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A Reassessment of Seismic Hazards and Risk at Nuclear Power Plants in the U.S.: An NRC Perspective

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U.S. Nuclear Regulatory Commission
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Outline

- Background and Regulatory Framework
- Generic Issue 199
- Fukishima Task Force
- Implementation
- Summary

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Background

- Significant advancements in our understanding of seismic hazard processes have occurred since the existing fleet of reactors was licensed.
- New data has been acquired and models have been developed in the past 30+ years that suggest significant differences in assumptions relative to those used in licensing of existing fleet.
- Evaluation of the impact of these changes on plant safety is not straightforward.

Applicable Regulations (pre-1997)

- **10 CFR 100.10(c)(1) and Appendix A establish the seismic design basis (Safe Shutdown Earthquake-SSE) for plants licensed before January 10,1997 (i.e., currently operating plants):**
  - **Based on a review of earthquakes that have occurred nearby the site**
  - **A deterministic approach- no specification of frequency of occurrence**
  - **Different approach than probabilistic seismic hazard assessment (PSHA)**
- 10 CFR Part 50, Appendix A, General Design Criteria (GDC-2) and similar principle design criteria require that structures, systems, and components (SSCs) be designed to withstand the effects of natural phenomena without loss of capability to perform their safety functions:
  - **Appropriate consideration of the most severe of the natural phenomena that have been historically reported for the site and surrounding area**
  - **Include sufficient margin for the limited accuracy, quantity, and period of time in which the historical data have been accumulated**
- No requirement for periodic reassessment of the seismic design basis.

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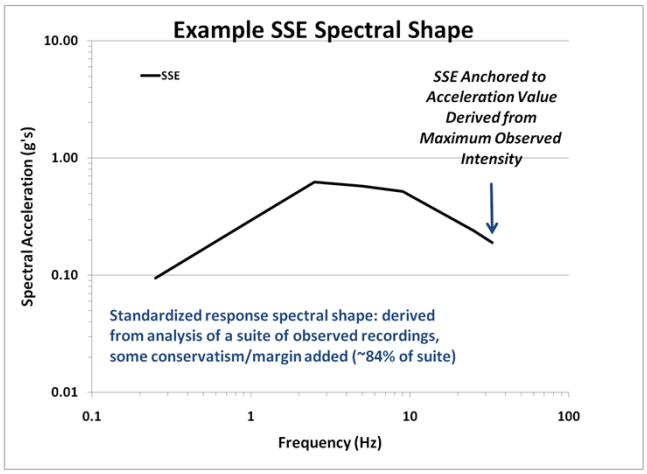
Safe Shutdown Earthquake -SSE

(Ground Motion)



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Applicable Regulations (post-1997)

- **10 CFR 50, 100.23 and Appendix S establish the seismic design basis for plants licensed after January 10,1997:**
  - Appendix S defines SSE as *"Safe-shutdown earthquake ground motion* is the vibratory ground motion for which certain structures, systems, and components must be designed to remain functional"
  - 10 CFR Part 100.23 "Geologic and Seismic Siting Criteria" requires that the applicant determine the SSE **and its uncertainty**, the potential for surface tectonic and nontectonic deformations.
- Regulatory Guide 1.208 provides guidance on satisfying 10 CFR Part 100.23, by performing a probabilistic seismic hazard assessment (**PSHA**). Determine (ground motion response spectrum-GMRS) SSE using the performance-based approach. Specifies target frequencies of exceedance linked to performance goals.
  - Different approach than deterministic Appendix A process:
    - **PSHA is a major input to seismic risk evaluation using SPRA or** SMA
- No requirement for periodic reassessment of the seismic design basis.

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Comparisons of GMRS with SSE

- Staff compared the ground motion response spectrum (GMRS) from Early Site Permits (North Anna, Clinton, Grand Gulf) with SSEs for co-located operating units
- Comparison resulted in initiation of **Generic Issue-199 (“*Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants”)***
- Comparisons with subsequent applications (COLs and ESPs) confirmed initial observations

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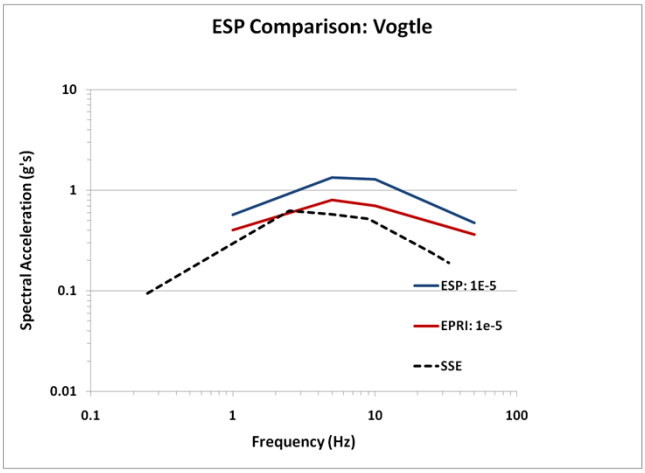
GI-199: Observations From Early Site Permit Reviews



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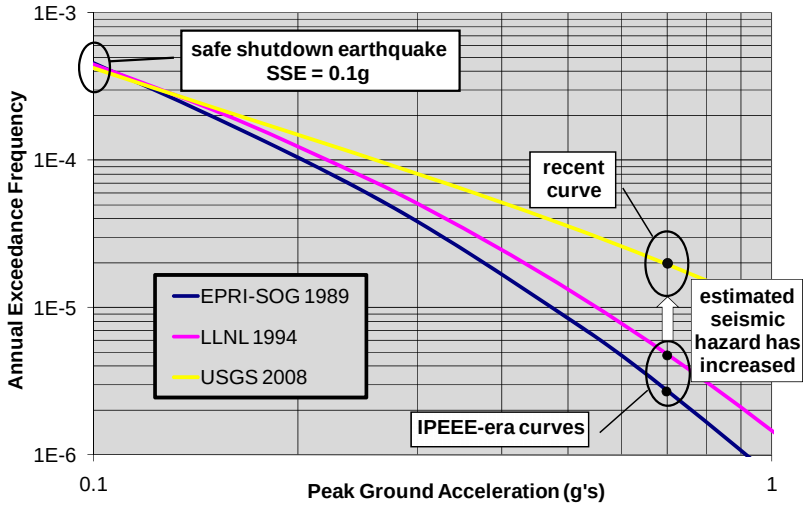
Example Seismic Hazard Curves: PSHA Output



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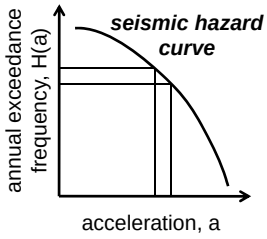
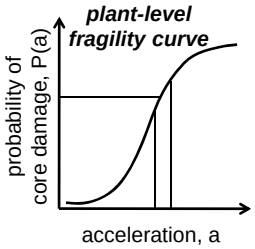
Risk Metric: Computing Seismic Core Damage Frequency (SCDF)





Over a small range of accelerations, the SCDF contribution is the product of:

- The frequency of earthquakes with accelerations in the range, and
- The probability of core damage given acceleration within the range

Add up the contributions over all accelerations.

$$SCDF = \int_0^\infty P(a)\left(-\frac{dH(a)}{da}\right)da$$

$$= \int_0^\infty H(a)\frac{dP(a)}{da}da$$

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GI-199 History

- Accepted into Generic Issues Program (GIP) (2005)
- Screened to Safety/Risk Assessment portion of GIP (2007)
- Safety/Risk Assessment completed (2010)
- Public meetings held, transfer from RES to NRR (2011)
- Draft Generic Letter issued, public comments received (2011)
- Subsumed into Fukishima Near-Term Task Force Recommendation 2.1 (2012)

Fukishima: Background

- NRC established Near Term Task Force (NTTF) in response to accident at Fukushima Dai-ichi nuclear power plant
- NTTF developed a set of recommendations
- SECY-11-0124 identified recommendations to be taken without unnecessary delay
  - Three 10 CFR 50.54(f) information requests
    - Seismic and Flooding Design (R2.1 and R2.3)
    - Emergency Preparedness (R9.3)

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Overall Approach: Recommendation 2.1

- NTTF Recommendation 2.1 implemented in two phases
  - Phase 1: Licensees *reevaluate* seismic hazard **using present-day regulatory guidance and methodologies** and, if necessary, perform a risk assessment
  - Phase 2: Based on results of Phase 1, NRC will determine if further regulatory actions are necessary to protect against updated hazard

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NTTF Recommendations: Scope

R 2.1: Seismic Hazard Reevaluation

- Determine Ground Motion Response Spectrum (GMRS) for Site
  - Use Probabilistic Method (PSHA)
    - Seismic Source Models
      - **(CEUS-SSC Model for 96 Plants)**
      - **Site-Specific for WUS**
    - Seismic Ground Motion Models
    - Site Response Evaluation (Site-Specific)
    - Follow SSHAC Guidelines
- Compare GMRS with Safe Shutdown Earthquake Plant (SSE) Spectrum

R 2.3: Perform Seismic Walkdowns

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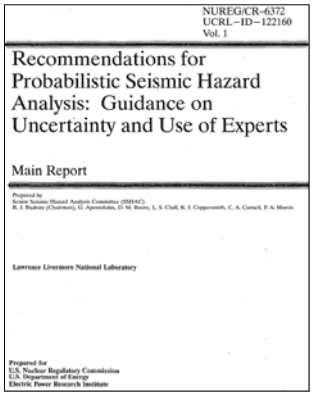
Senior Seismic Hazard Analysis Committee (SSHAC)

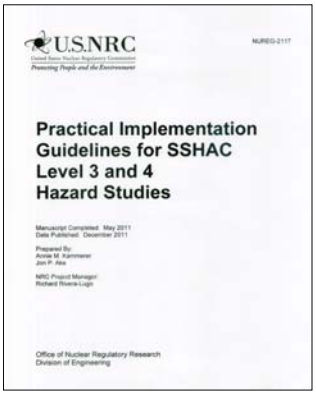

NUREG/CR-6372
UCRL-ID-122160
Vol. 1

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

Main Report

Lawrence Livermore National Laboratory

Prepared for
U.S. Nuclear Regulatory Commission
U.S. Department of Energy
Electric Power Research Institute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Practical Implementation Guidelines for SSHAC Level 3 and 4 Hazard Studies

Office of Nuclear Regulatory Research
Division of Engineering

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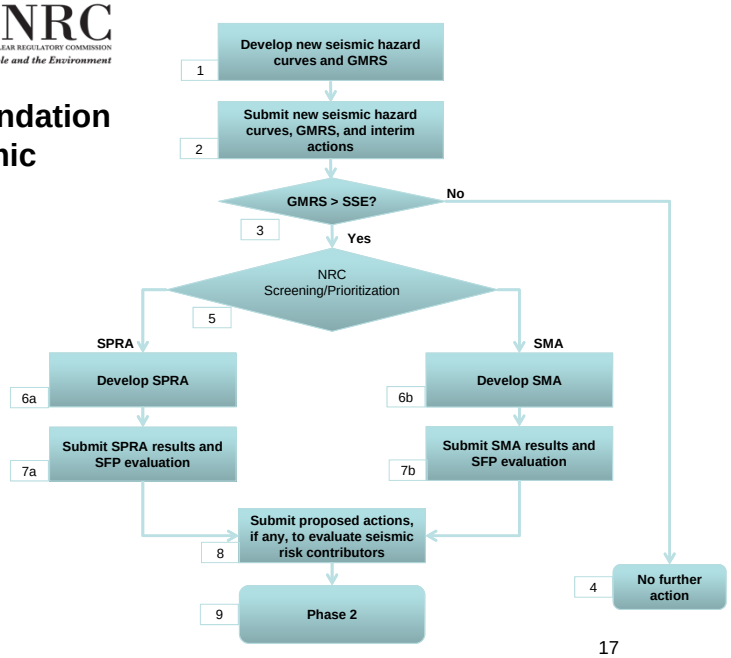
SSHAC Process Objectives

- Create reproducible, stable estimates of probabilistic seismic hazard at a site. This provides greater regulatory assurance.
- Obtain this stability by:
  - Evaluation: Considering the data, models, and methods of the larger technical community
  - Integration: Building models that represent the center, body, and range of technically defensible interpretations.
- Assess uncertainties in the input data and quantify uncertainties in the results.

Recommendation 2.1: Seismic



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NTTF Recommendation 2.1 and 2.3 Schedules

- Recommendation 2.1: Seismic Hazard Reevaluation
  - Complete Phase 1 including hazard and risk evaluations within 4 to 7 years (accelerated for plants in the CEUS)
  - Complete High-Priority Plants within 5 years
- Recommendation 2.3 (Seismic Walkdowns)
  - Complete within approximately 1 year

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Summary

- Significant advancements in our understanding of seismic hazard processes have occurred since the existing fleet of reactors was licensed
- Potential issues associated with these changes in state-of-knowledge have been known for some time.
- Proposed process for NTTF Recommendation 2.1 utilizing current regulatory framework provides a risk-informed method to evaluate the potential safety significance of these changes.
- This will provide relatively transparent “linkage” to NTTF Recommendation 2.2 which requires periodic re-assessment of natural hazards.

Background/Discussion Slides

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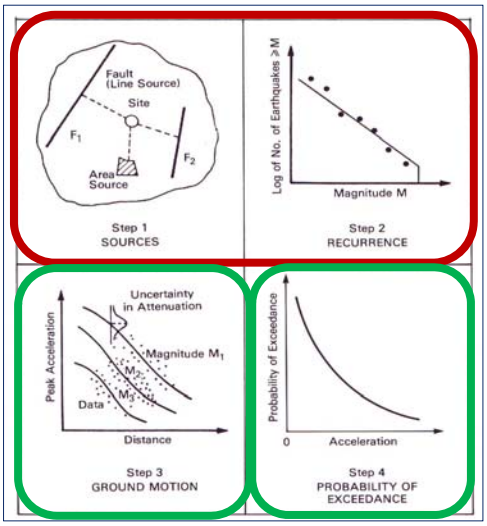
Input Models for PSHA



SSC
Seismic Source Characterization

GMC
Ground Motion Characterization

Hazard Calculations

Reiter (1990)

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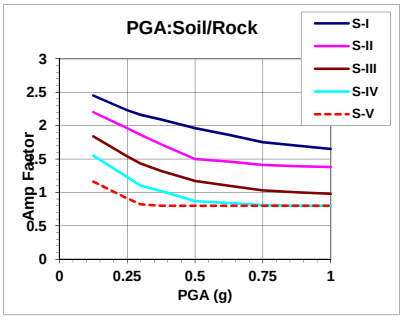
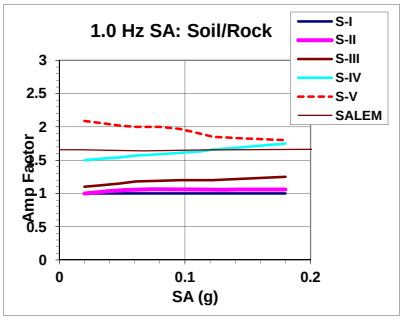
Example Soil Amplification Functions





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Needed for GI-199 Regulatory Analysis

- Updated site specific hazard curves
- Frequency dependent, site specific amplification functions
- Plant level fragility information
- Plant specific contributors to seismic risk
  - Can be produced for plants with seismic PRA
  - Will need method developed for plants with SMA
- Need repeatable approach for evaluating new seismic hazard information being developed

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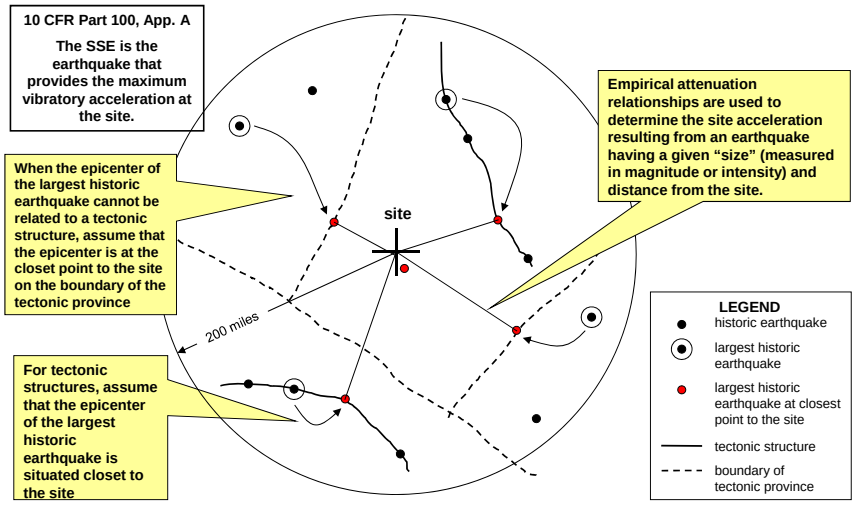
Determination of the Safe Shutdown Earthquake (SSE)



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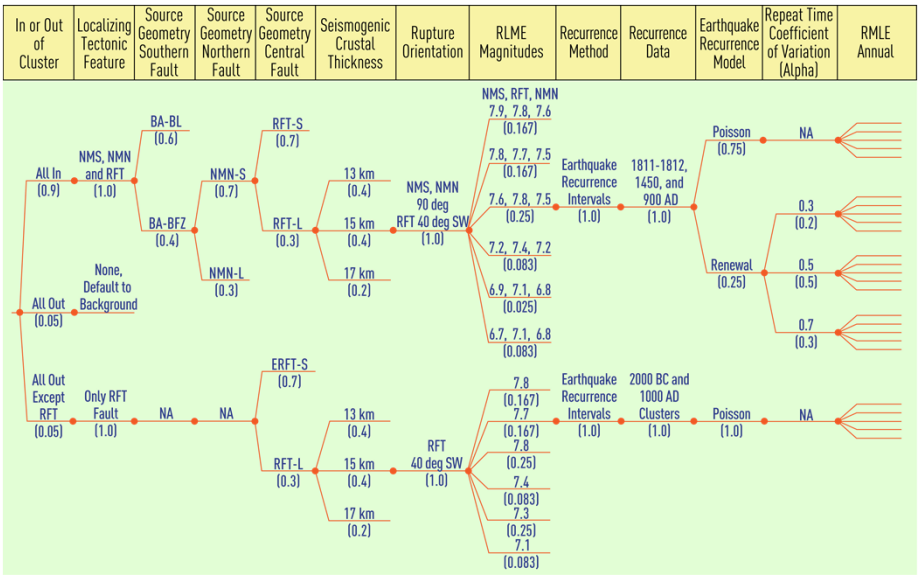
NMFS Logic Tree: CEUS SSC Project



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Seismic Source

- Unique seismic sources are defined for PSHA to account for distinct differences in the following criteria:
  - Earthquake recurrence rate
  - Maximum earthquake magnitude
  - Expected future earthquake characteristics (e.g., style of faulting, depth distribution)
  - Probability of activity of tectonic feature(s)
- CEUS SSC methodology attempts to work through the criteria sequentially and logically
  - Each criterion adds complexity to the seismic source model
  - Each criterion is only applied if its application would lead to hazard-significant changes in the model

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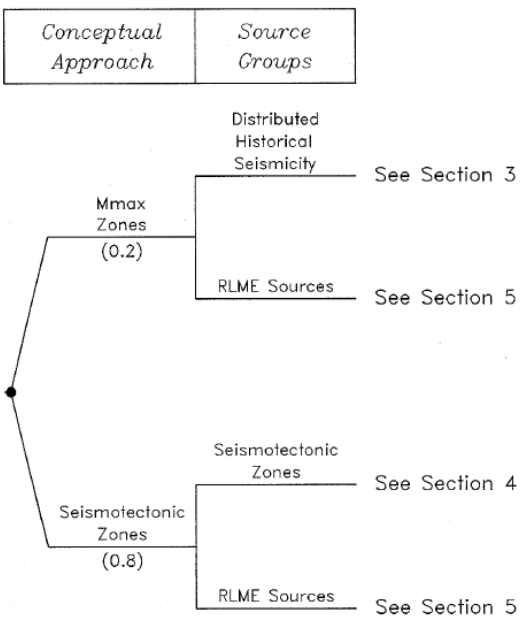
Master Logic Tree



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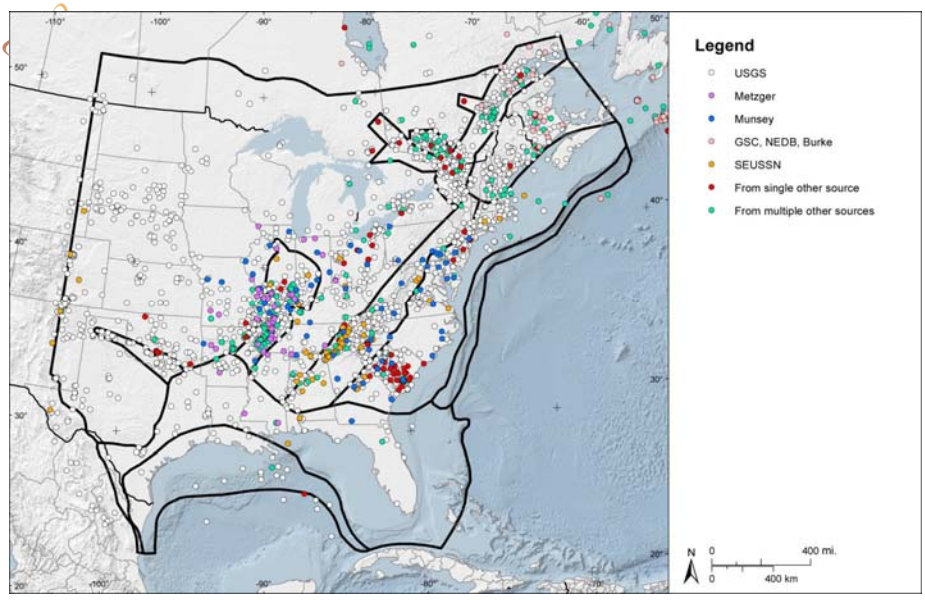
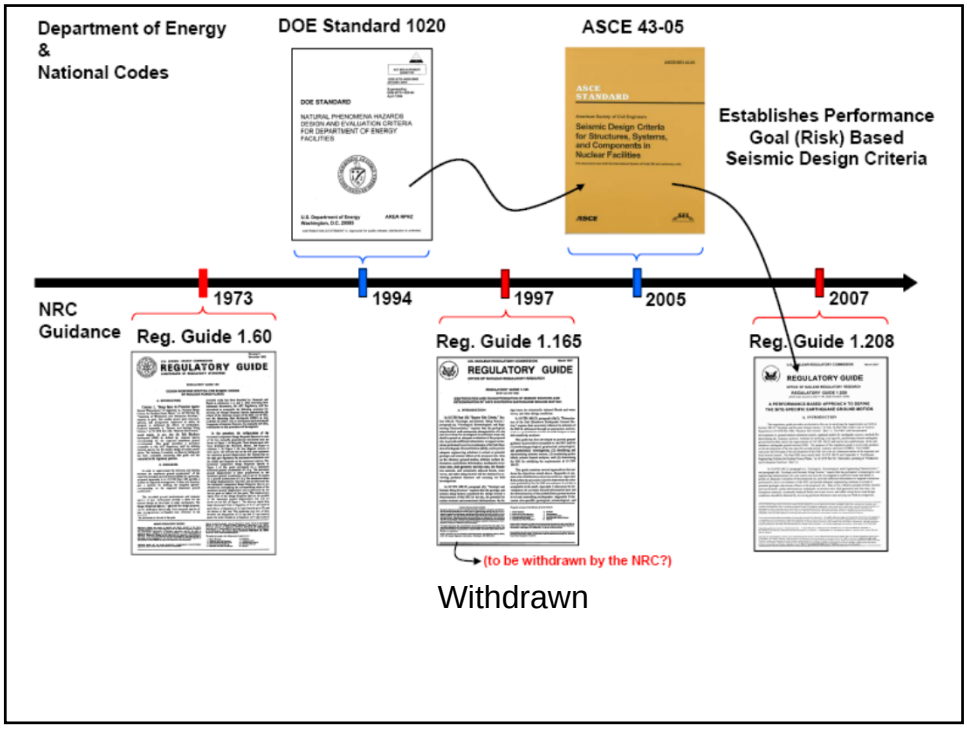


Map of the CEUS SSC Project catalog showing earthquakes of uniform moment magnitude E[M] 2.9 and larger. Colored symbols denote earthquakes not contained in the USGS seismic hazard mapping catalog.


Department of Energy
&
National Codes
DOE Standard 1020
ASCE 43-05
Establishes Performance Goal (Risk) Based Seismic Design Criteria
NRC Guidance
1973
1994
1997
2005
2007
Reg. Guide 1.60
Reg. Guide 1.165
Reg. Guide 1.208
(to be withdrawn by the NRC?)
Withdrawn