United States Nuclear Regulatory Commission

Protecting People and the Environment

GENERIC ISSUE 199:
Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants

Safety/Risk Assessment

Public Meeting
October 6, 2010

United States Nuclear Regulatory Commission

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Generic Issue 199
Public Meeting Agenda

- 9:00-9:10 Introductions (NRC) (B. Sheron, NRC)
- 9:10-9:30 Generic Issues Program and GI-199 Background (J. Kauffman, NRC)
- 9:30-10:15 GI-199 Safety/Risk Assessment (J. Ake, M. Stutzke, NRC)
- 10:15-10:45 Planned Regulatory Approach (P. Hiland, NRC)
- 10:45-11:15 Industry Remarks
- 11:15-11:45 Public Question and Answers

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The Generic Issues Program (GIP)

- Agency-wide program administered by Office of Nuclear Regulatory Research (RES), implemented by Management Directive 6.4

- Value Added
  - Advance understanding of the issue
  - Find the best place for the issue to be worked
  - Develop NRC consensus
  - Engage stakeholders

(http://www.nrc.gov/about-nrc/regulatory/gen-issues.html)

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Generic Issues Program Stages

1. Identification
2. Acceptance
3. Screening
4. **<u>Safety/Risk Assessment</u>**
   - Issue Analyzed
   - Paneled, Report Issued
   - Recommendations Endorsed
5. Regulatory Assessment

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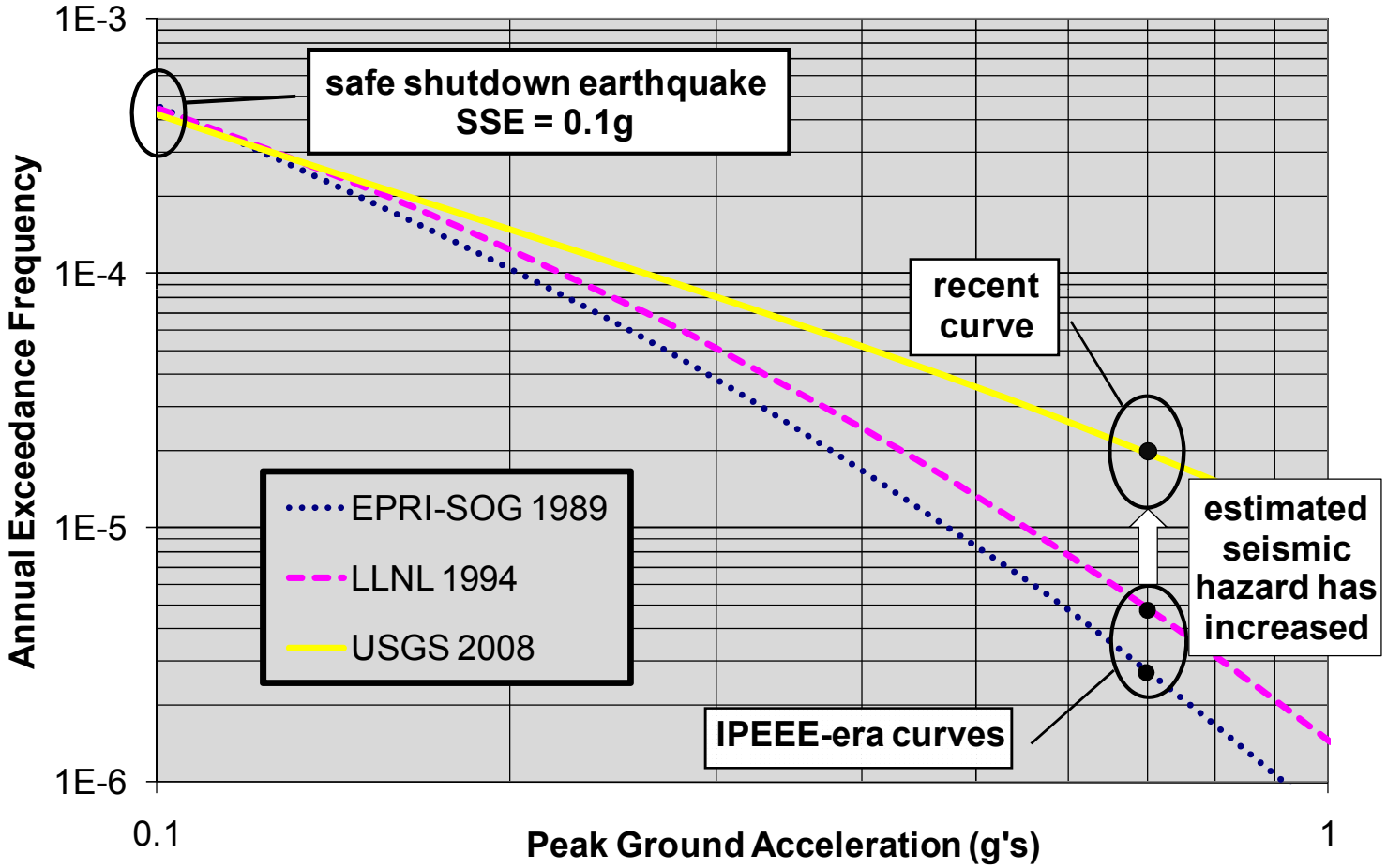
What is GI-199 About?



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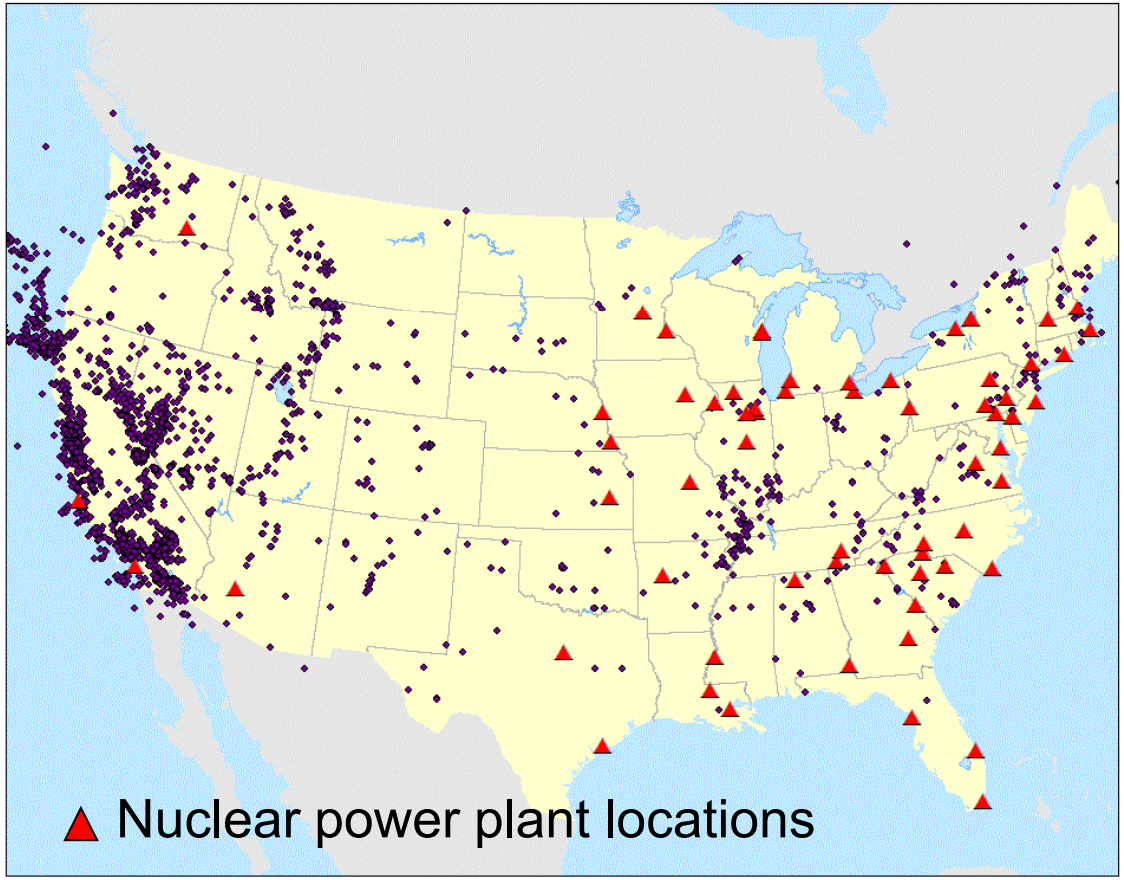
The GI-199 Safety/Risk Assessment

- Safety/Risk Assessment (S/RA) Stage Goals:
  - Determine, on a generic basis, if the risk associated with GI-199 warrants further investigation for potential imposition of cost-justified backfits.
  - Provide a recommendation regarding the next step (i.e., continue to the Regulatory Assessment for identification and evaluation of potential generic, cost-justified backfits, be dropped due to low risk, or have other actions taken outside the GIP).

GI-199: Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants

● Felt and Damaging Earthquakes In the U.S.

Source: USGS



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Applicable Regulations (pre-1997)

- **10 CFR 100.10(c)(1) and Appendix A establish the seismic design basis 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, GDC-2 and similar principle design criteria require that 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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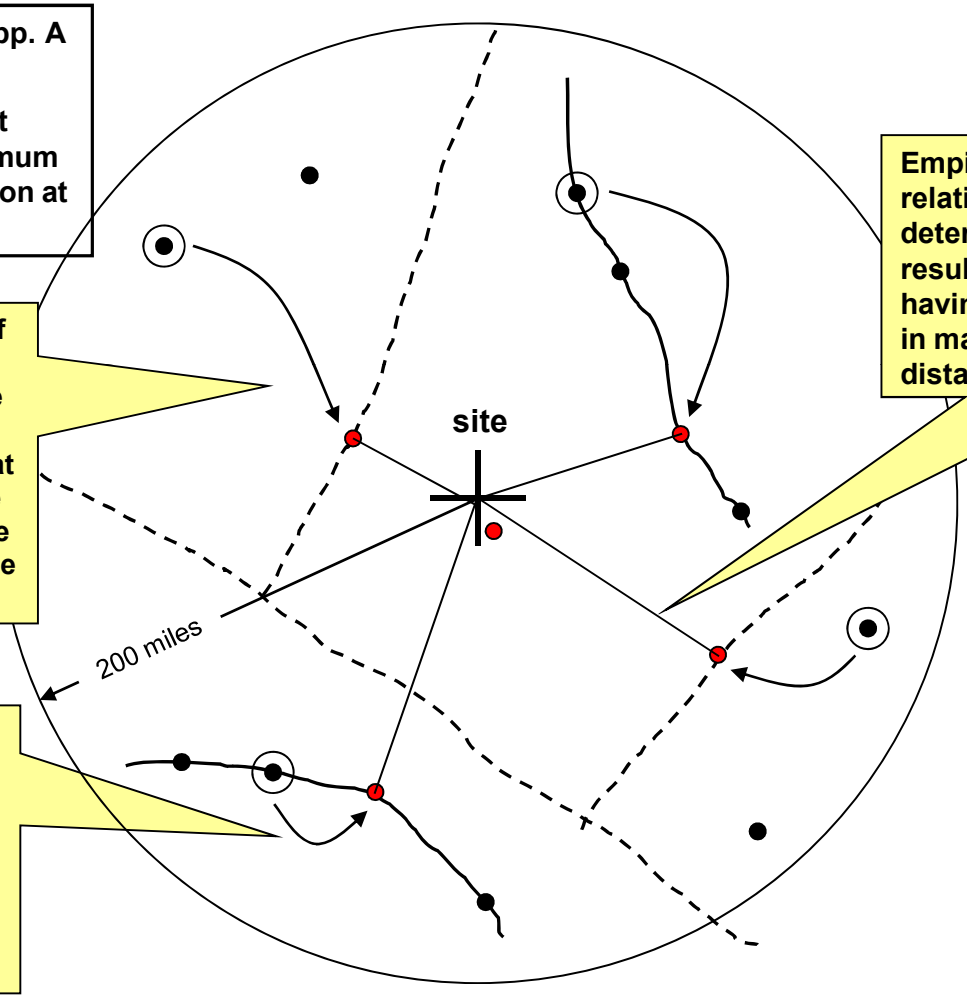
Determination of the Safe Shutdown Earthquake (SSE)

10 CFR Part 100, App. A

The SSE is the earthquake that provides the maximum vibratory acceleration at the site.

When the epicenter of the largest historic earthquake cannot be related to a tectonic structure, assume that the epicenter is at the closet point to the site on the boundary of the tectonic province

For tectonic structures, assume that the epicenter of the largest historic earthquake is situated closet to the site

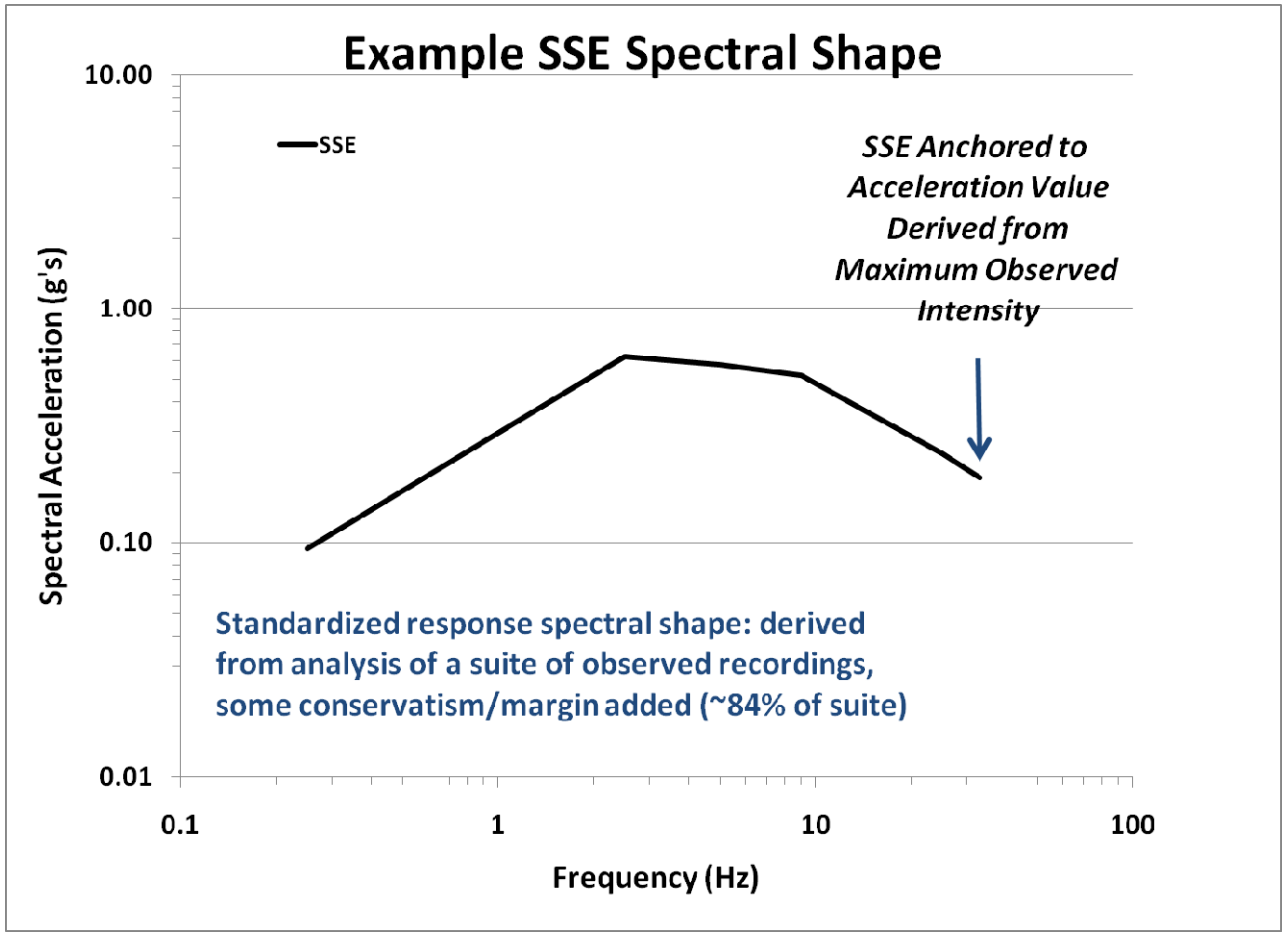


Empirical attenuation relationships are used to determine the site acceleration resulting from an earthquake having a given "size" (measured in magnitude or intensity) and distance from the site.

LEGEND
- historic earthquake
- largest historic earthquake
- largest historic earthquake at closest point to the site
- tectonic structure
- boundary of tectonic province

Safe Shutdown Earthquake (Ground motion)

Response Spectrum:
Peak response of a series of SDOF oscillators of varying frequency



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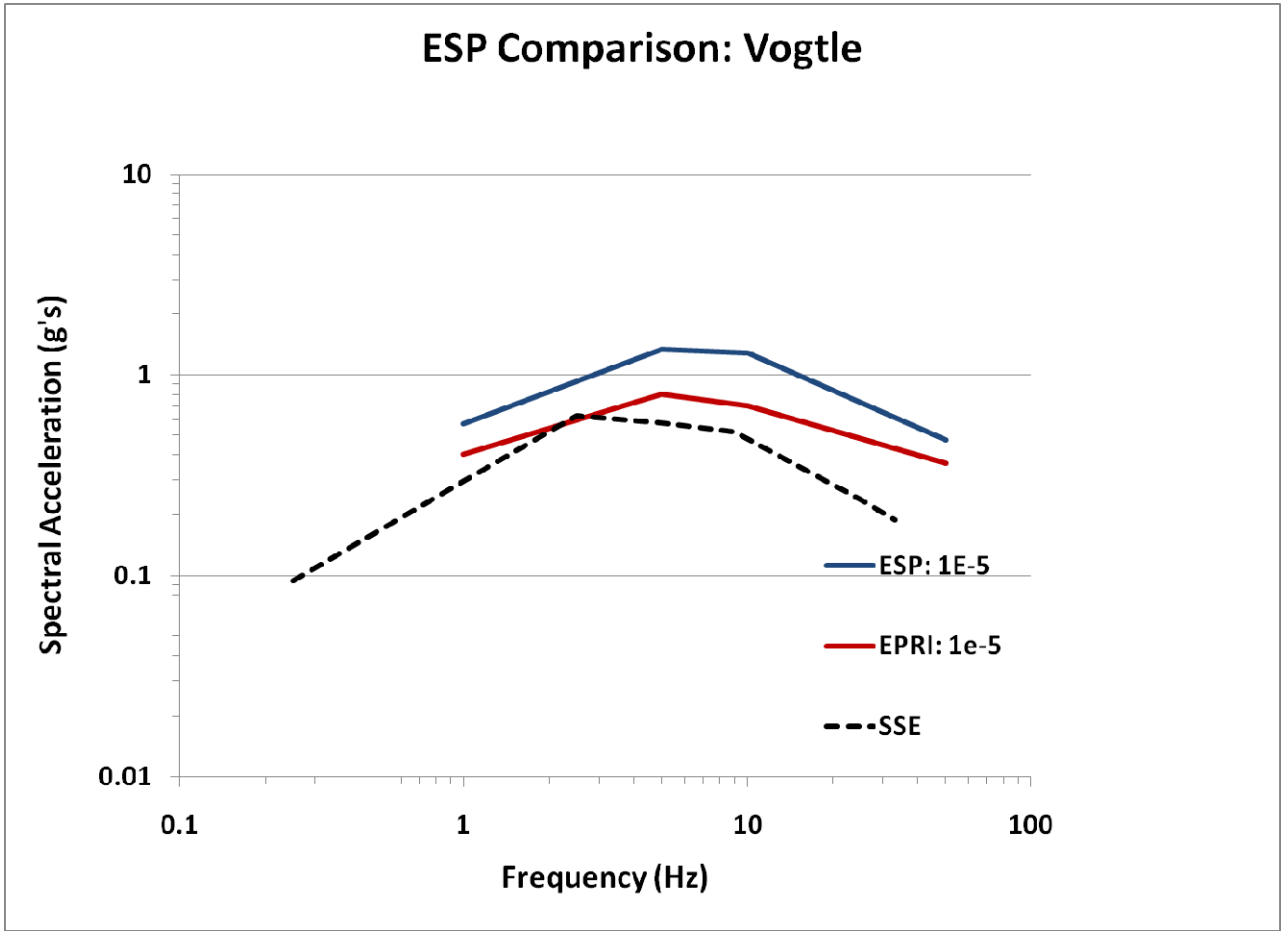
Observations From ESP Reviews

Uniform Hazard Response Spectrum: Represents Constant Annual Frequency/ Probability



Calculation of Seismic Hazard

- **Requirements:** produce consistent estimates for 68 different sites across the CEUS.
  - Incorporate site-specific geological information.
- **Solution**: utilize the 2008 USGS software used to develop National Seismic Hazard maps. Calculate for rock site conditions, adjust to “site specific” conditions.
- **Output**: seismic hazard curves for four spectral frequencies for each NPP. Following Regulatory Guide 1.208 compute ground motion response spectra (GMRS) for each NPP.

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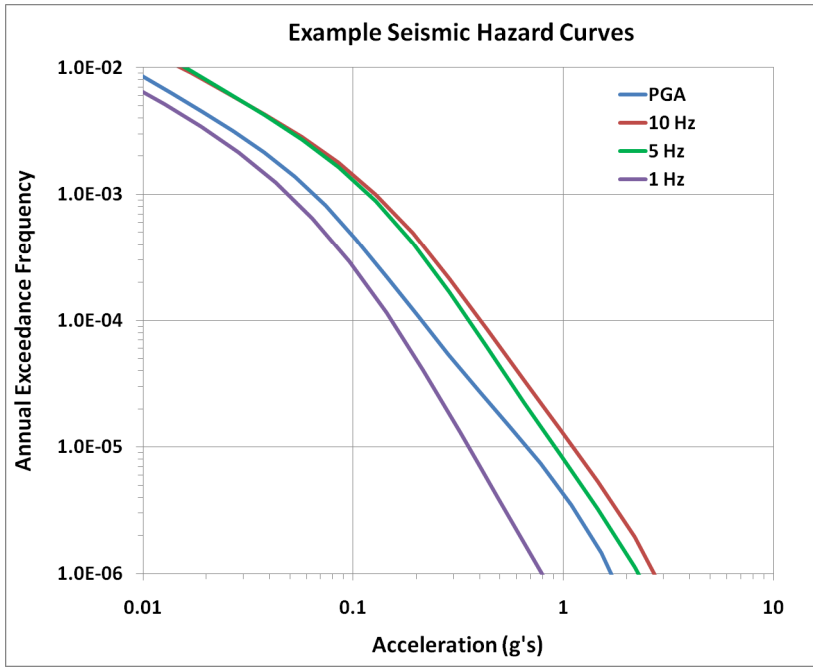
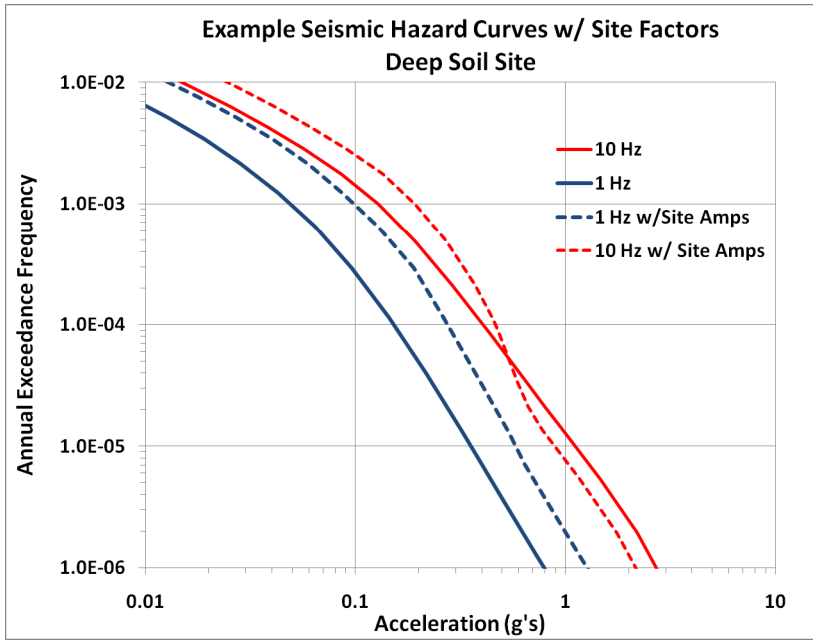
Seismic Hazard Results- For Each Site





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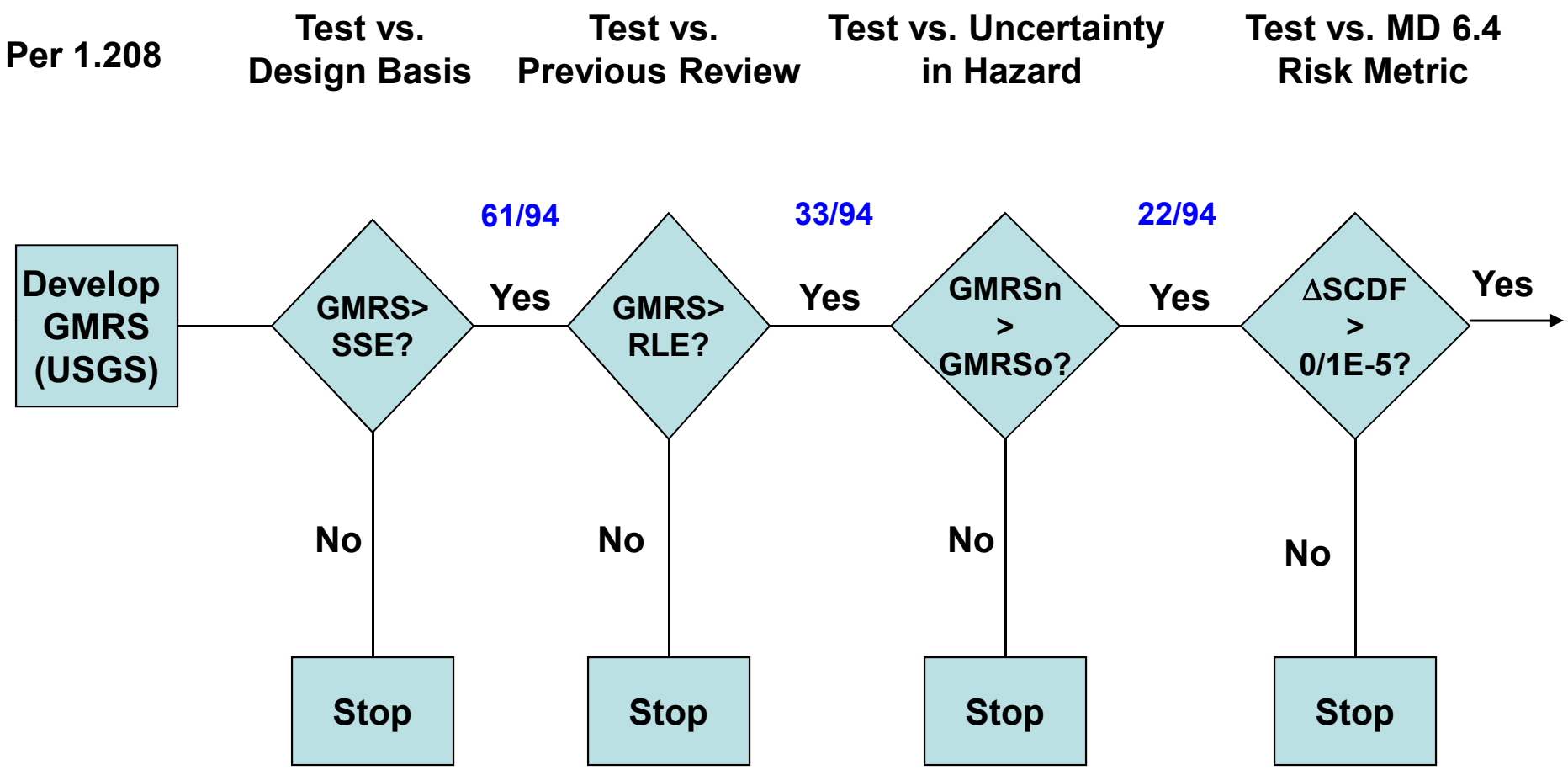
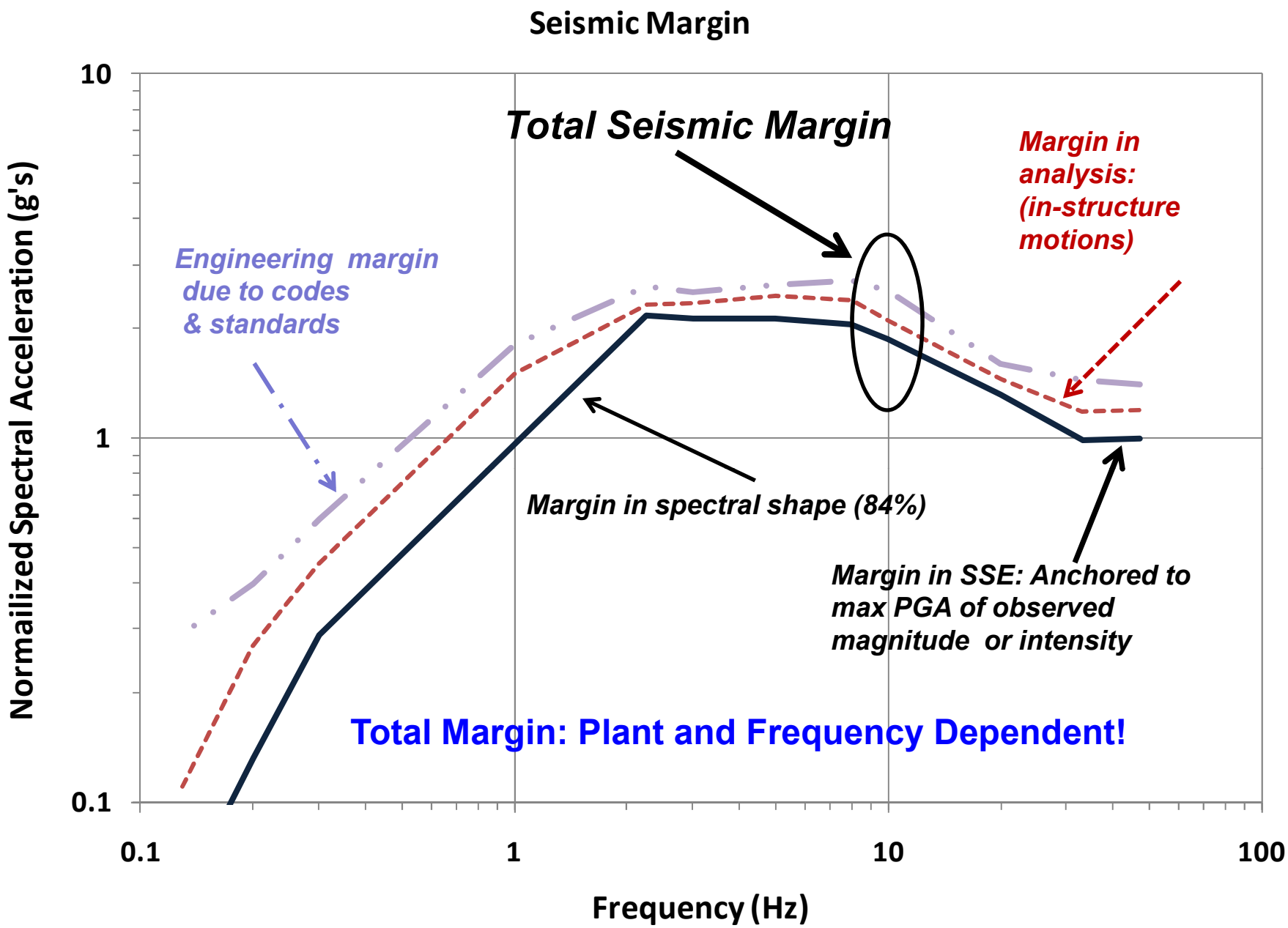
Individual Plant Examination of External Events (IPEEE) Program

- The IPEEE program also considered the implications of Beyond Design Basis Ground Motions.
- IPEEE used a review-level earthquake (RLE) whose spectra exceeded/equaled the SSE and demonstrated plant safety either with low core damage frequency (via SPRA: ~30% CEUS plants) or high seismic margin (via SMA: ~70% CEUS plants).
- The emphasis was on developing risk insights.
- Seismic hazard curves from EPRI and LLNL used.

Hazard/Risk Evaluation Process




Seismic Margin
Total Seismic Margin
Margin in analysis: (in-structure motions)
Engineering margin due to codes & standards
Margin in spectral shape (84%)
Margin in SSE: Anchored to max PGA of observed magnitude or intensity
Total Margin: Plant and Frequency Dependent!
Normailized Spectral Acceleration (g's)
10
1
0.1
0.1
1
10
100
Frequency (Hz)

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Assessing the Implications of Increased Seismic Hazard

- Compare risk due to different seismic hazard curves:
  - IPEEE-era curves:
    - 1989: EPRI/SOG (EPRI NP-6395) – many plants
    - 1994: LLNL (NUREG-1488) – all plants
  - Recent curves:
    - 2000s: ESP and COL applications for co-located plants – few plants
    - 2000s: EPRI curves – proprietary information for six sites provided under NRC/EPRI Memorandum of Understanding for collaborative seismic research
    - 2008: USGS – all plants
- When performing a Safety/Risk Assessment of a generic issue, usually pick several "representative" plants for analysis. However, for GI-199, need to conduct analyses for each CEUS plant:
  - Nationwide variability of seismic hazards
  - Variability in plant-specific seismic fragilities

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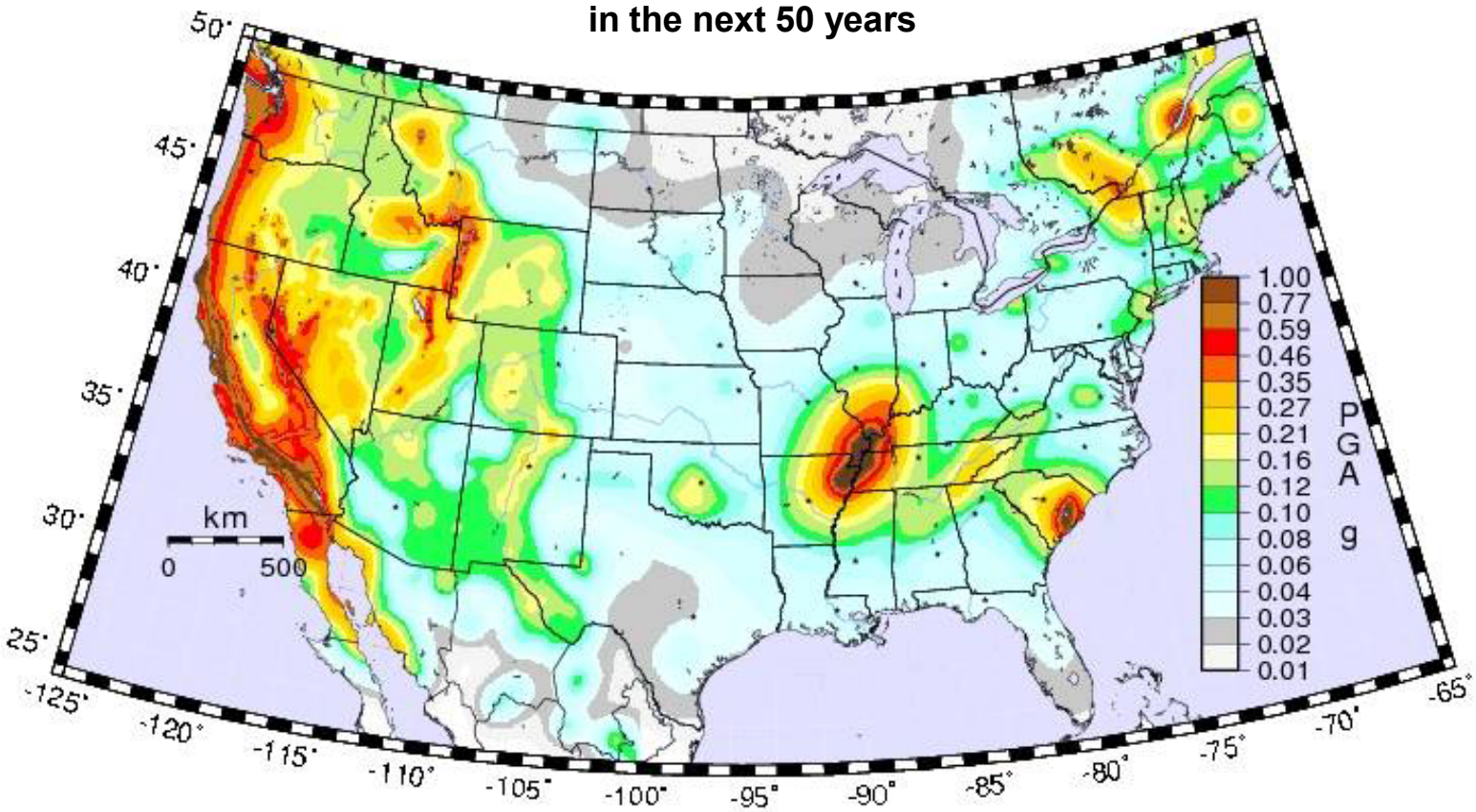
Seismic Hazard Variability

Peak ground acceleration (PGA) 2% probability of exceedance in the next 50 years



Source: earthquake.usgs.gov

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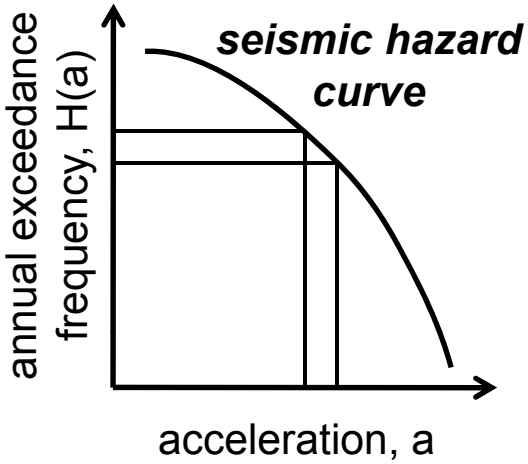
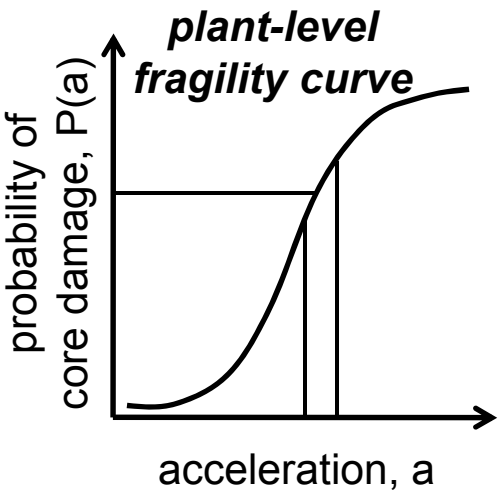
Crafting an Approach

- Available seismic fragility information from IPEEEs:
  - 30% based on Level 1 seismic PRAs (SPRAs)
  - 70% based on seismic margins analysis (SMAs)
  - Limited information on seismic containment performance
  - Plants have been modified since the IPEEEs, but the impact of these modifications on seismic fragility is not well understood
  - IPEEEs completed before consensus standards on PRA quality were developed; no peer review or in-depth staff review.
- Prohibitive effort to develop SPRAs for all plants.
- The approach:
  - For each CEUS plant,
  - Combine mean seismic hazard curves (EPRI/SOG, LLNL, and USGS)
  - With the mean plant-level fragility curve
  - Developed from IPEEE information to
  - Estimate SCDF.

Computing 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

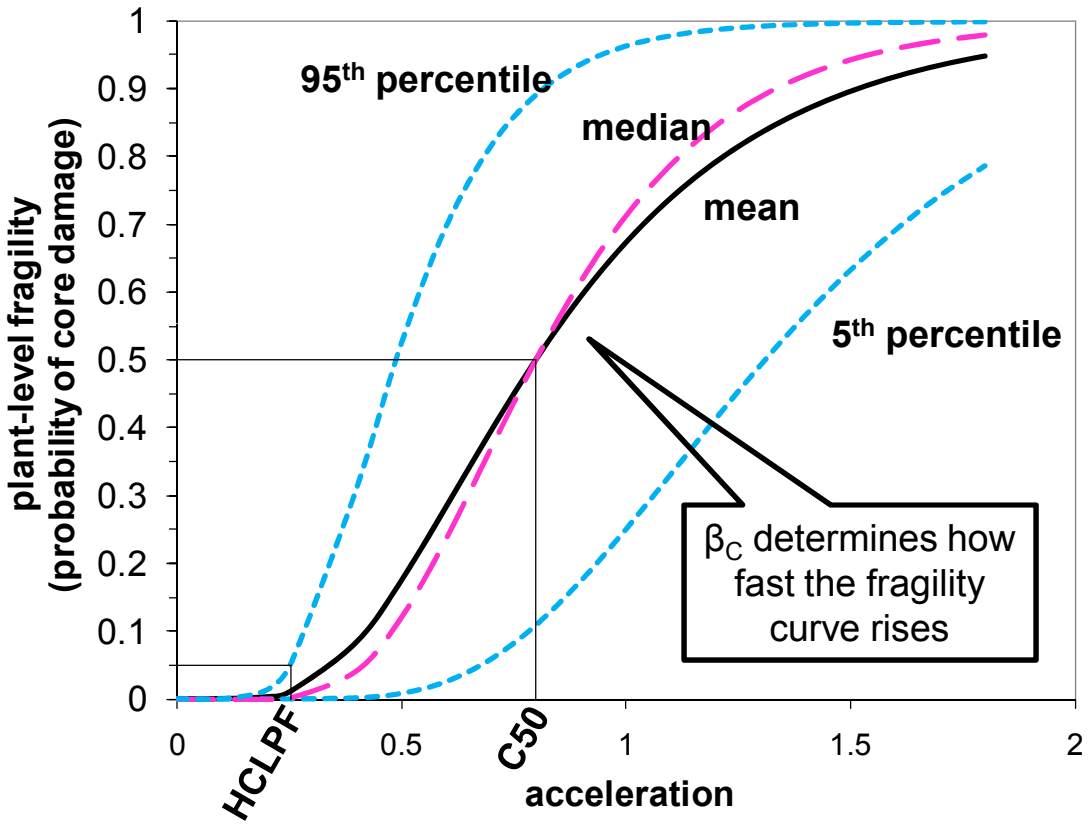
Add up the contributions over all accelerations.

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

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

Plant-Level Seismic Fragility Curves

- Determined by SPRA
- Log-normal shape with two parameters:
  - C_{50} is the median seismic capacity
  - β_C is the composite logarithmic standard deviation
- Can be estimated from SMA: The plant-level HCLPF approximately corresponds to a conditional core-damage probability of 0.01



PGA, acceleration for a specific spectral frequency (e.g., 10 Hz), or acceleration over a range of spectral frequencies (e.g., 3-8Hz)

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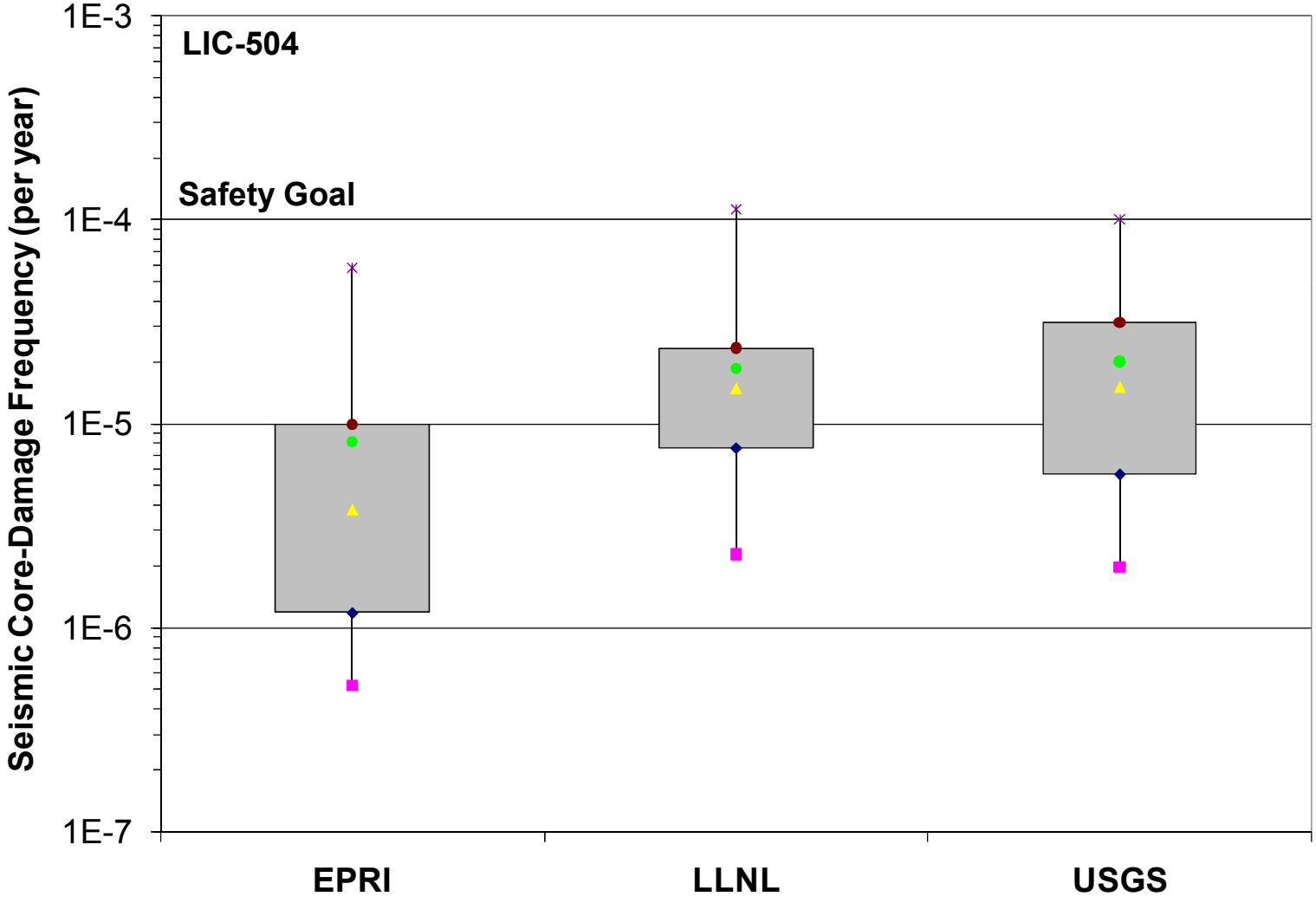
Fleetwide SCDF Variability



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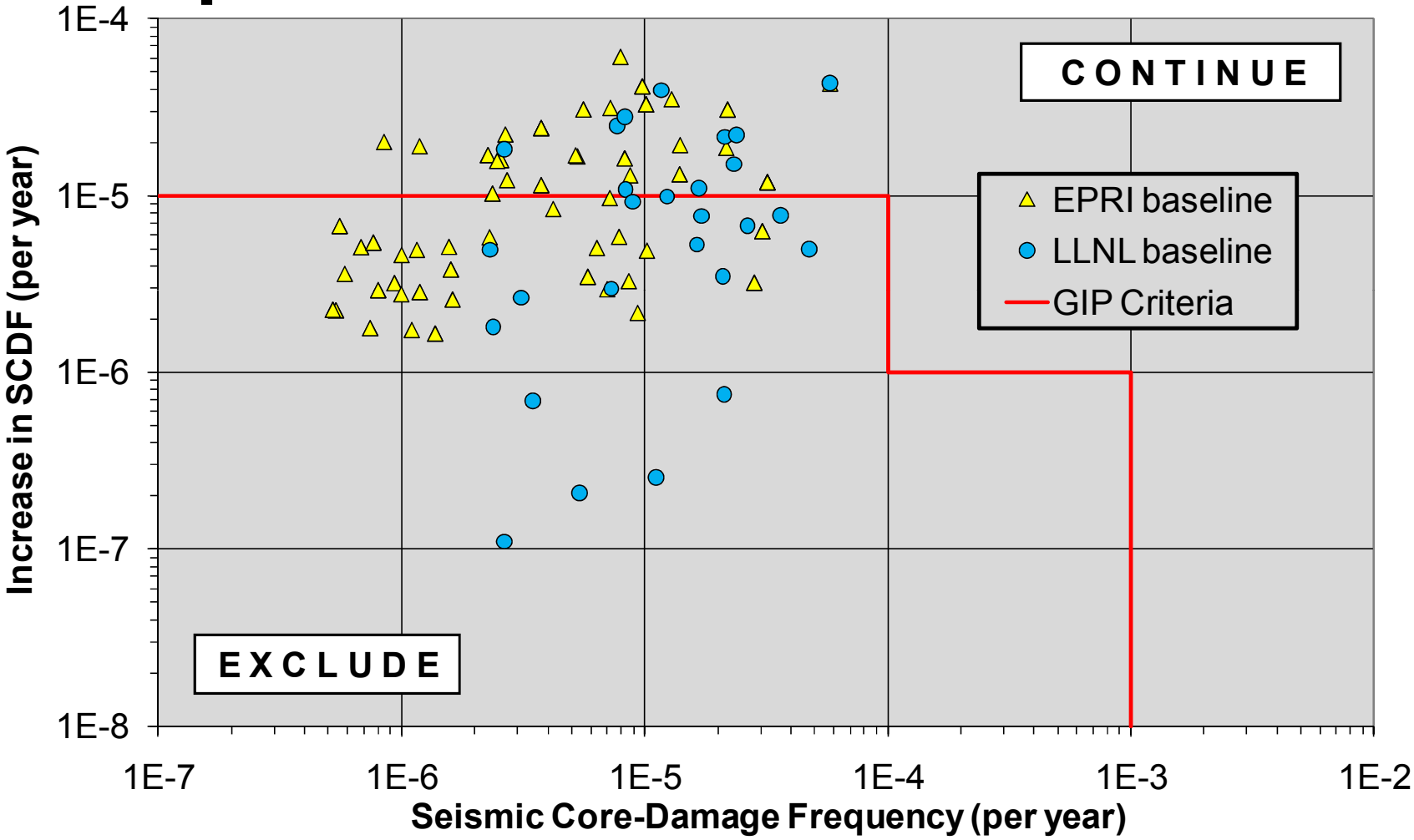
Comparison to GIP Criteria



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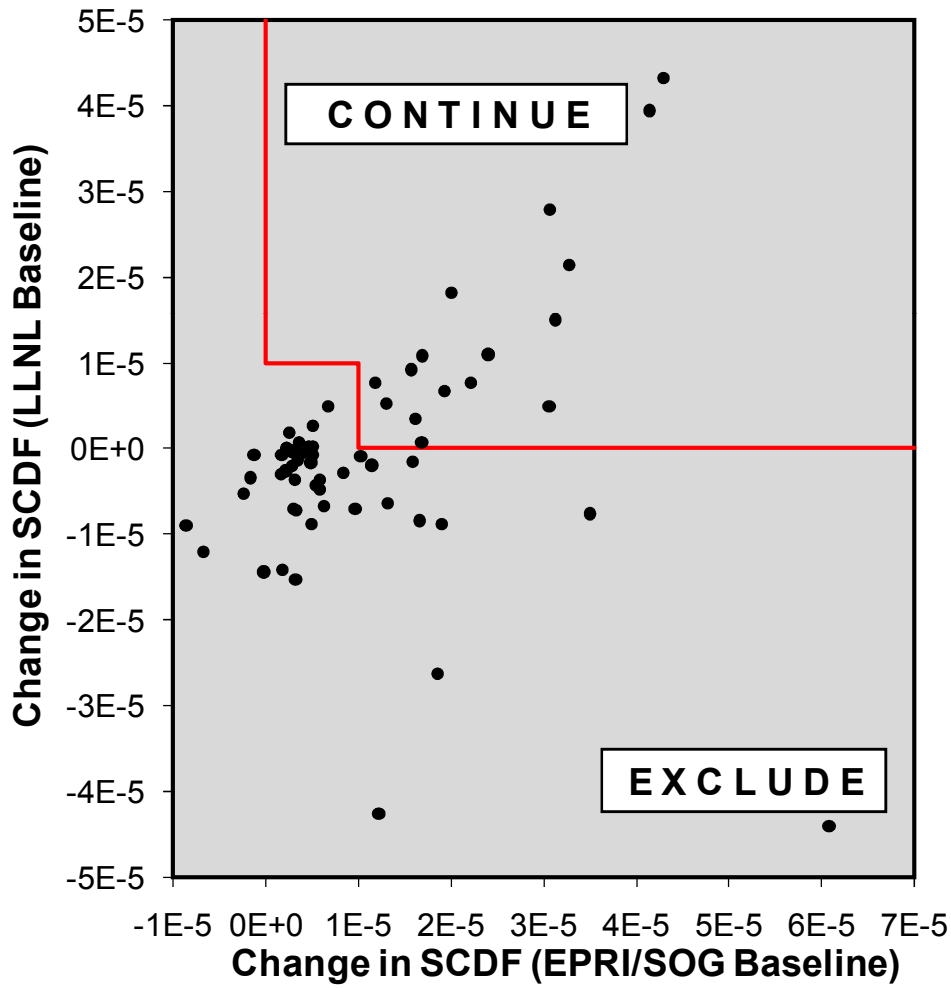
Delta-Delta Plot



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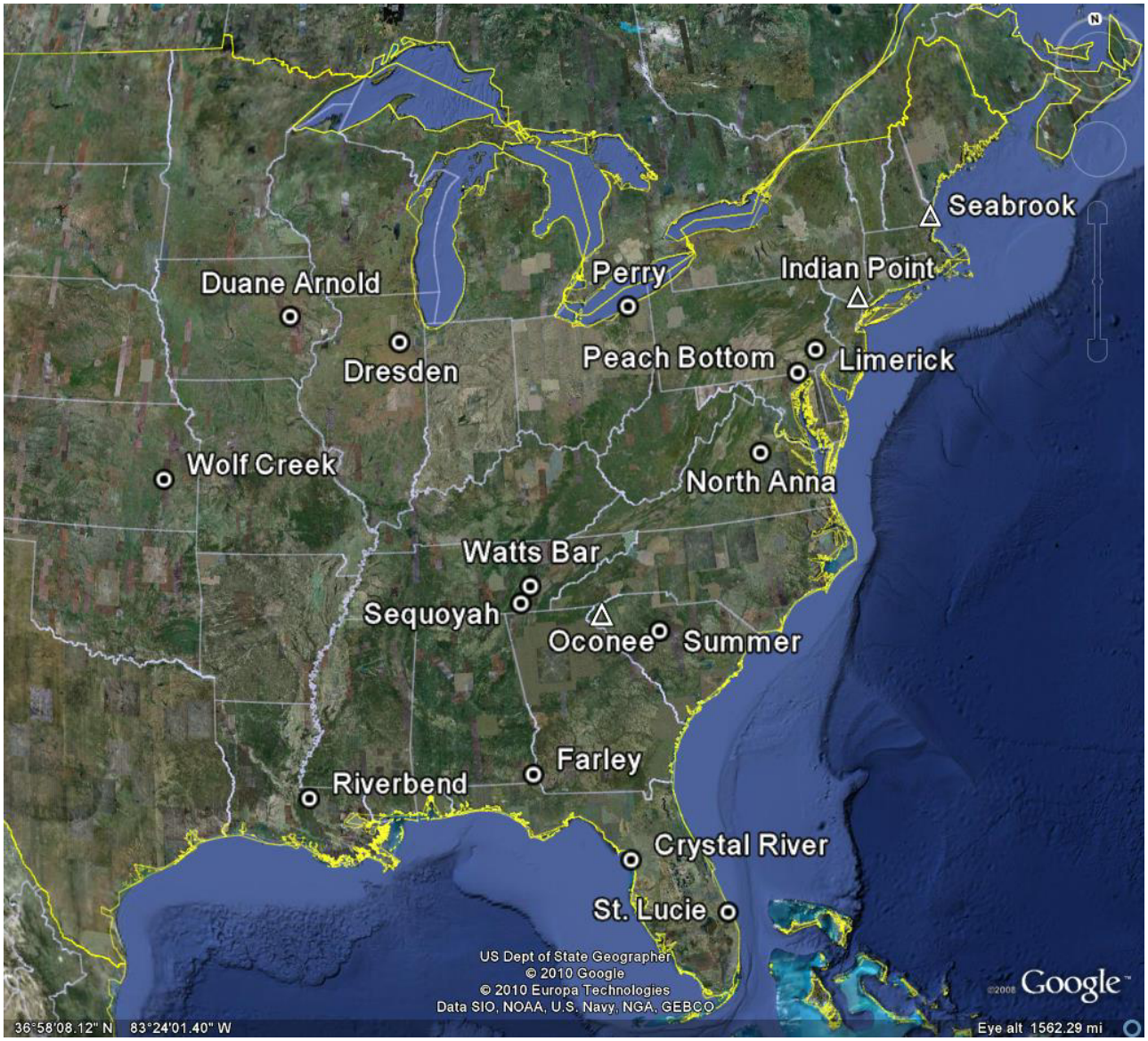

Plants in the "Continue" Zone

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Do We Need to Consider Backfits?

Cost-Justified Backfits That Provide Substantial Safety Enhancements

Safety Goal Evaluation Screening Criteria (NUREG/BR-0058)

Distribution of GI-199 Safety/Risk Assessment Results

1E-4

Seismic CDF (2008) USGS

2E-6

Change in CDF From Proposed Backfit

	1E-2	1E-1
1E-3	Proceed to value/impact portion of regulatory analysis	Proceed to value/impact portion of regulatory analysis (priority)
1E-4	Management decision whether to proceed with value/impact portion of regulatory analysis	Proceed to value/impact portion of regulatory analysis
1E-5	No action taken	Management decision whether to proceed with value/impact portion of regulatory analysis
1E-6		

Conditional Containment Failure Probability

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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 and future updates

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Path Forward

- NRR lead with RES support
  - Issue has transitioned from the GI Program to Regulatory Office Implementation
  - Issued Information Notice 2010-018 to inform plants of the GI-199 Safety/Risk Assessment results
  - Develop a generic communication to request needed data
  - RES works with EPRI on method for plants that used Seismic Margins Analysis (SMA)
  - RES develops inputs for GI-199 regulatory analysis under a user need request

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Overview of Generic Issue 199 Safety/Risk Assessment Results

- Operating power plants are safe
- Though still small, some seismic hazard estimates have increased
- Assessment of GI-199 will continue
  - Information is needed to perform regulatory assessments
  - NRC will request the needed information

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INDUSTRY REMARKS

QUESTIONS?

Acronyms and Initialisms

ANS	American Nuclear Society
ANSI	American National Standards Institute
CAV	cumulative absolute velocity
CDF	core-damage frequency
CEUS	Central and Eastern United States
EPRI	Electric Power Research Institute
ESP	early site permit
GI	Generic Issue
GMRS	ground motion response spectrum
HCLPF	high confidence of low probability of failure
IPEEE	Individual Plant Examination of External Events
LLNL	Lawrence Livermore National laboratory
MD	Management Directive
MOU	memorandum of understanding
NRR	Office of Nuclear Reactor Regulation
PGA	peak ground acceleration
RES	Office of Nuclear Regulatory Research
RG	regulatory guide
SCDF	seismic core-damage frequency
SMA	seismic margins analysis
SPRA	seismic probabilistic risk assessment
SSE	safe shutdown earthquake
USGS	U.S. Geological Survey