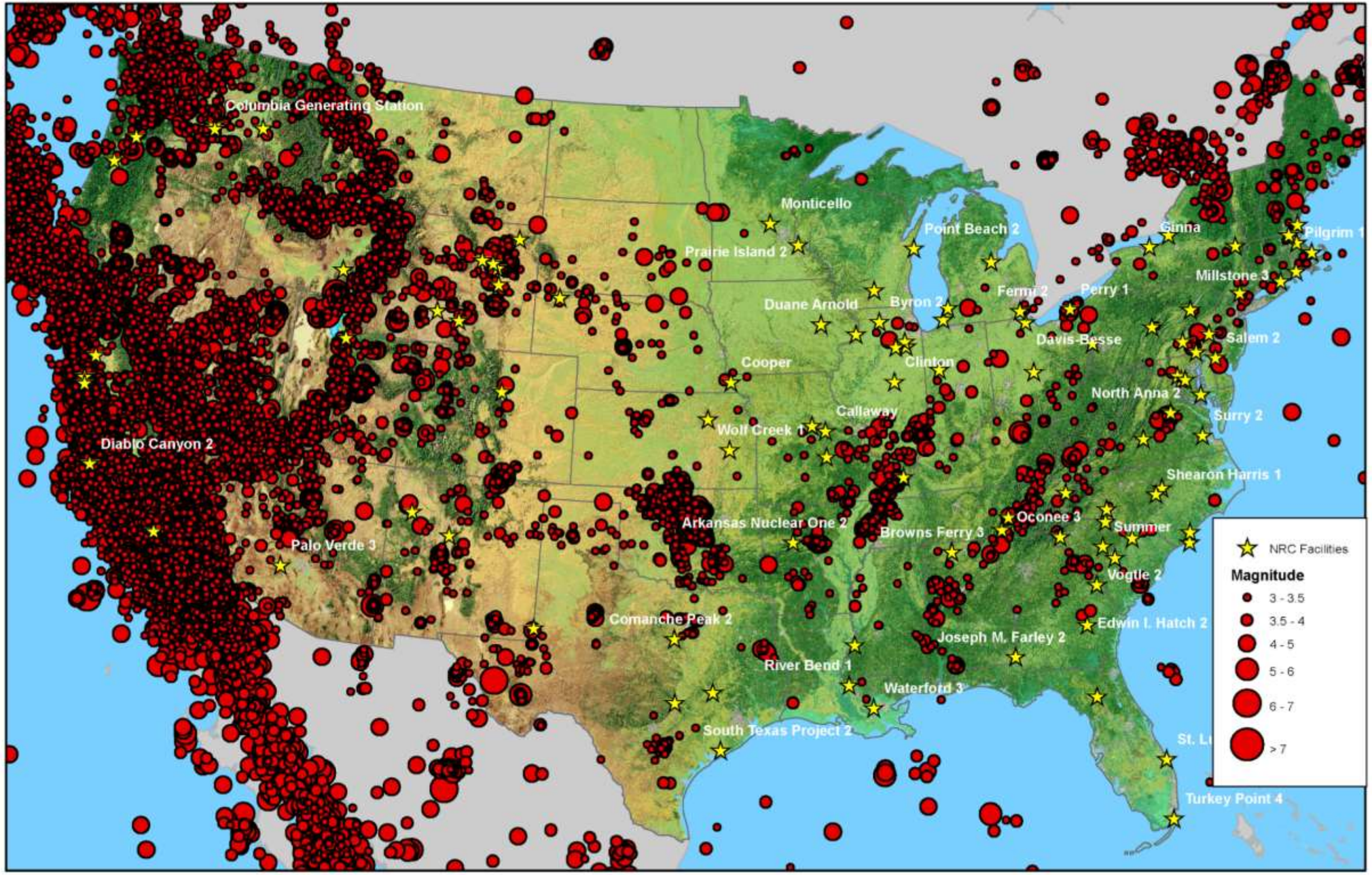
Licensing Modernization Project for Advanced Reactor Technologies: FY 2018 Project Status Report

September 2018



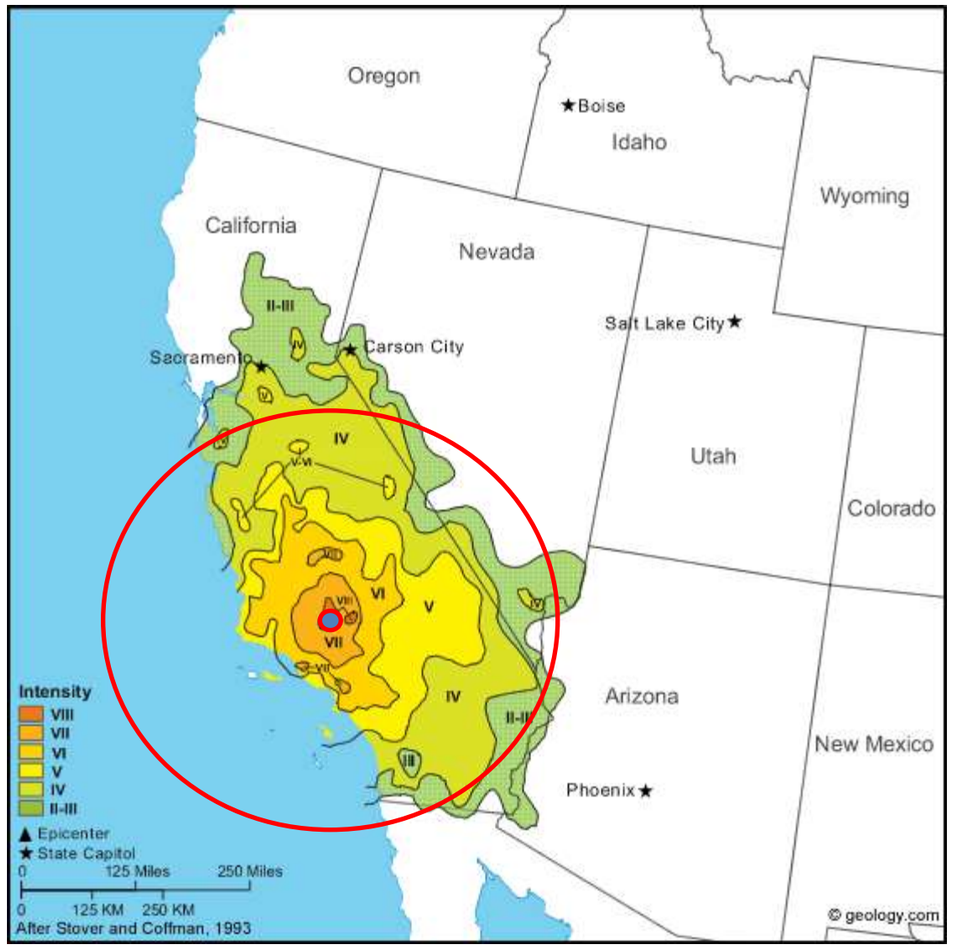
The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance

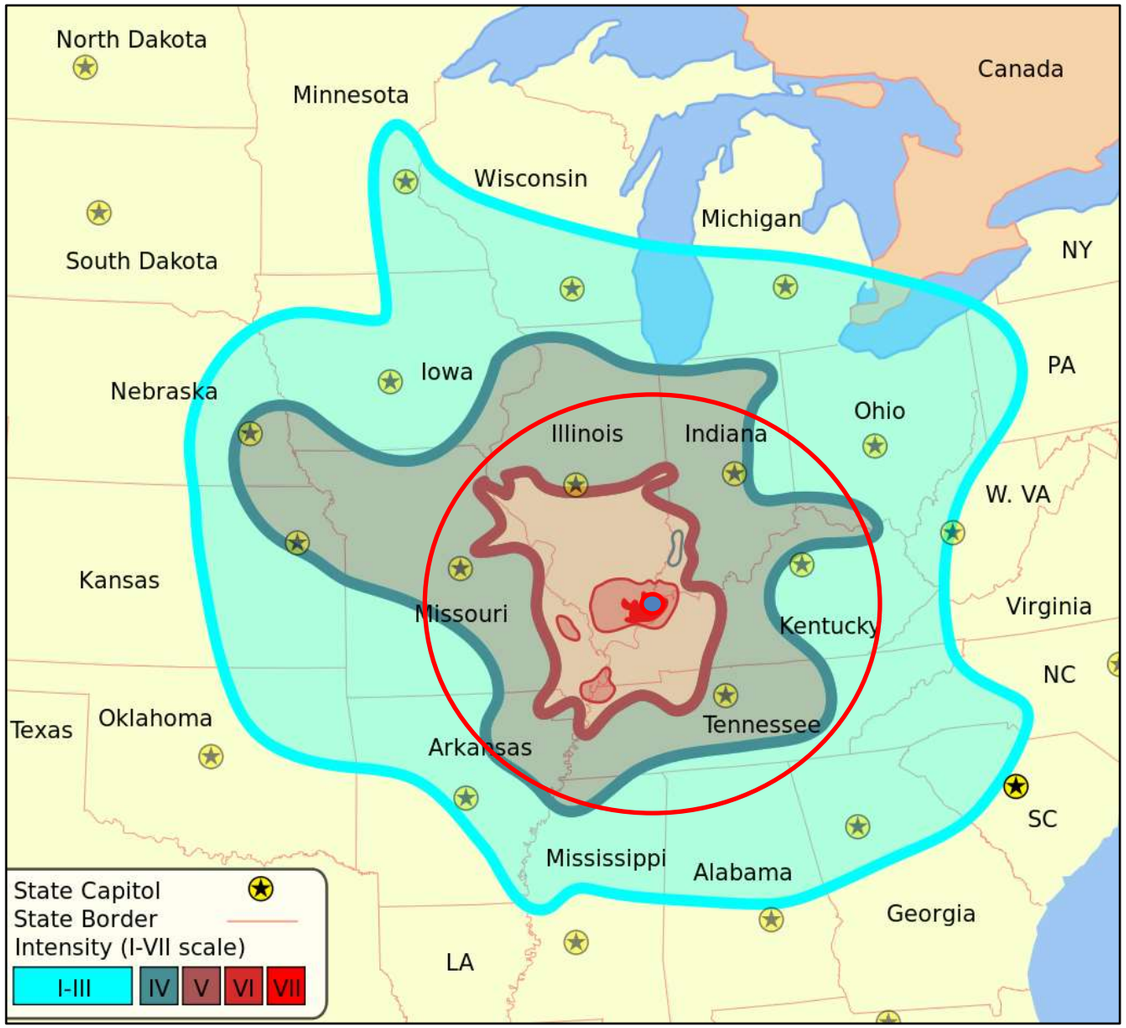
INL
Idaho National Laboratory


Columbia Generating Station
Monticello
Point Beach 2
Ginna
Pilgrim 1
Prairie Island 2
Millstone 3
Fermi 2
Perry 1
Duane Arnold
Byron 2
Davis-Besse
Salem 2
Cooper
Clinton
North Anna 2
Callaway
Wolf Creek 1
Surry 2
Diablo Canyon 2
Shearon Harris 1
Arkansas Nuclear One 2
Oconee 3
Browns Ferry 3
Summer
Palo Verde 3
Vogtle 2
Comanche Peak 2
Edwin I. Hatch 2
Joseph M. Farley 2
River Bend 1
Waterford 3
South Texas Project 2
Turkey Point 4
NRC Facilities
Magnitude
3 - 3.5
3.5 - 4
4 - 5
5 - 6
6 - 7
> 7
Miles
0
125
250
500
750
1,000

An Aside: Differences Between Eastern and Western US

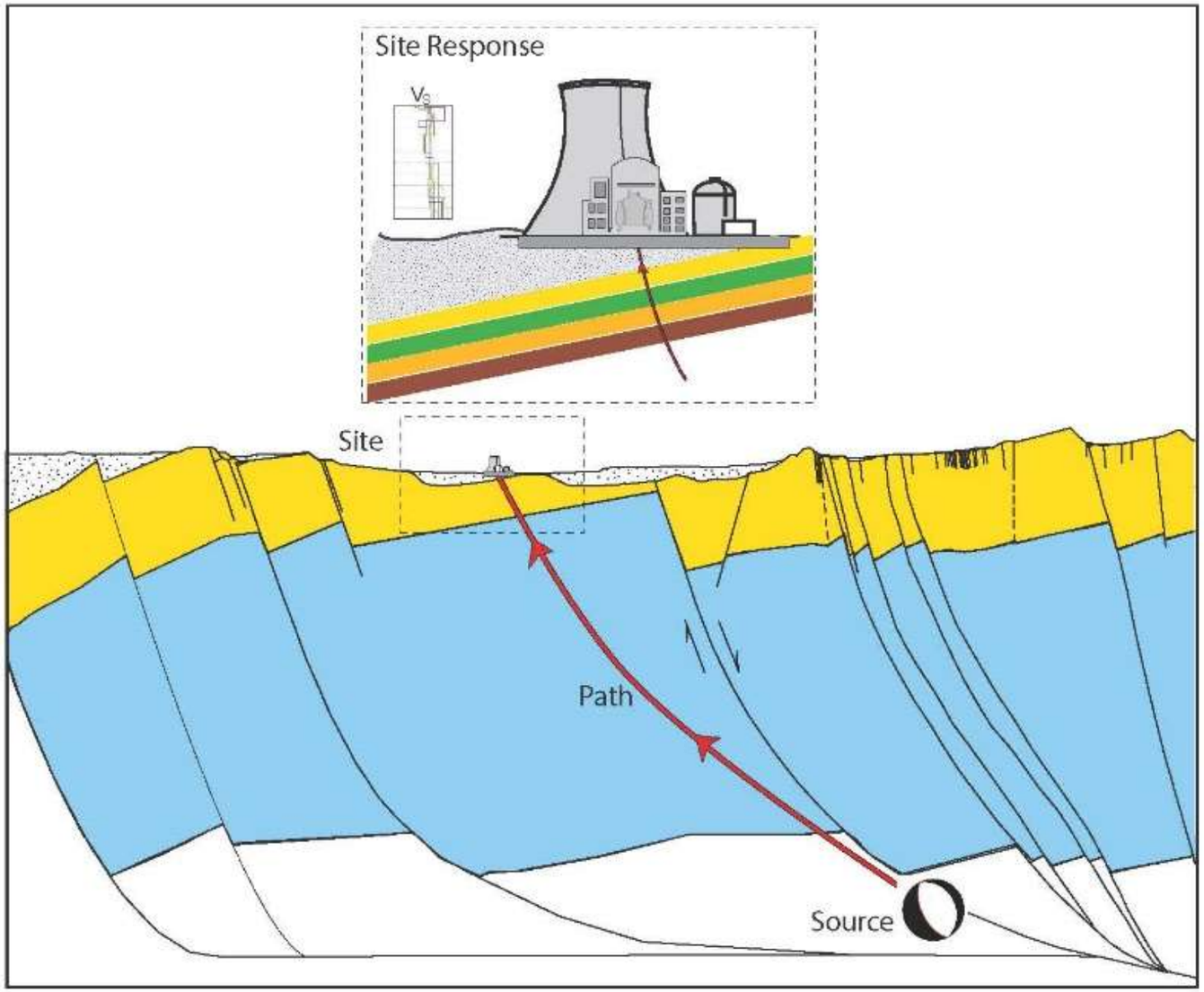
Kern County Earthquake - 7.3 - July 21, 1952





Illinois Earthquake - 5.4 – November 9, 1968

Components of a PSHA



Seismic Source Model (SSM):

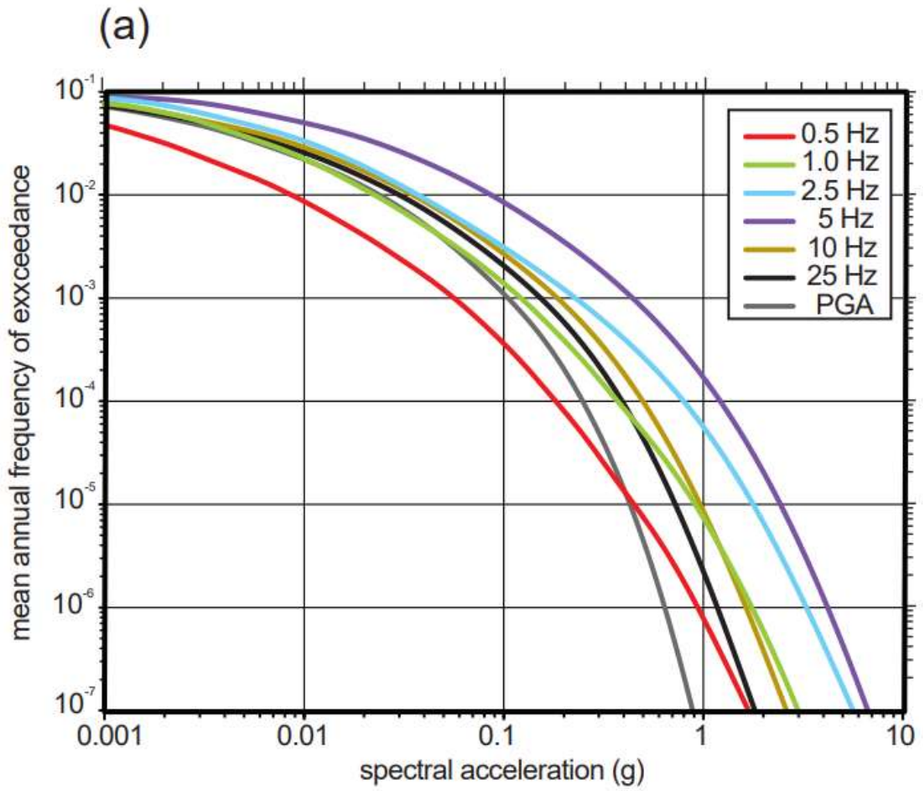
- predicts future earthquakes based on geological and seismological characteristics of the site and region
- how big, how deep, how far away, what flavor (normal, reverse, strike-slip), how frequent, and the uncertainties of these characteristics.

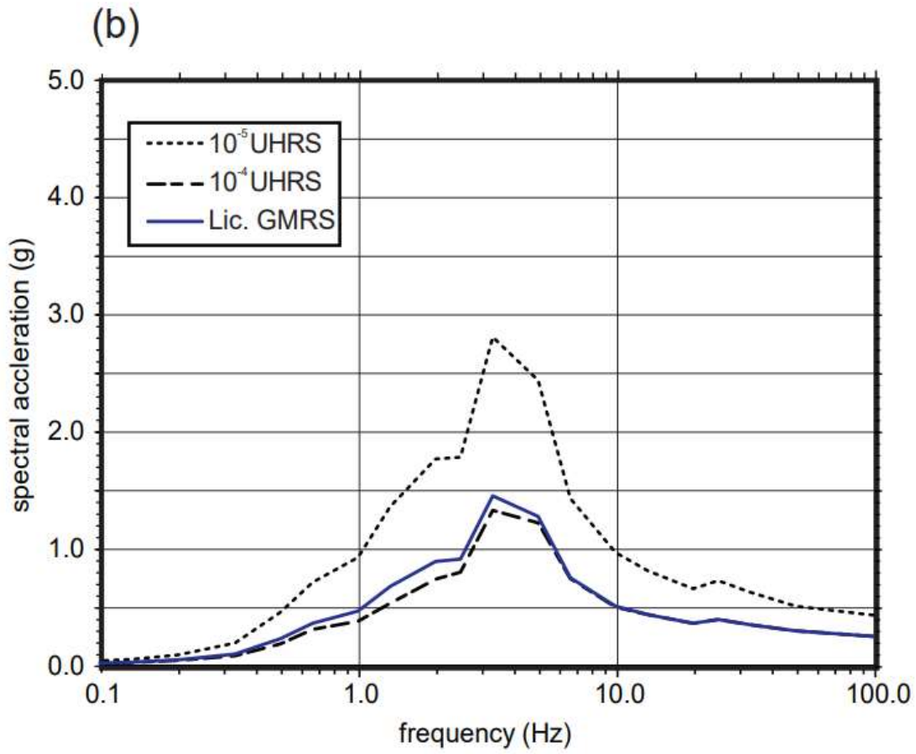
Ground Motion Model (GMM)

- predicts the ground shaking at the site based on seismological and geotechnical properties of the source, path, and site
- energy attenuation, impedance contrasts, damping, stress drop, and the uncertainty of these properties

Probabilistic Seismic Hazard Assessment (PSHA)

- PSHA results are a family of hazard curves developed for a range of spectral frequencies, usually between 0.5 Hz to PGA (100 Hz).
- For a single exceedance frequency, the results can be plotted as a uniform hazard response spectrum (UHS).

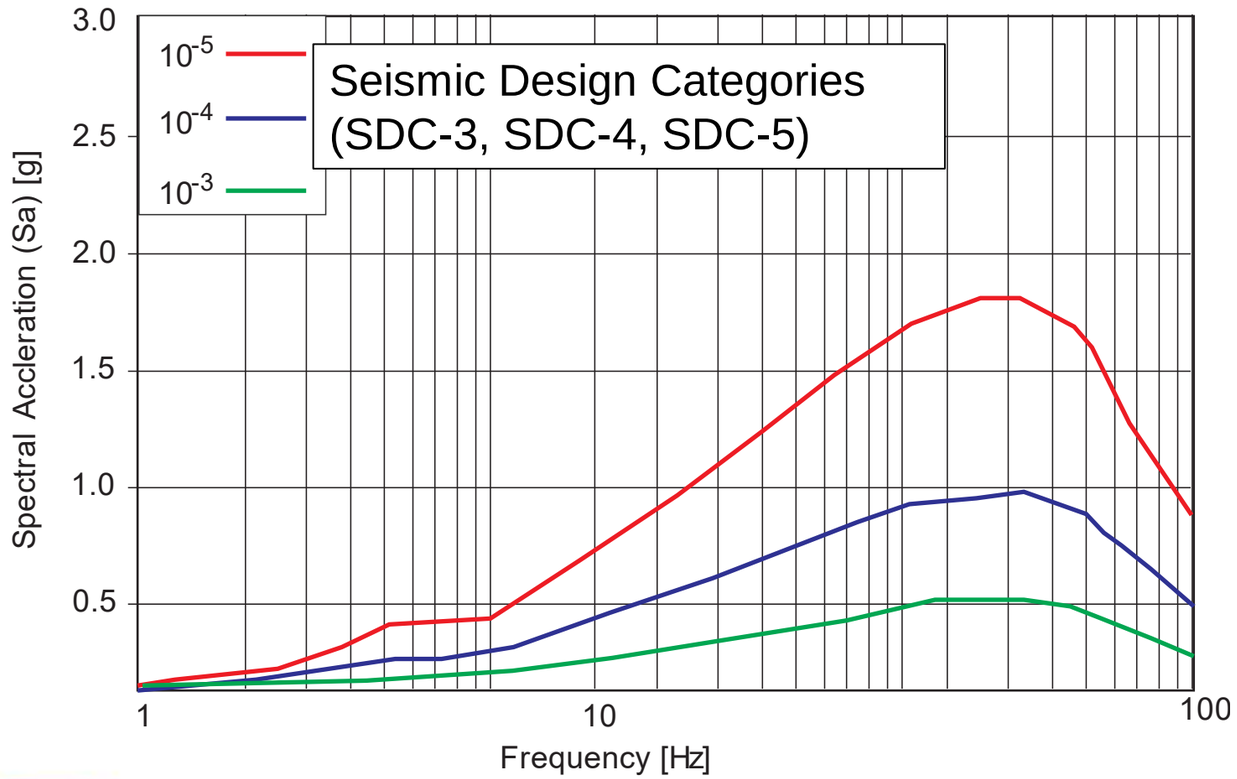




Graded Approach

- Under existing regulations, all structures, systems, components (SSCs) deemed important to safety in a NPP are designed SDC 5 and Limit State (LS) D.

- Under the proposed approach for advanced reactors, SSCs important to safety would be designed to one of three SDCs and LS-C or LS-D according to their contribution to the risk profile of the NPP.



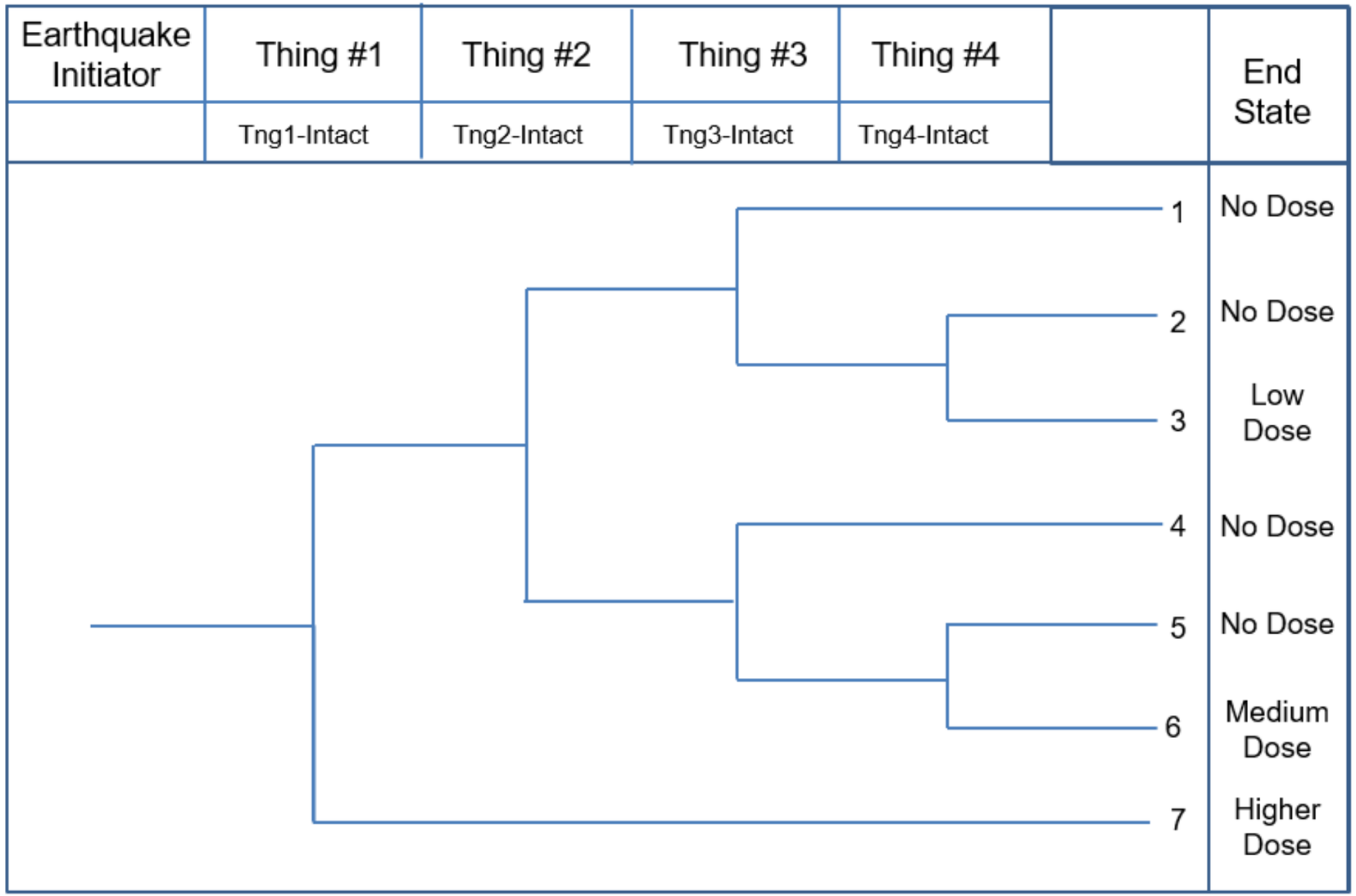
Limit State	Structural Deformation Limit
A	Large permanent distortion, short of collapse
	Significant damage
B	Moderate permanent distortion
	Generally repairable damage
C	Limited permanent distortion
	Minimal damage
D	Essentially elastic behavior
	Negligible damage

Risk Matrix Example of Graded Approach to Categorizing and Evaluating Risk

Consequences	Likelihood of Occurrence		
	Highly Unlikely	Unlikely	Likely
Low	Tolerable	Tolerable	Intolerable
Medium	Tolerable	Intolerable	Intolerable
High	Tolerable	Intolerable	Intolerable

An Aside: An Observation About Highly Unlikely and High Consequence Events.

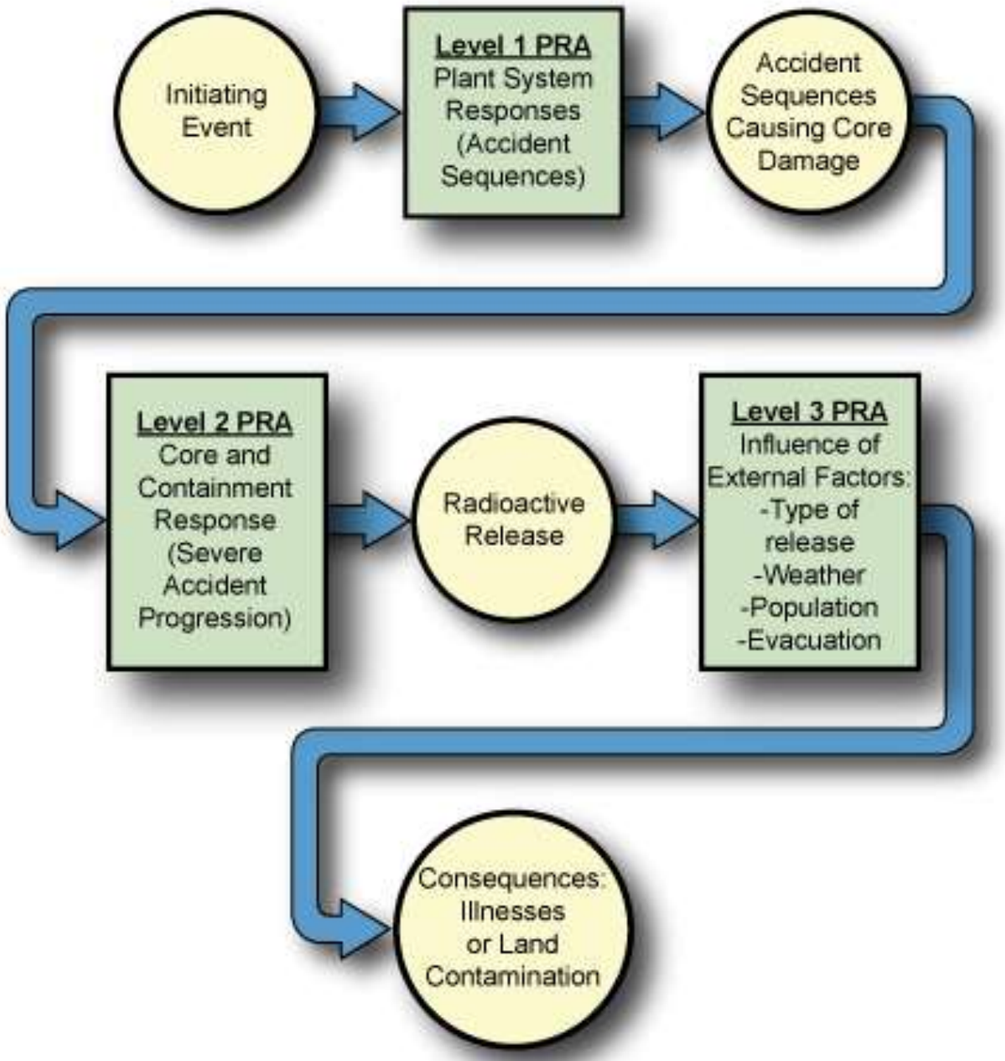
Integrated Safety Analysis



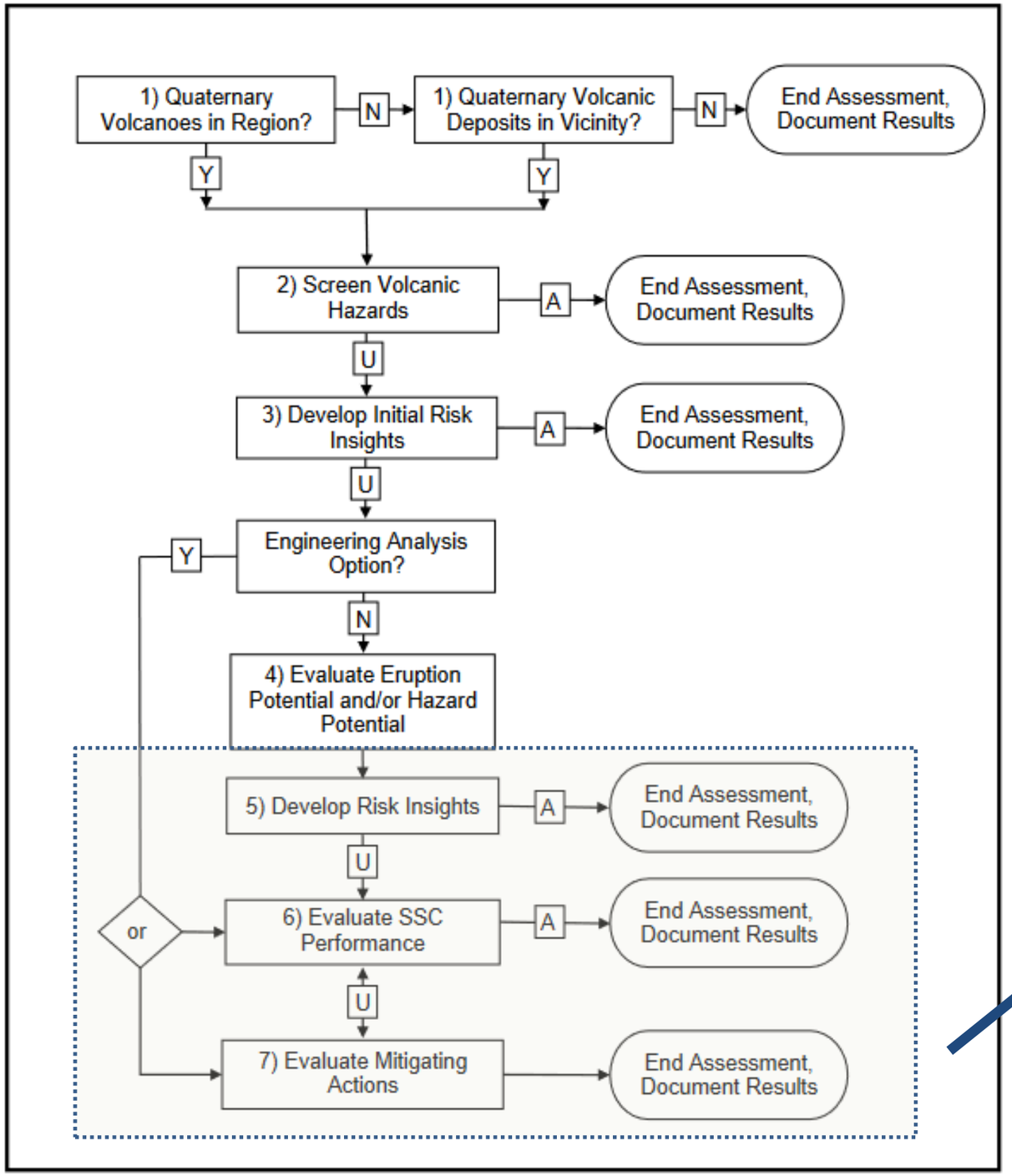
NRC. "Review Methodology for Seismically Initiated Event Sequences." Division of High- Level Waste Repository Safety, Interim Staff Guidance HLWRS–ISG–01. Washington, DC: NRC. 2006.

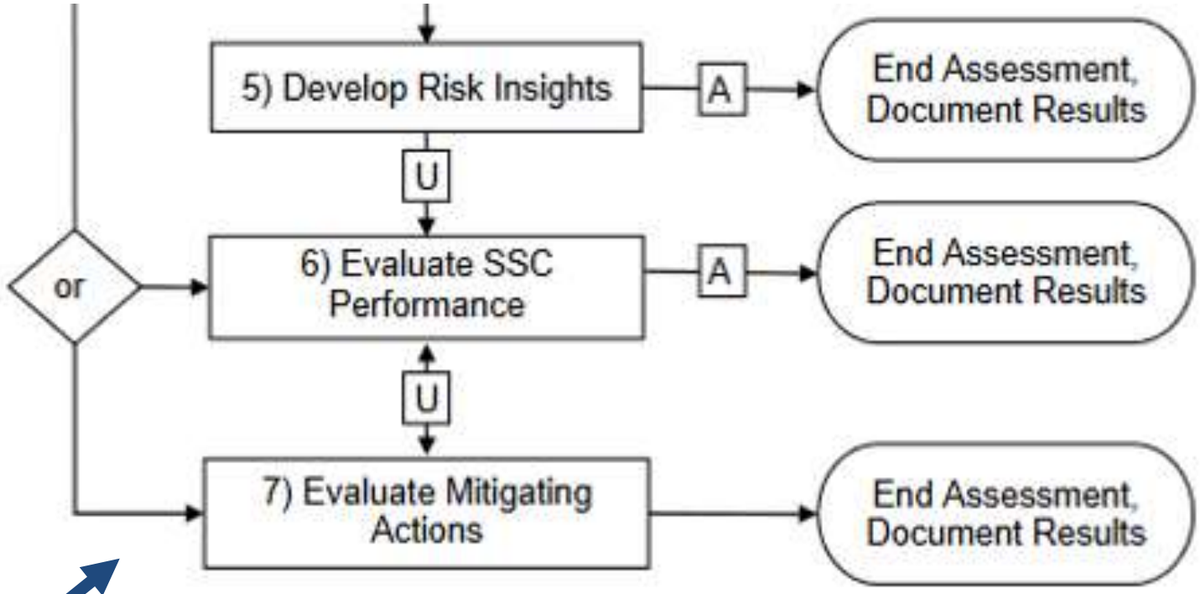
Other Tools in the RIPB Toolbox

- **Seismic Probabilistic Risk Assessment (SPRA)**
  - Levels 1, 2, and 3
  - For Level 1 need appropriate surrogates for consequences, e.g., core damage frequency (CDF) or likelihood of early release fraction (LERF).
- **Seismic Margins Analysis**
- **Graded PRA**
  - relies on an integrated decision-making process
- **Defense in Depth**
- **Cost Benefit Analysis**
- **Mitigation**



RG 4.26: Volcanic Hazards Assessment for Proposed Nuclear Power Rector Sites





How Might RIPB Apply Elsewhere?

Non-Seismic applications:

- Flooding
- Volcanic
- High winds/tornadoes
- Climate change considerations
- Terrorism
- Aging management/condition-based maintenance
- Transitions to digital

Non- Power Reactor Applications

- Used fuel storage
- Used fuel transportation
- Repository/disposal sites
- Low-level, TRU, GTCC wastes
- Advanced reactor wastes
- Reprocessing byproducts

Summary

- A risk-informed and performance-based (RIPB) approach requires **evaluation and integration** of varied and unequal information (some quantitative and some qualitative).

- Developing and regulating a more RIPB framework for used fuel will require:
  - A **formal and structured decision-making framework** that includes the necessary integrated constituents (e.g., design, construction, safety, cost, operation, maintenance, community, regulation).
  - Use and **adaptation of all the existing risk analysis tools** in the toolbox, including graded risks assessments, mitigation, defense-in-depth.
  - **Flexibility** in defining and assigning performance objectives

Let's Discuss

Do you use risk-informed, performance-based methods in your area? If so, how?

Thank You