Seismic Hazards and Risk at U.S. Nuclear Power Plants: An NRC Perspective

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Outline

- Background and Regulatory Framework
- NRC Activities and Codes/Standards
- Post-Fukushima Activities
- Seismic/Structural Research Plan
- Summary

Background

- Significant advancements in our understanding of seismic hazard processes have occurred since the existing fleet of reactors was licensed
  - Review of new reactor applications and Post-Fukushima seismic re-evaluations
- Evaluation of the impact of these changes on plant safety is not straightforward

Background (2)

History of Seismic Reevaluations

SEP	Systematic Evaluation Program	1977-1990	Limited seismic reassessment of older NPPs. Resulted from development of seismic building codes in the 1970s, changes in hazard assessment, and other improvements.
USI-A46	Unresolved Safety Issue-A46	1980s	Seismic operability of equipment in older NPPs. Resulted from development of seismic qualification of equipment. SQUG formed by industry. Assessment approaches developed.
IPEEE	Individual Plant Examinations for External Events	1990s	Evaluation at or beyond design loads. Generally qualitative with emphasis on risk insights. Resulted from increased awareness of potential for beyond DBE loads & advances in SPRA.
GI-199	Generic Issue-199	2005-2012	Assess implications of updated seismic hazard estimates in the CEUS. Resulted from ESP applications at co-located NPPs
NTTF R2.1	Near Term Task Force Recommndation2.1	2012-Ongoing	Reevaluation of seismic and flood hazard and risk as one of many recommendations in the NTTF report published after the Fukushima Daiichi accident.

Regulatory Motivations

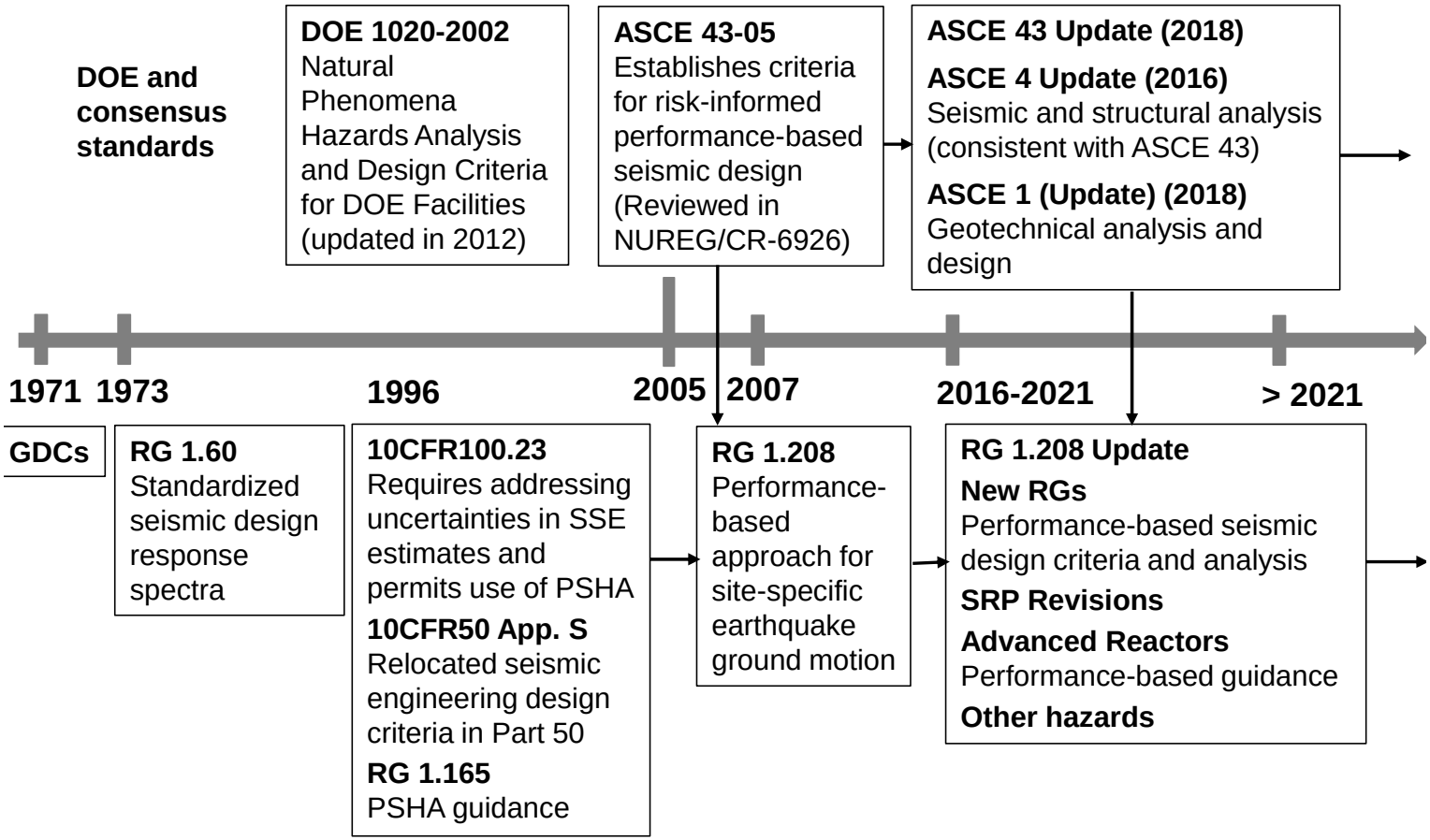
- These re-evaluations were in response to:
  - Increased scientific knowledge regarding seismic sources and associated ground motions
  - The Commission's 1985 *Severe Accident Policy Statement* (SECY-86-162)
  - The Commission's Policy on Probabilistic Risk Assessment (FRN, 1996).
  - These re-evaluations and generic issues have been accompanied by industry, DOE, and NRC research programs
- To address lessons-learned from recent licensing reviews and safety assessments (new reactors, licensing amendments, and post-Fukushima safety re-assessments of operating reactors)
- Informing periodic seismic hazard re-evaluations and, as needed, review of ongoing seismic re-evaluations (SECY-15-137).
- Assessing the safety implications of new knowledge

Regulatory Drivers, Objectives and Scope

<u>Important Drivers and Outcomes</u>:

- Continue to advance the potential for risk-informed and performance-based (RIPB) approaches to regulation of seismic and structural safety for nuclear facilities.
  - Update NRC guidance (regulatory guides (RG) and Standard Review Plan) for seismic design and analysis.
  - Incorporate RIPB philosophy to align with developments by the design community, industry (Standards Development Organizations) and other external stakeholders
- Facilitate extending or updating the regulatory framework to designs other than large LWRs (NLWRs) in a manner that minimizes technology-specific aspects
- Supporting subsequent license renewal (SLR) (SECY-14-016) and long-term operations (LTO)

Evolution of Performance-Based and Risk-Informed Seismic Design



Seismic Codes and Standards: Relationship to NRC Activities

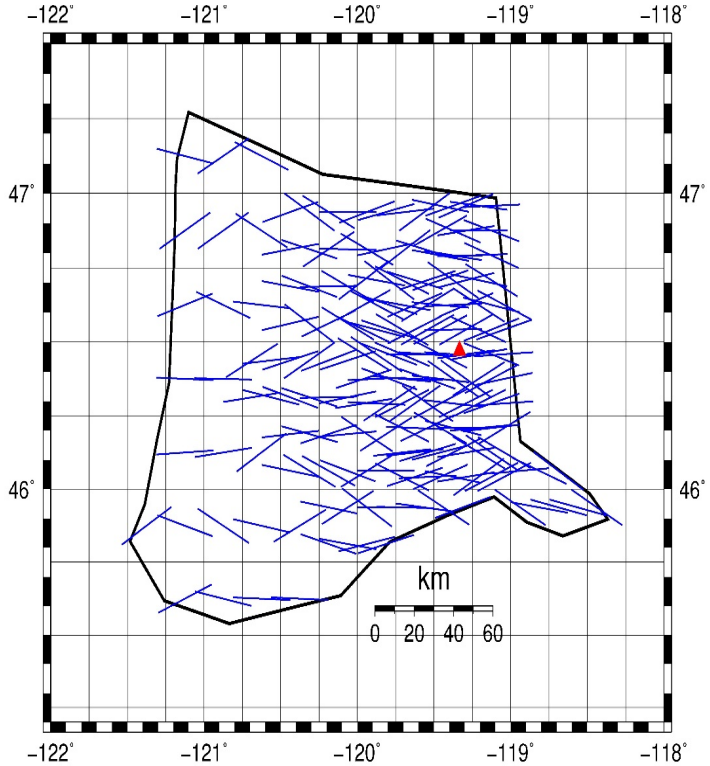
- NRC staff involved in relevant codes and standards development
  - Risk-informed Performance-based Seismic Design Criteria (ASCE 43---impact on RG 1.208 update)
  - Seismic Analysis for Risk-informed Performance-based Design (ASCE- 4, 43, and 1–-- impact on seismic analysis RGs and SRP)
    - Includes geotechnical analysis/design and SSI
  - ASME/ANS PRA Standard
  - Performance-based Approach for Seismic Design of Non-LWRs
  - Seismic Hazard Evaluation (ANS-2.26, 2.27, and 2.29--- impact on RG 1.208 update and SRP)

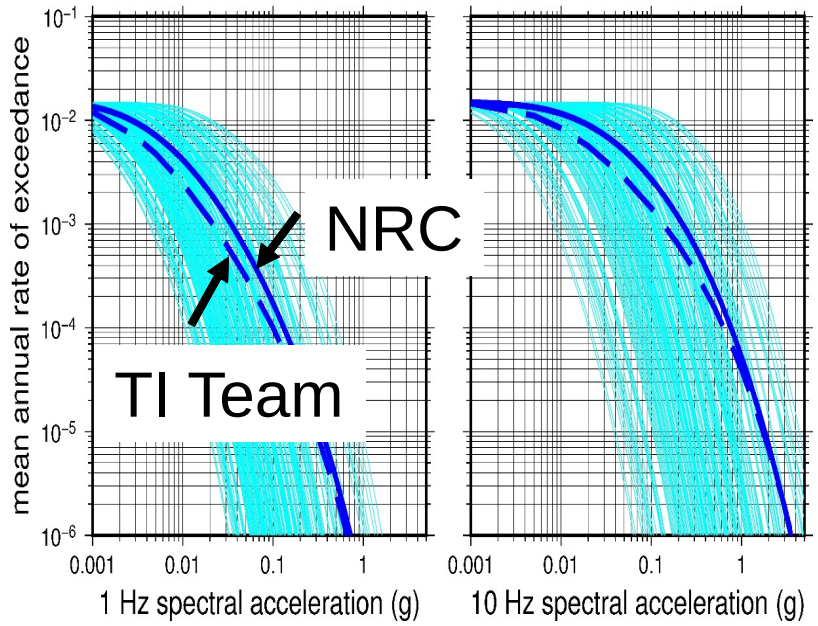
Insights from Fukushima NTTF R2.1 Process

- NRC staff reviewed licensee submittals and performed detailed independent confirmatory analyses for more than 50 plant sites (~90 reactors)
  - Plants located in the Central and Eastern U.S. relied on consensus regional models (CEUS-SSC and EPRI GMM)
  - Western U.S. plants performed site-specific hazard analyses
  - All developed following Senior Seismic Hazard Analysis Committee (SSHAC) guidelines
- For CEUS plants: completely independent analyses performed
- For WUS plants: selective evaluation of hazard significant elements of models

WUS Example: PSHA Confirmatory- YFTB Host Source Zone

- Developed 0.25° Grid
- Place 204 virtual faults in source zone
- Randomly orient between N60°E and N120°E (F_{rev})
- M_{max}=6.8 & uniform rate
- Truncated exponential MFD
- Run hazard for each virtual fault



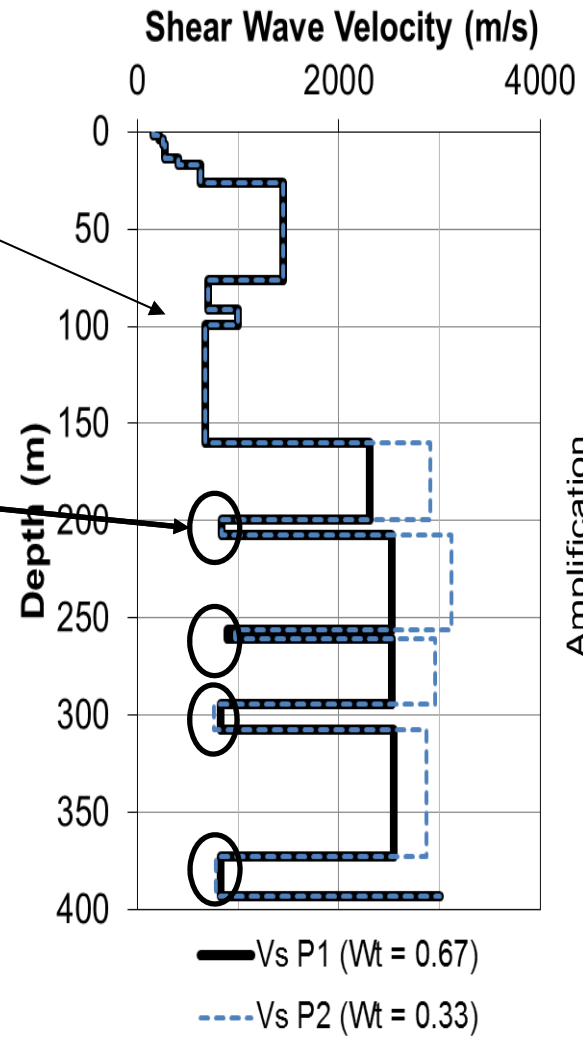


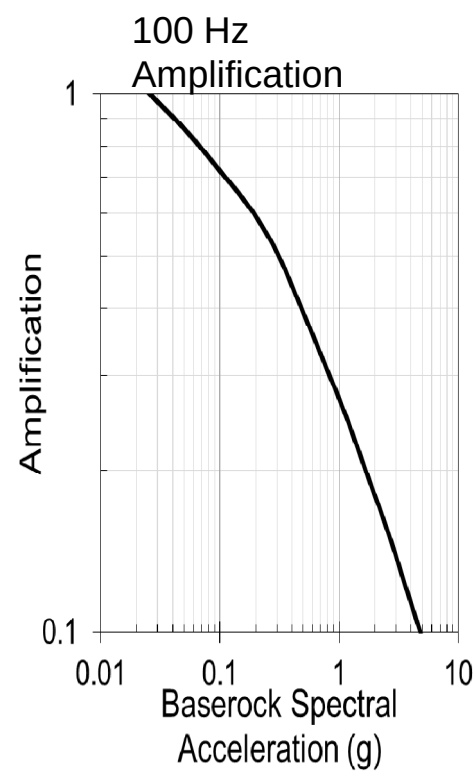
Example: NRC Staff's Site Response Sensitivity Analyses

- Epistemic uncertainty for upper base-case V_S profile-

  Evaluate-
  - Single vs. multiple profiles
- Sedimentary interbeds within Saddle Mtn. Basalts

  Evaluate-
  - Interbed dynamic properties
  - Potential absence of interbeds





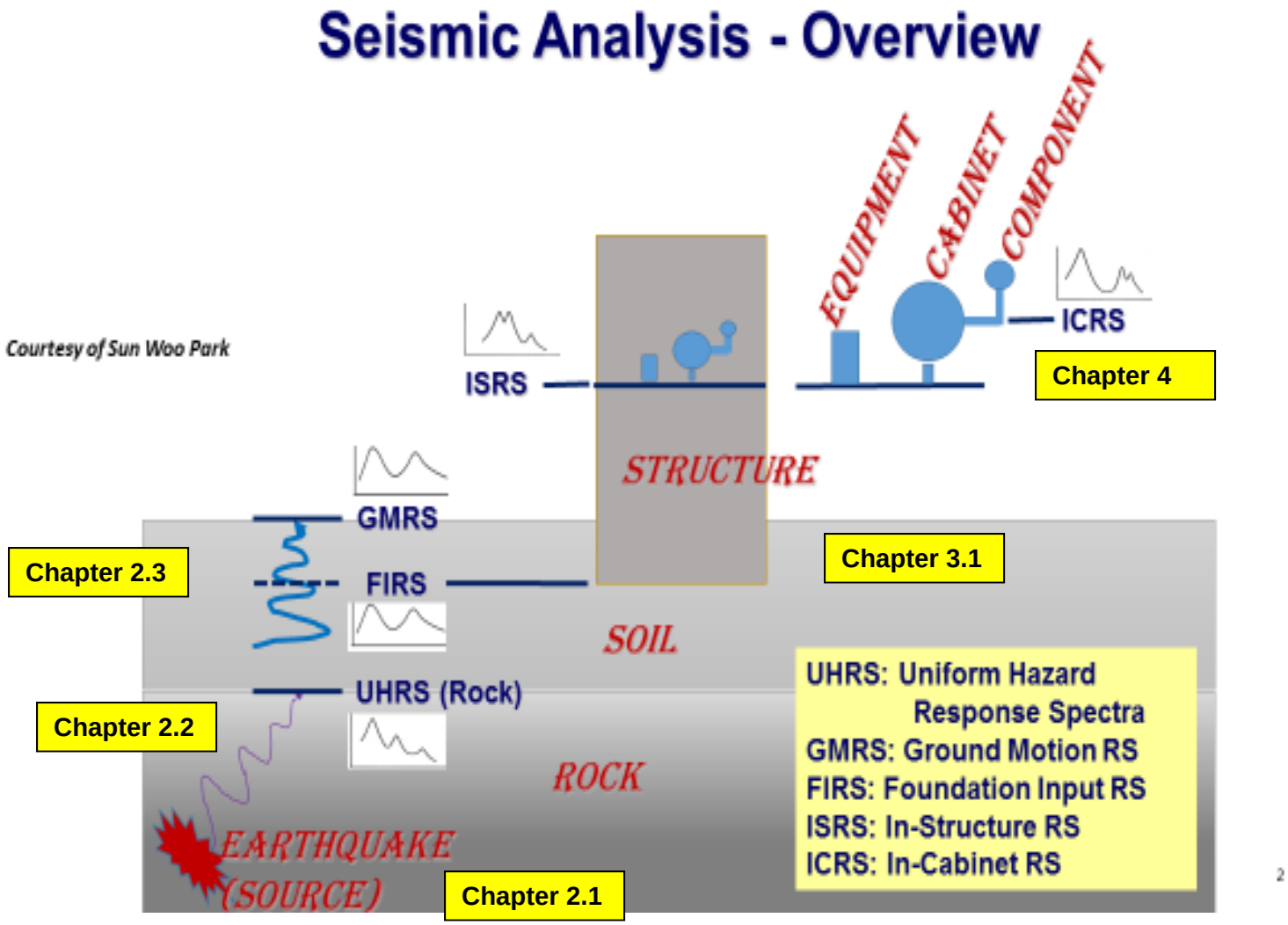
Insights from Fukushima NTTF R2.1 Process (2)

- New reactor reviews and post-Fukushima NTTF R2.1 re-evaluation process have identified issues:
  - Systematic incorporation of uncertainty into site response analysis
  - Use of multiple approaches to characterize site kappa
  - Use of Method 3 to develop final hazard curves
  - Use of partially non-ergodic sigma for WUS sites
  - Use of new approaches to capture range of median GMPEs
  - Use of site (Vs-kappa), source, and path adjustments for median GMPEs
- These issues have been incorporated into the updated version of the NRC Seismic Research Plan.

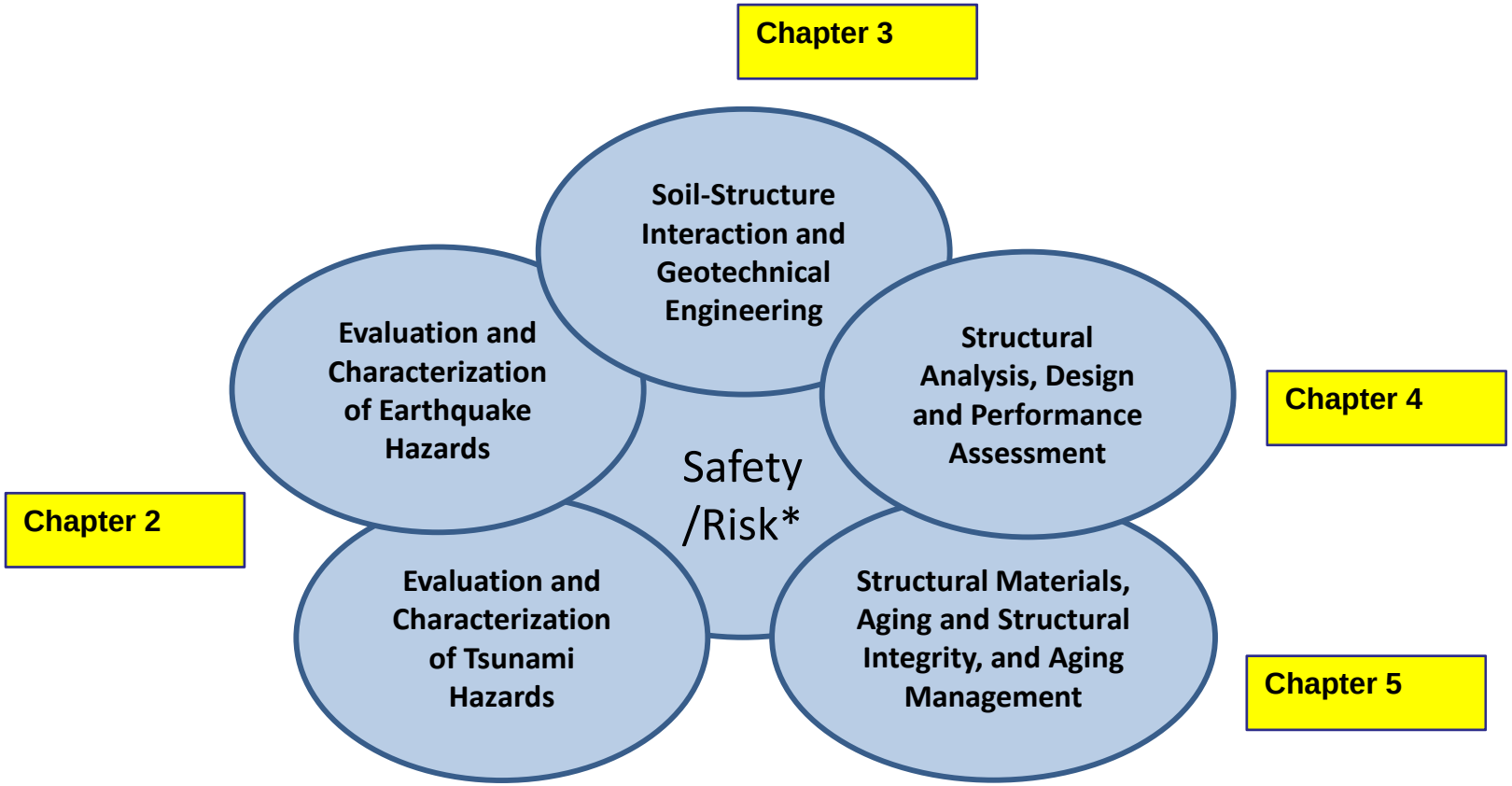
Seismic, Geotechnical and Structural Engineering Research Plan (SGSERP)

- A comprehensive, integrated plan across disciplines
  - Recognizes inter-relationships and dependencies between projects, subject areas, and standards development organizations
- Significant interaction with technical staff in NRC user offices and external stakeholders/entities in development of plan
- Plan continues development of tools and processes to support application of performance-based and risk-informed approaches to design and safety assessment
- Also addresses other current or anticipatory issues
  - (Subsequent License Renewal, Long-term Operations, Repair)

SGSERP- Contents



SGSERP: Relationship of Activities

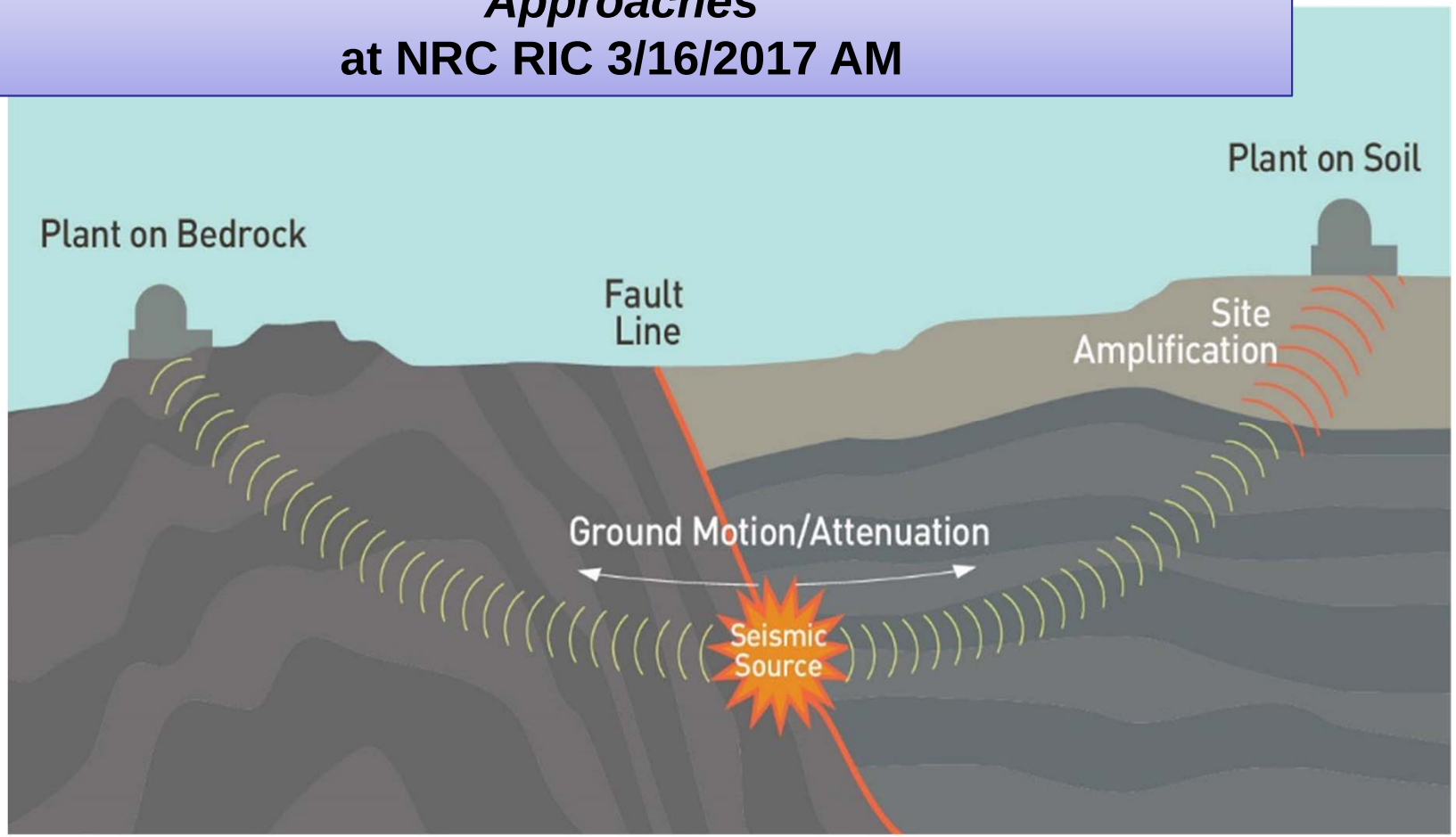


Summary

- Significant advancements in our understanding of seismic hazard processes have occurred since the existing fleet of reactors was licensed
  - These advancements pose regulatory challenges
  - Implementation of PBRI processes help to address these challenges
- Process implemented for NTTF R2.1 utilizing current regulatory framework provides a risk-informed method to evaluate the potential safety significance of these changes.
  - Provides transparent “linkage” to NTTF R2.2 which requires periodic re-assessment of natural hazards
- A number of important future research objectives have been identified as a result of Fukushima response
- The SGSERP contains research projects to address many of these issues

QUESTIONS?

Please Note: Upcoming session on *Seismic Safety: RIPB Approaches* at NRC RIC 3/16/2017 AM



Integration of SGSERP Topics