United States Nuclear Regulatory Commission

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

ACRS Siting Subcommittee Presentation
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Pat Hiland (NRR)
November 30, 2010

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Generic Issue 199 Presentation Agenda

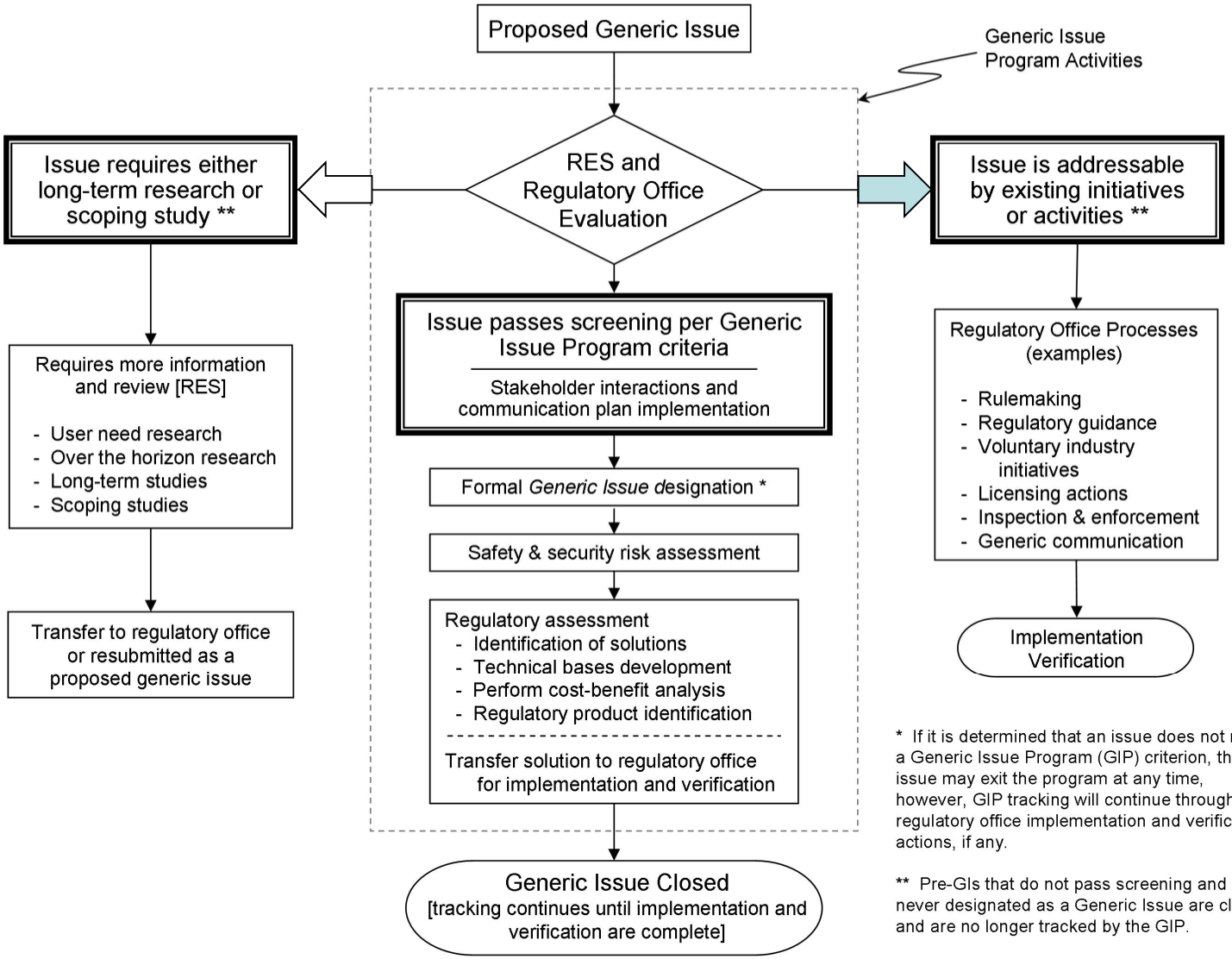
- Generic Issues Program Overview
- The GI-199 Safety/Risk Assessment
- Path Forward
- Subcommittee Discussion

Generic Issues Program (GIP) Overview

The GIP Stages

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

The GIP in perspective with other Regulatory Programs and Processes



* If it is determined that an issue does not meet a Generic Issue Program (GIP) criterion, the issue may exit the program at any time, however, GIP tracking will continue through regulatory office implementation and verification actions, if any.

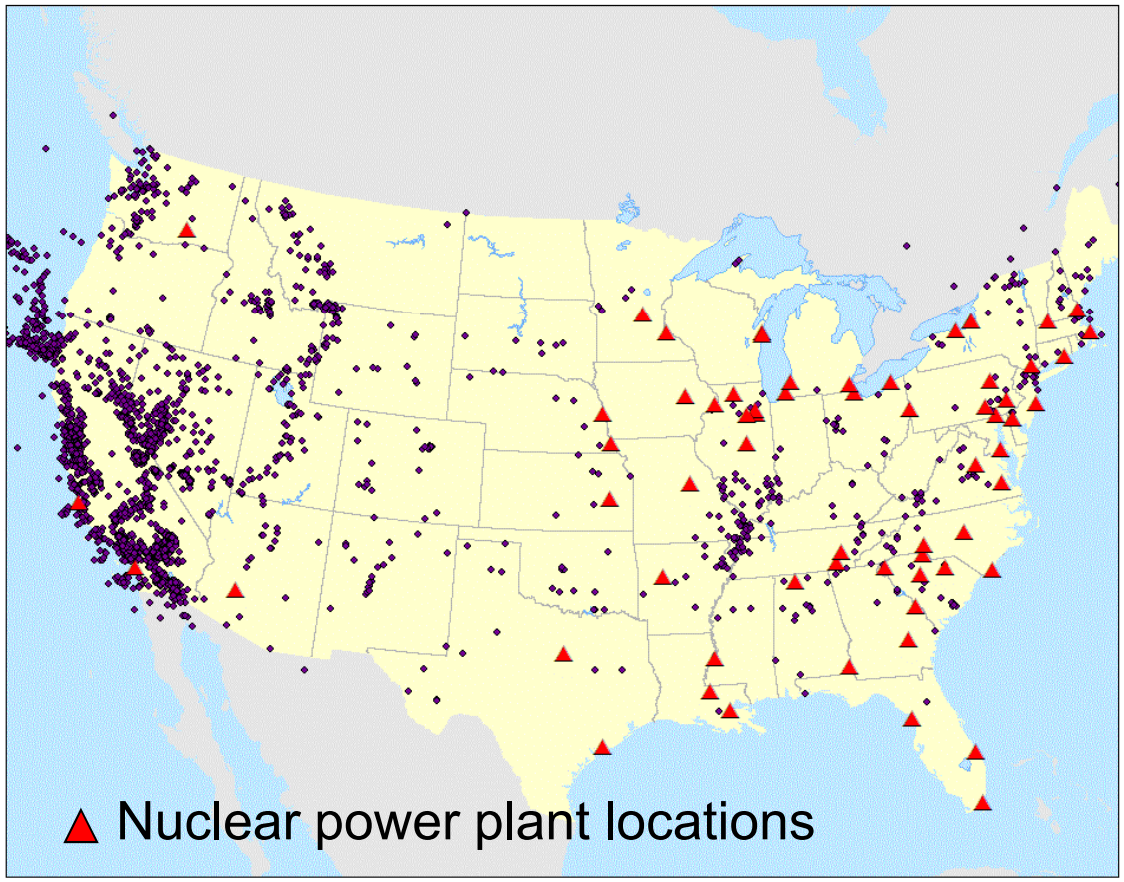
** Pre-GIs that do not pass screening and are never designated as a Generic Issue are closed and are no longer tracked by the GIP.

Safety/Risk Assessment for 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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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).
- S/RA: Background, Approach, and Results

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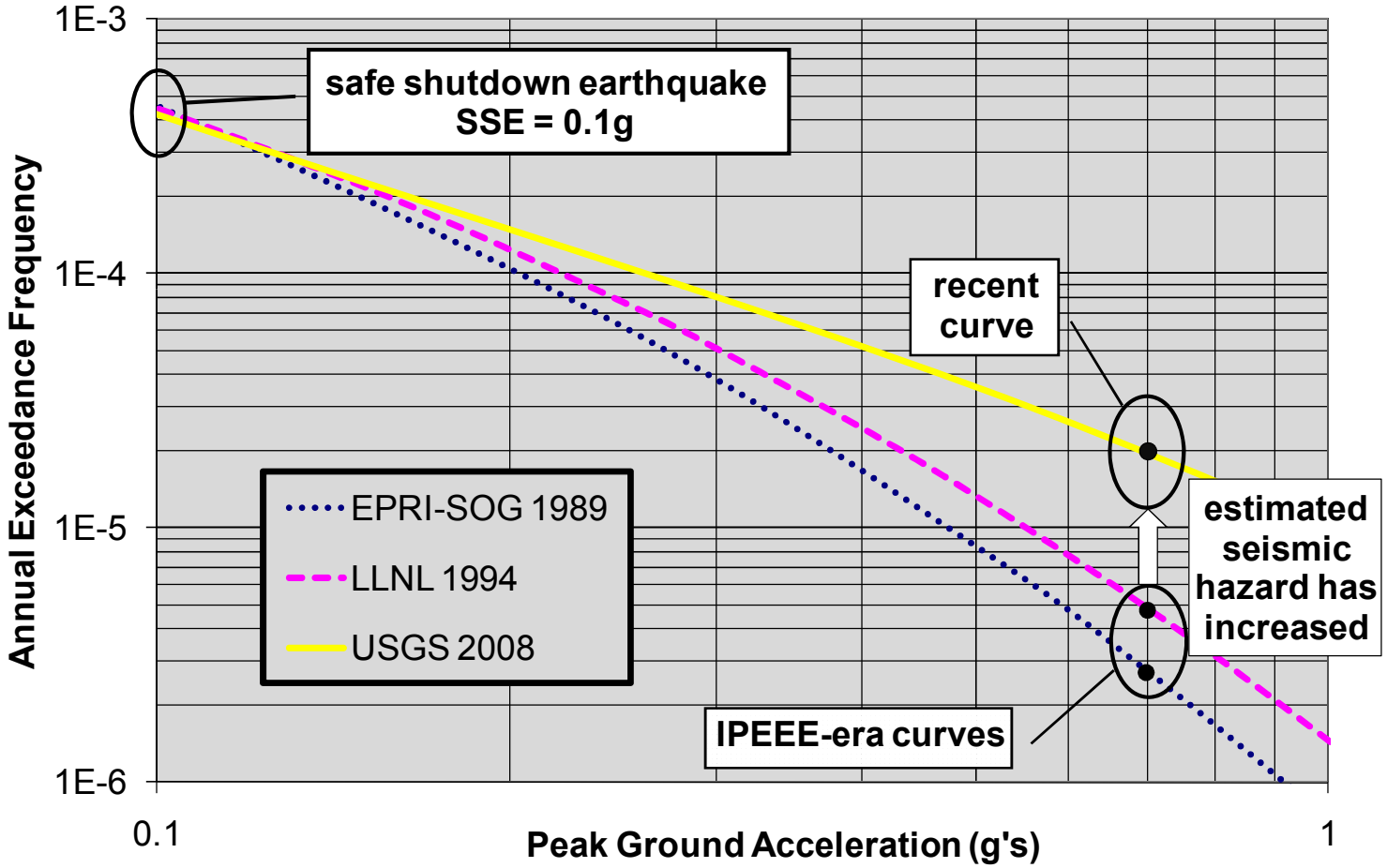
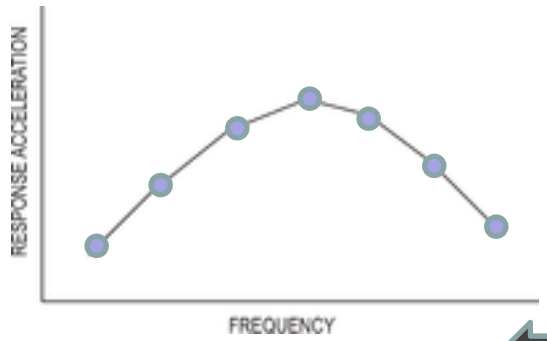
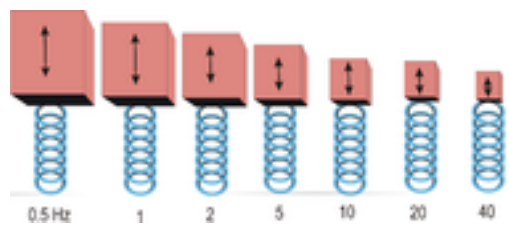
What is GI-199 About?

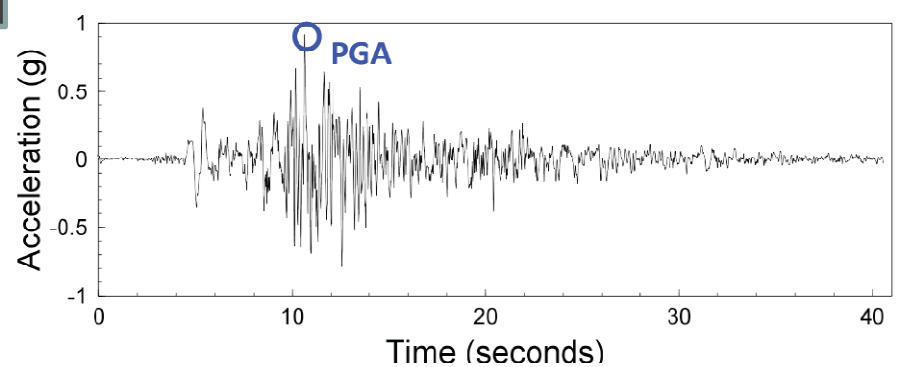


Response Spectrum

A plot of the peak response of a series of SDOF oscillators of varying natural frequency driven by the same input motion







Widely used in earthquake engineering to analyze the performance of structures and equipment and in design

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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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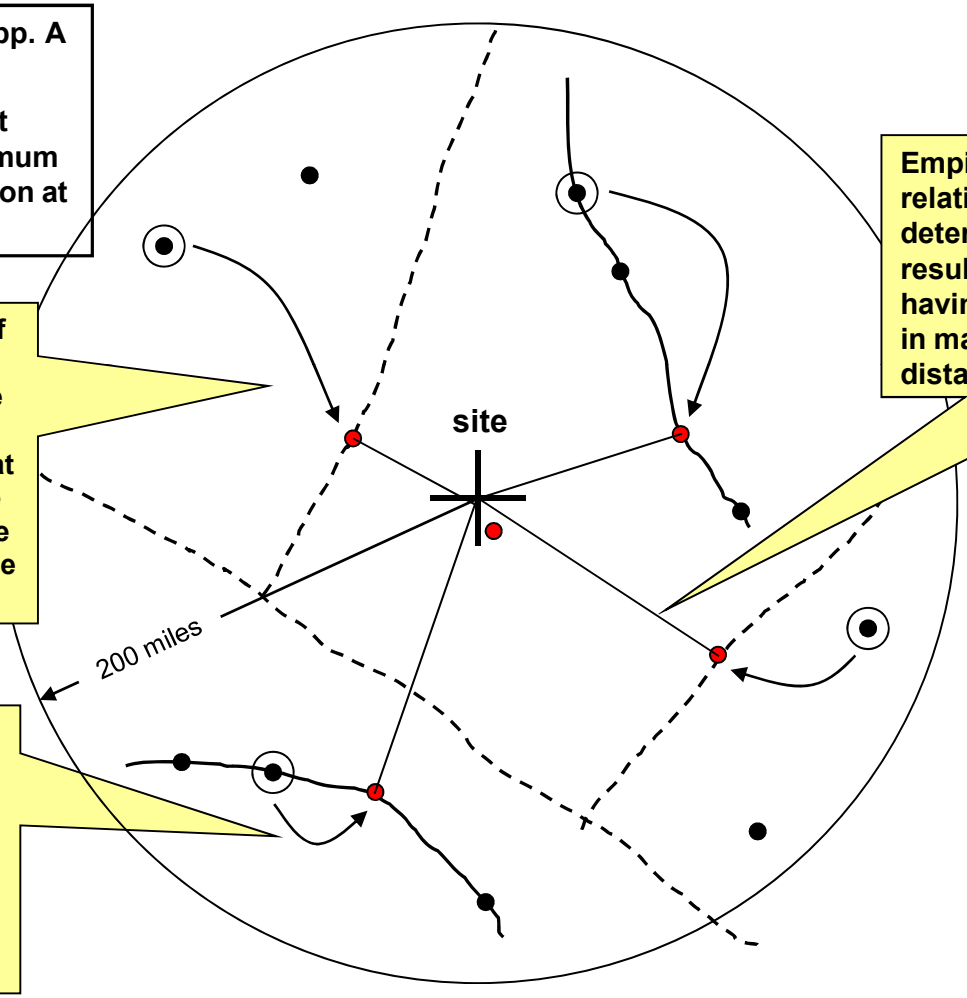
Determination of the Safe Shutdown Earthquake (SSE)

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

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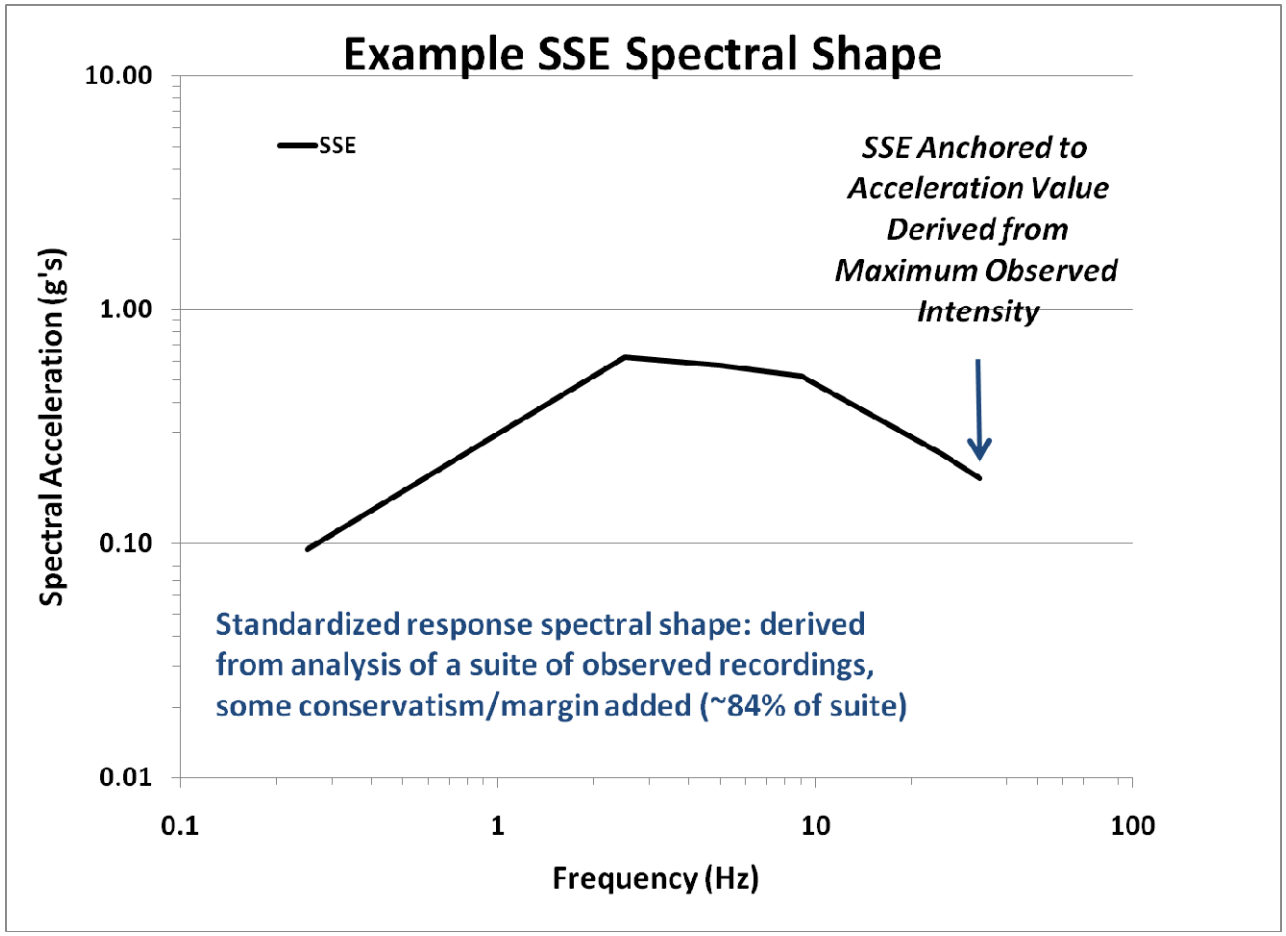
Safe Shutdown Earthquake (Ground motion)



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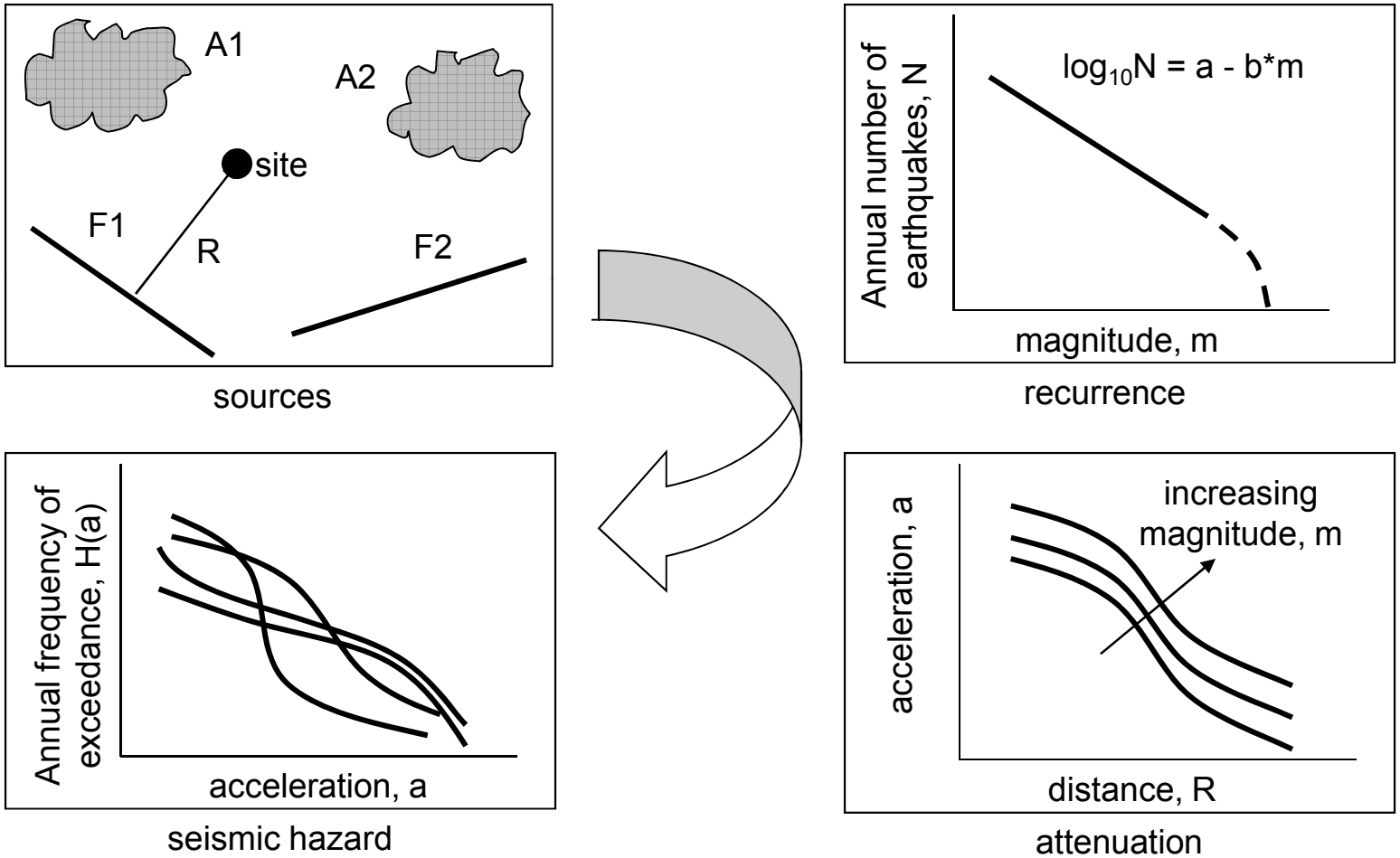
Applicable Regulations (post-1997)

- **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.
- RG 1.208 provides guidance on satisfying 10 CFR Part 100.23, one of which is performing a probabilistic seismic hazard assessment (**PSHA**). Determine (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.

Seismic Hazard Model (PSHA)

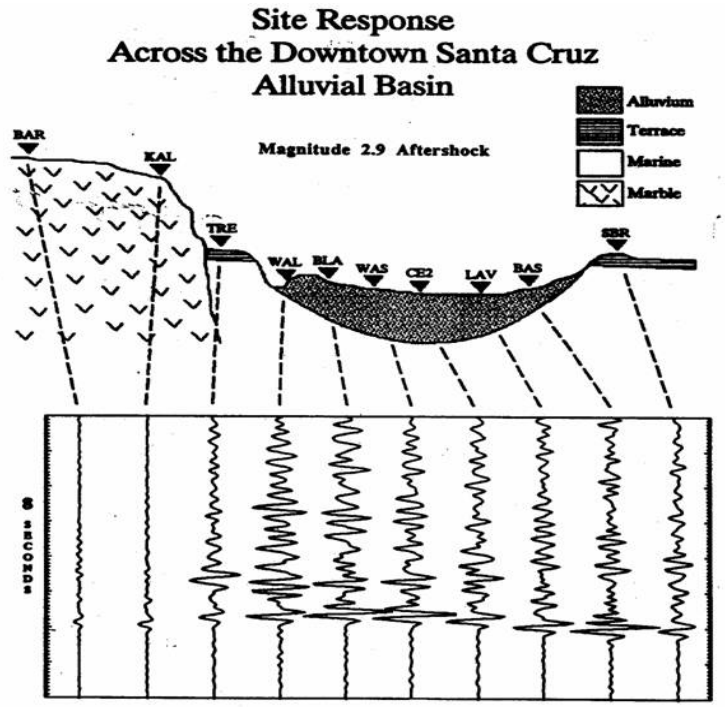


Site Response Effects (Amplification Functions)

The type and thickness of materials near the ground surface has a strong influence on the strength of ground shaking observed at a particular location

GI-199 used a generic approach to estimating site specific amplification functions (Amplitude and frequency Dependent)

Based on EPRI-SOG 1988



USGS

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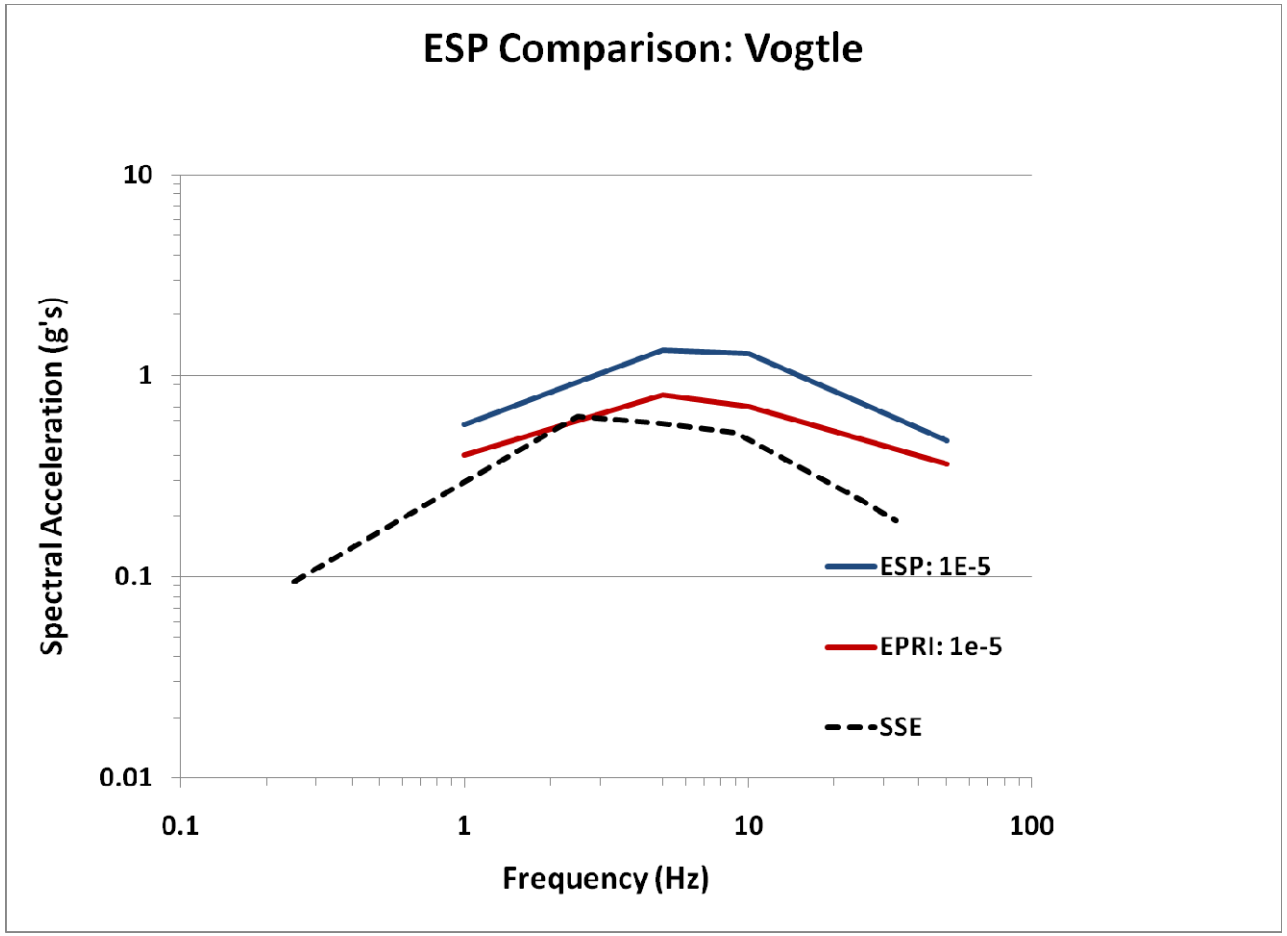
Observations From ESP Reviews



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.

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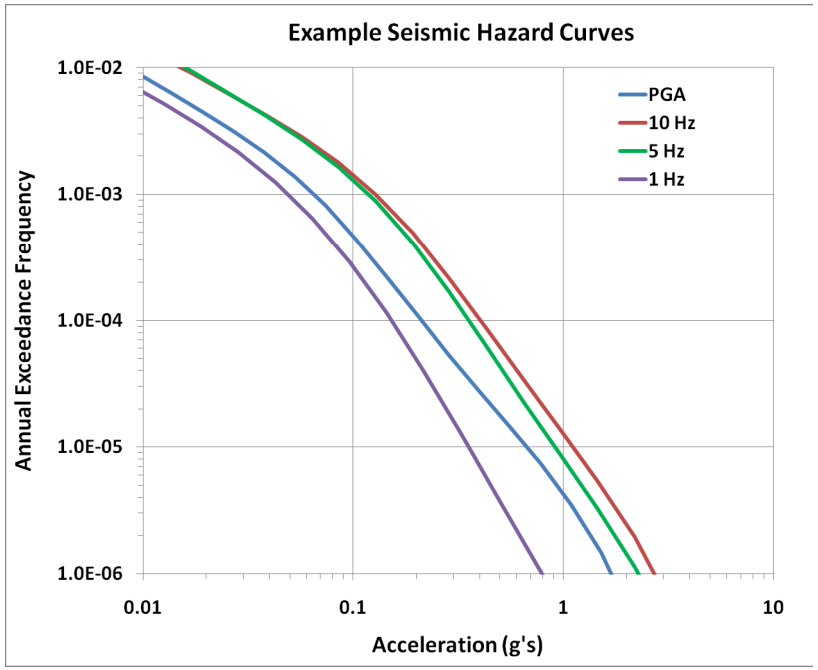
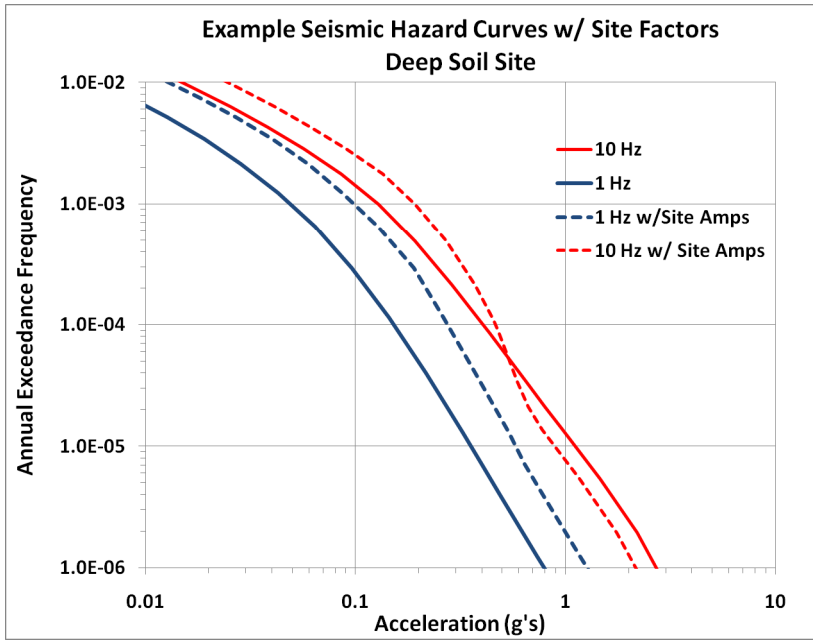
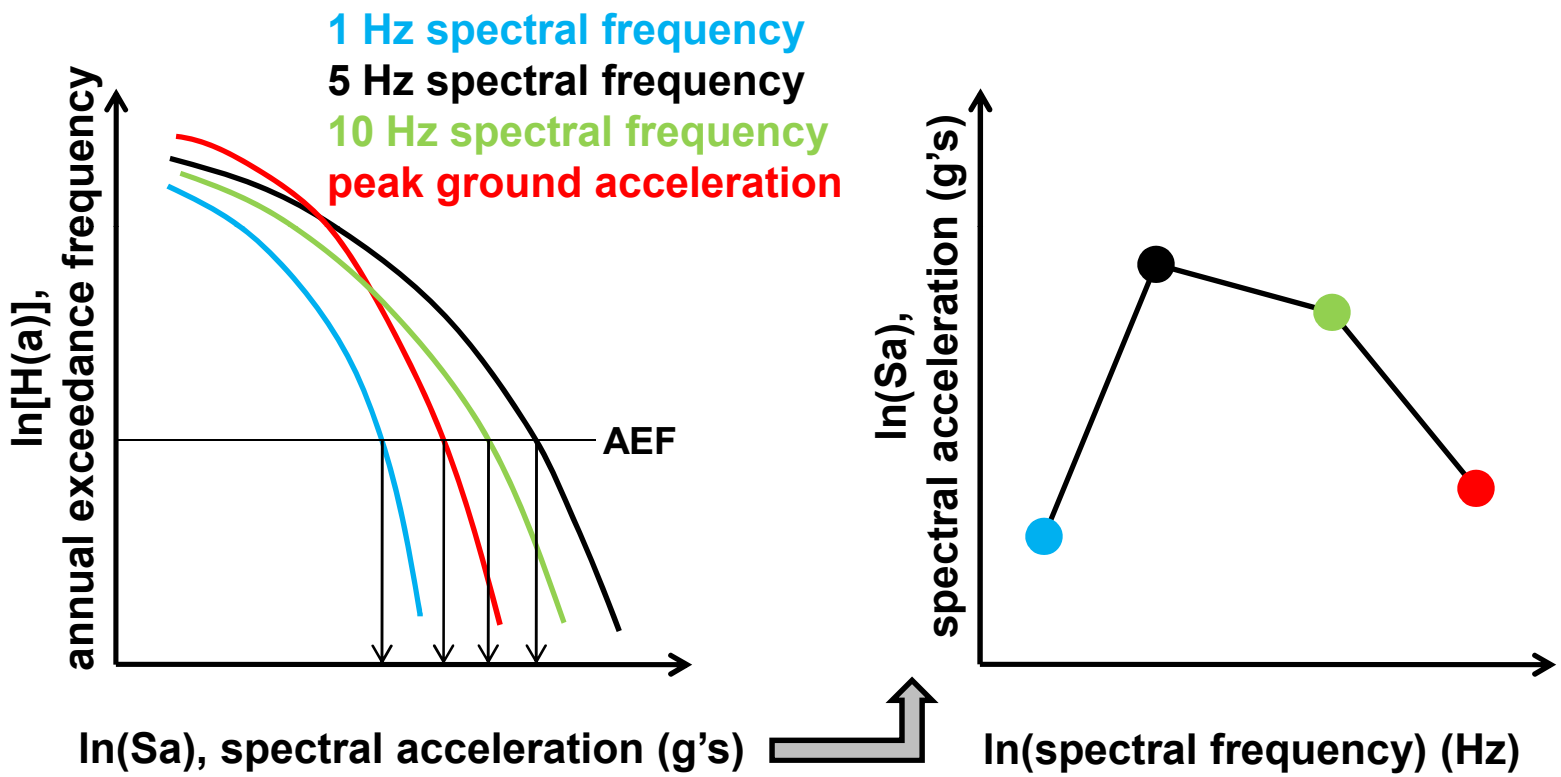
Seismic Hazard Results- For Each Site





Uniform Hazard Spectra



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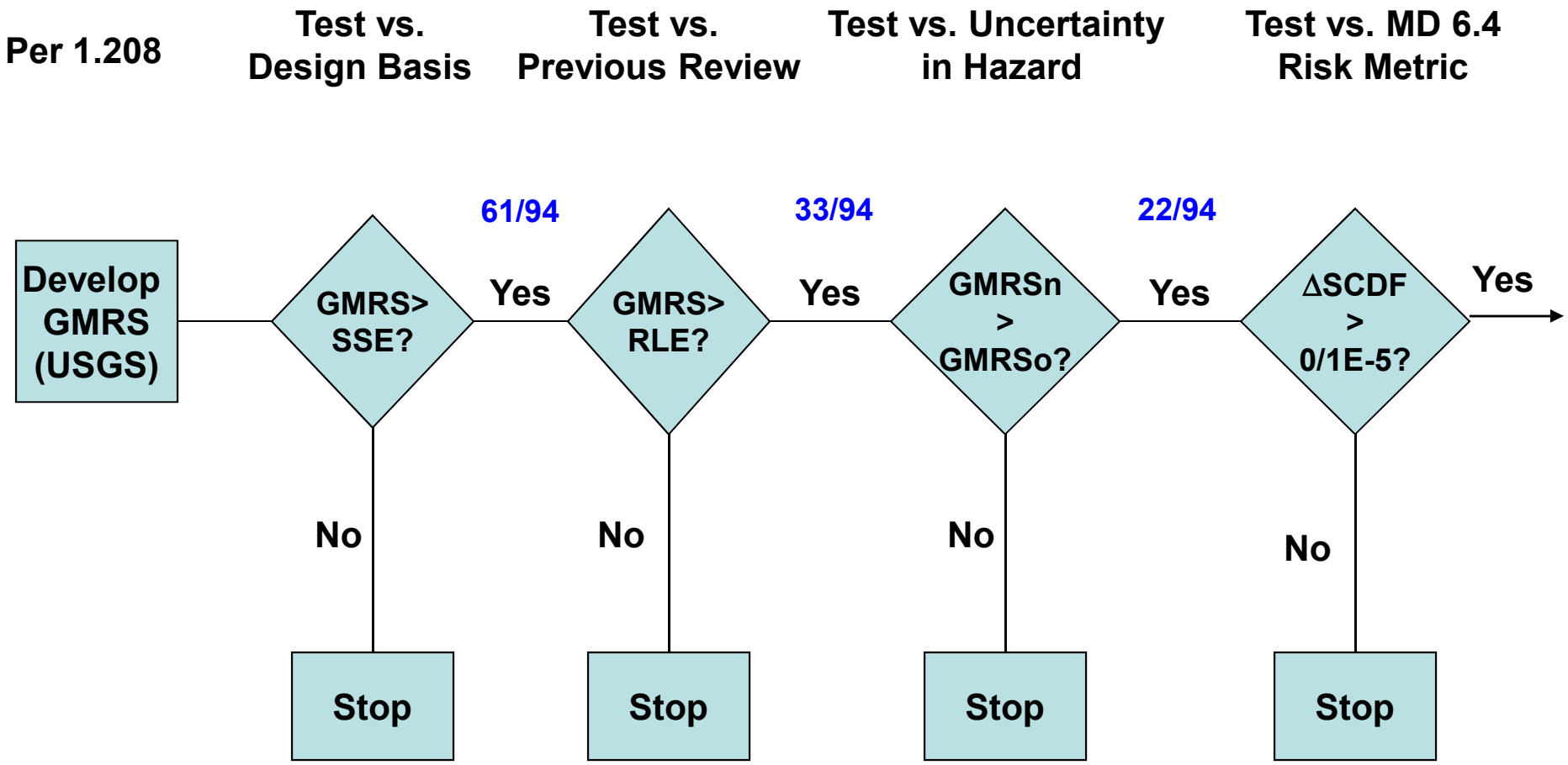
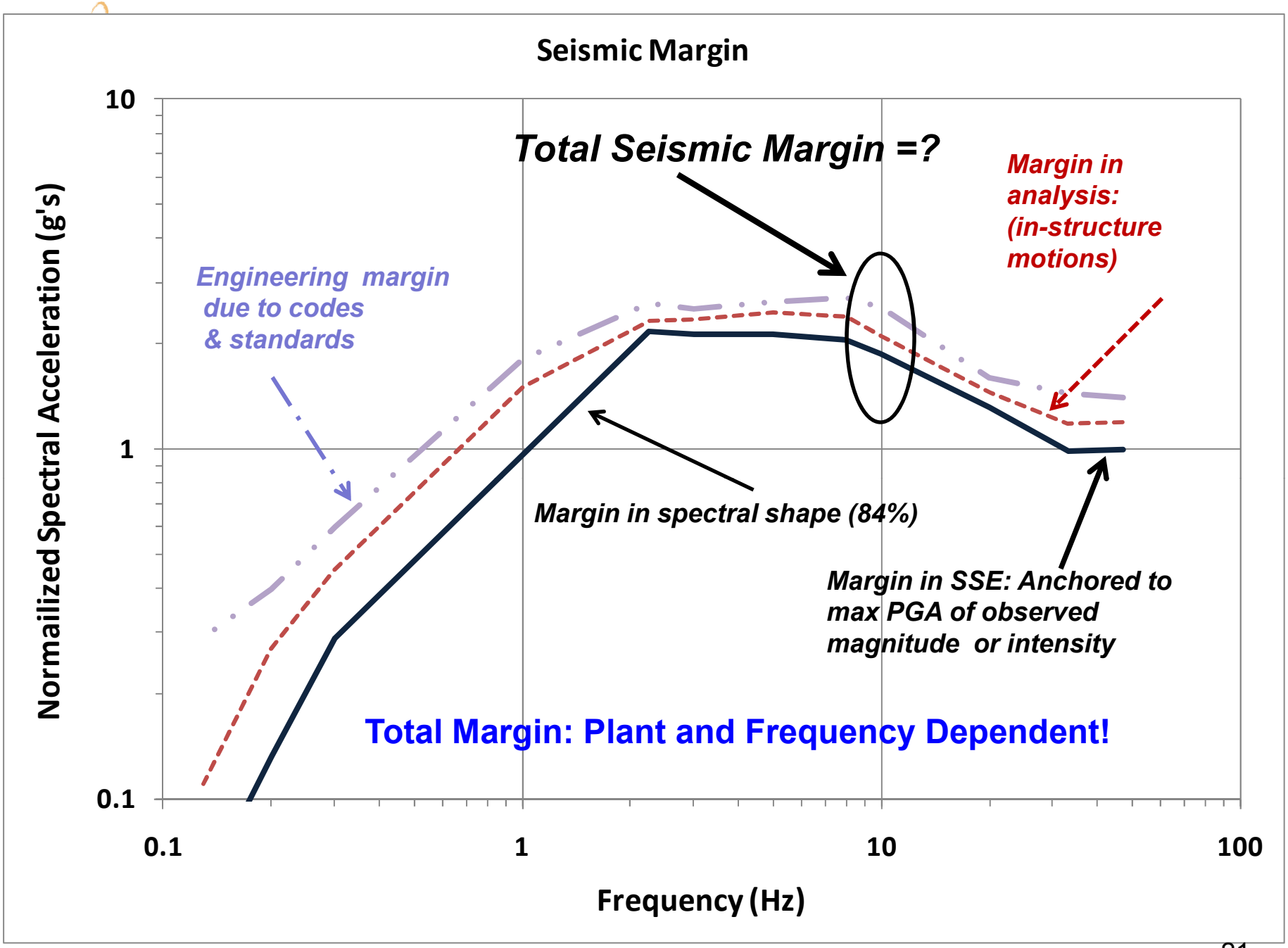
Individual Plant Examination of External Events (IPEEE) Program

- 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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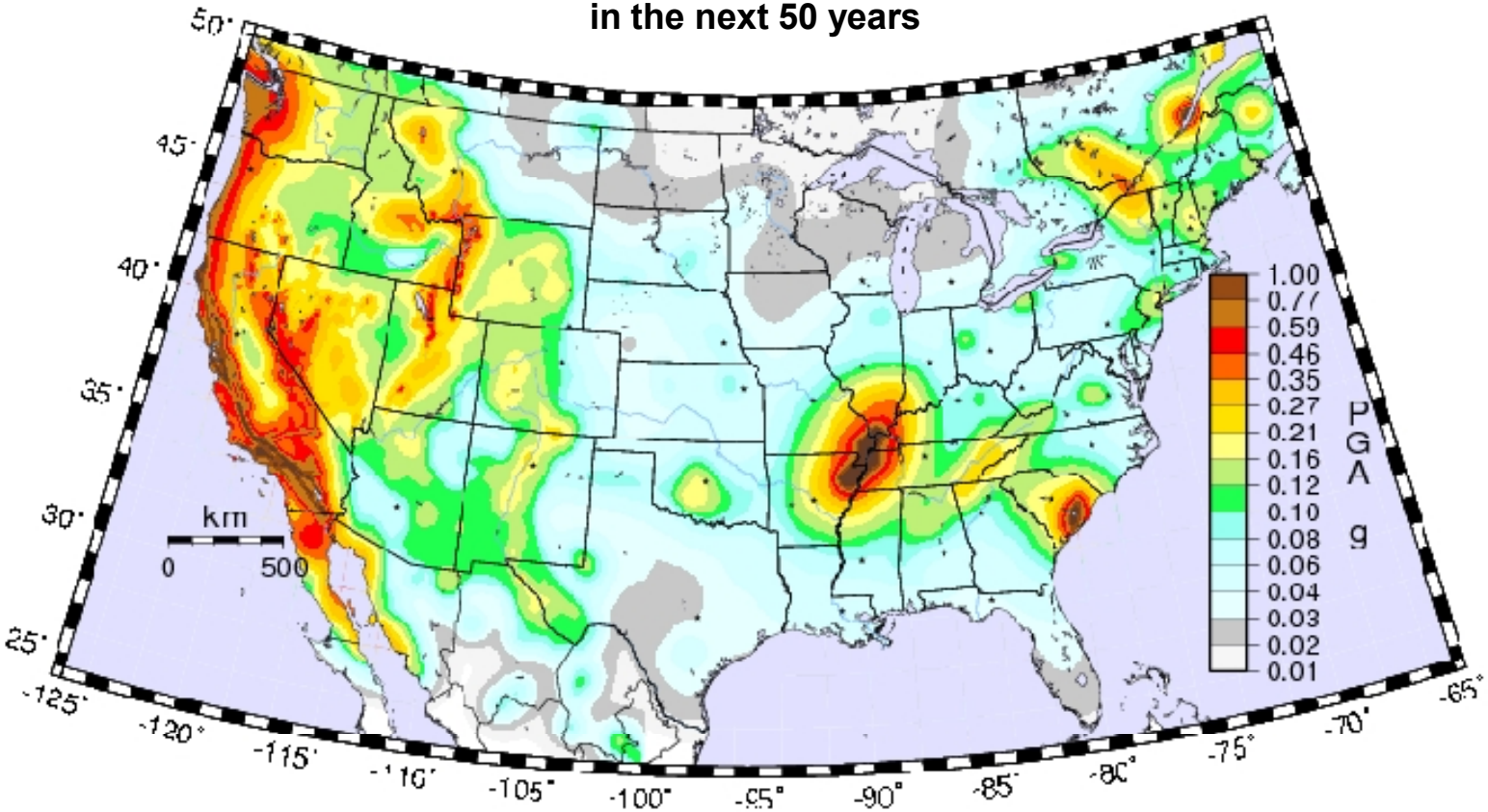
Seismic Hazard Variability

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



Source: earthquake.usgs.gov

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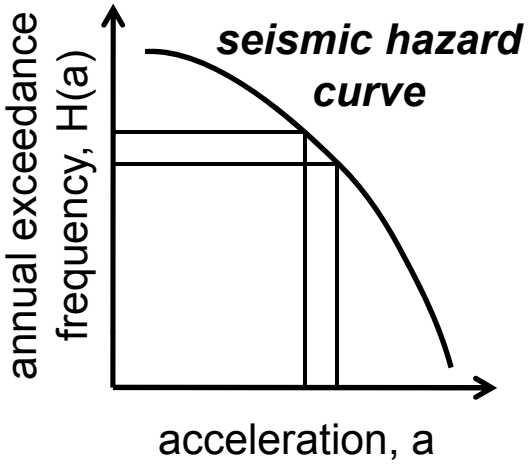
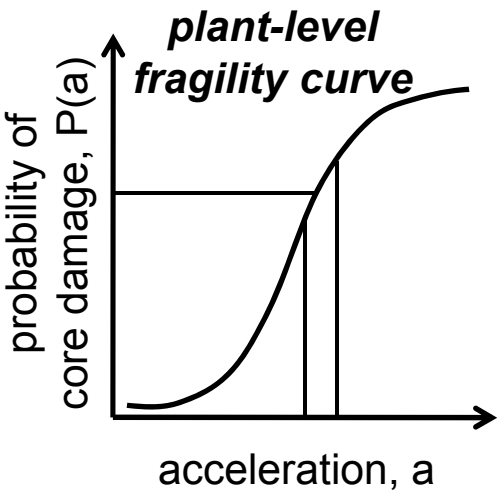
Crafting an Approach

- 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.

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

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

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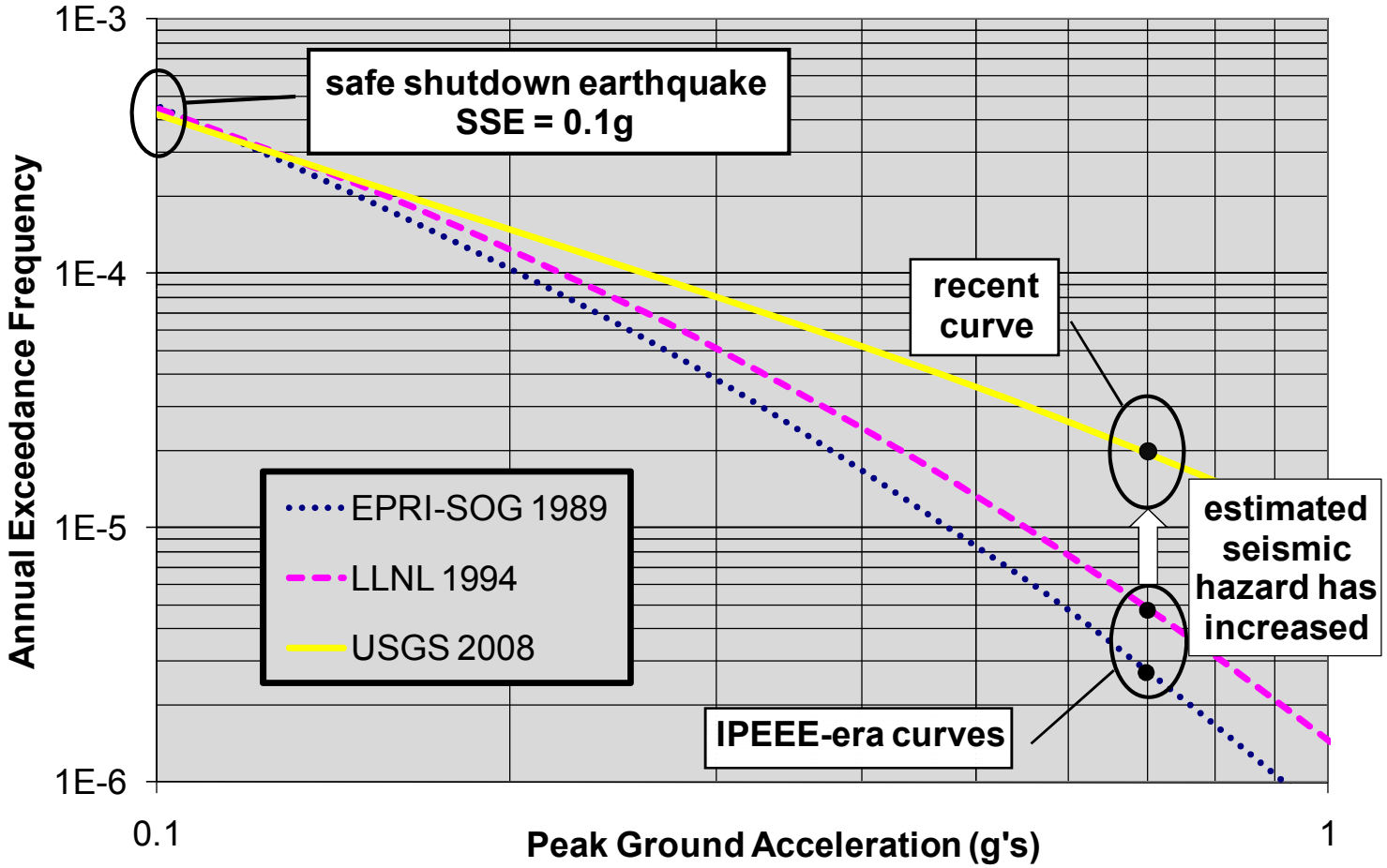
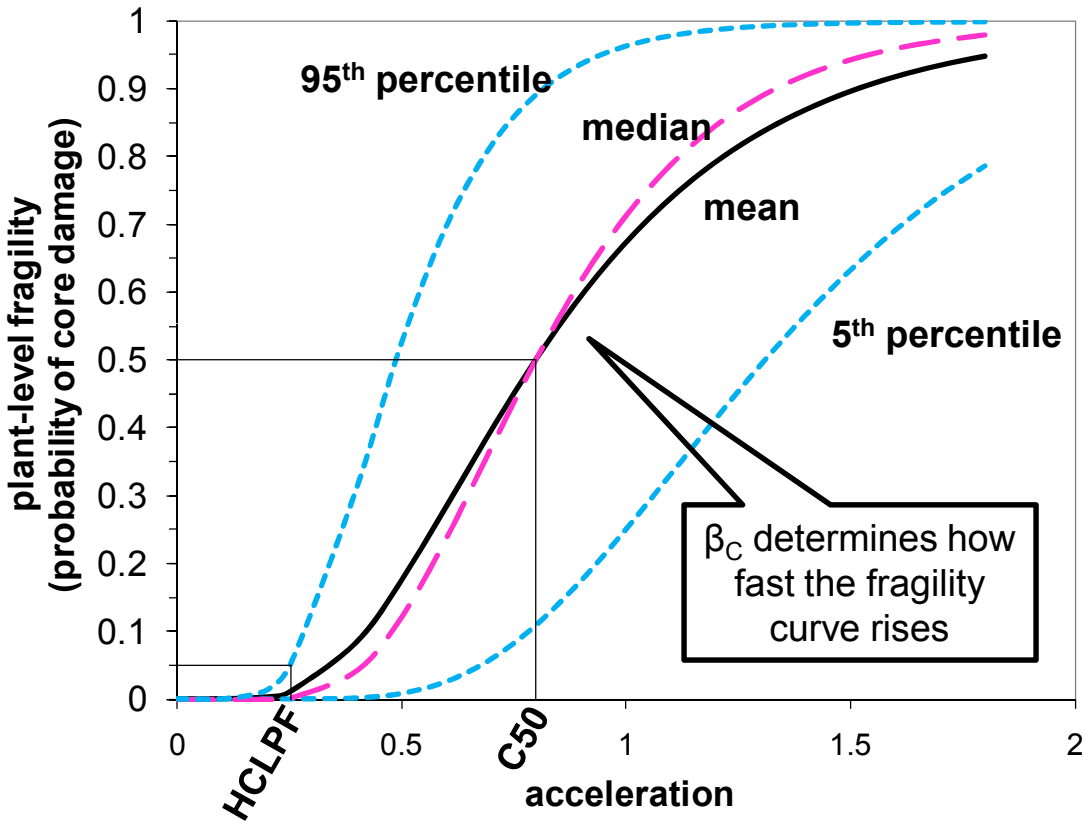
Example Seismic Hazard Curves



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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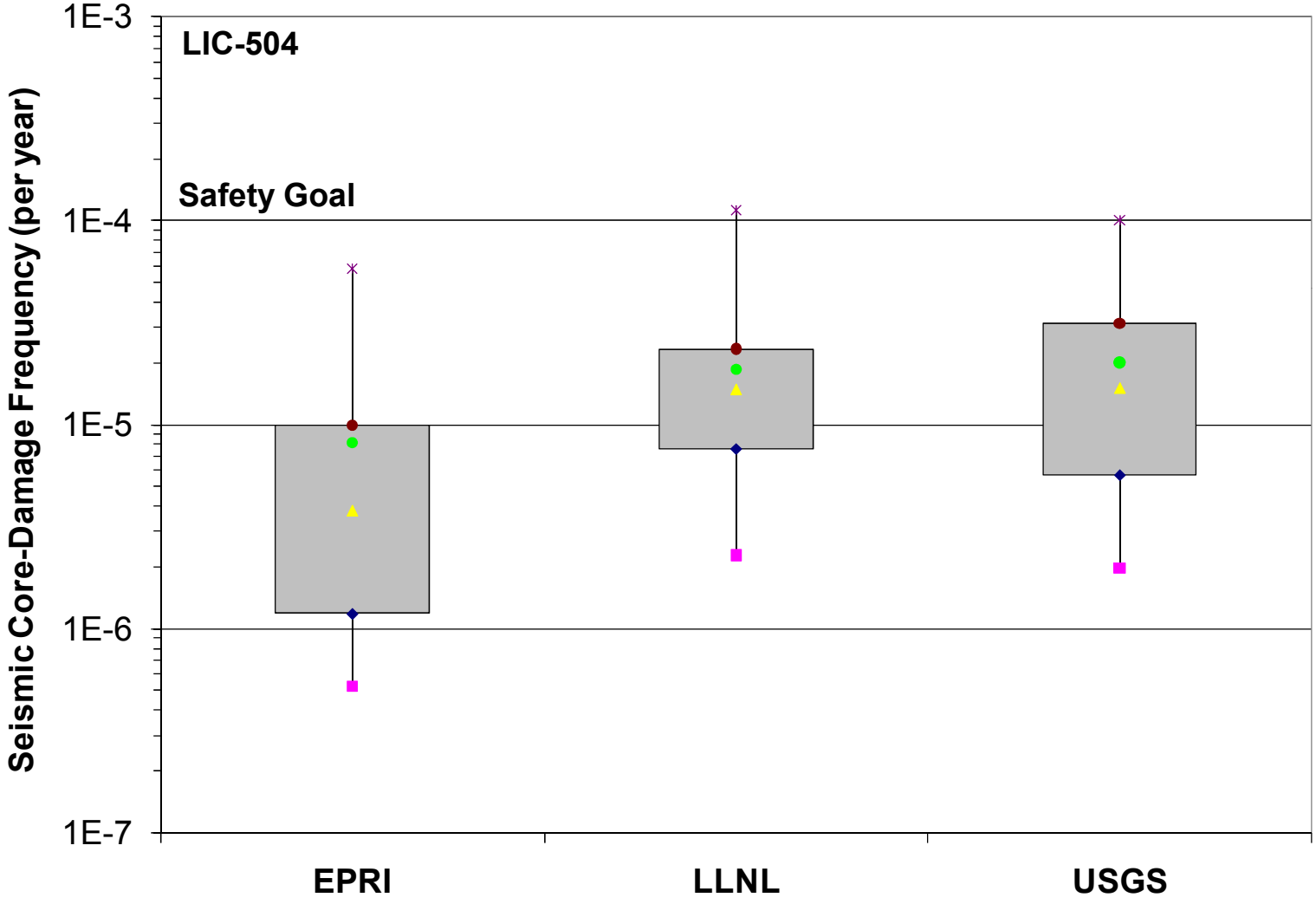
Fleetwide SCDF Variability



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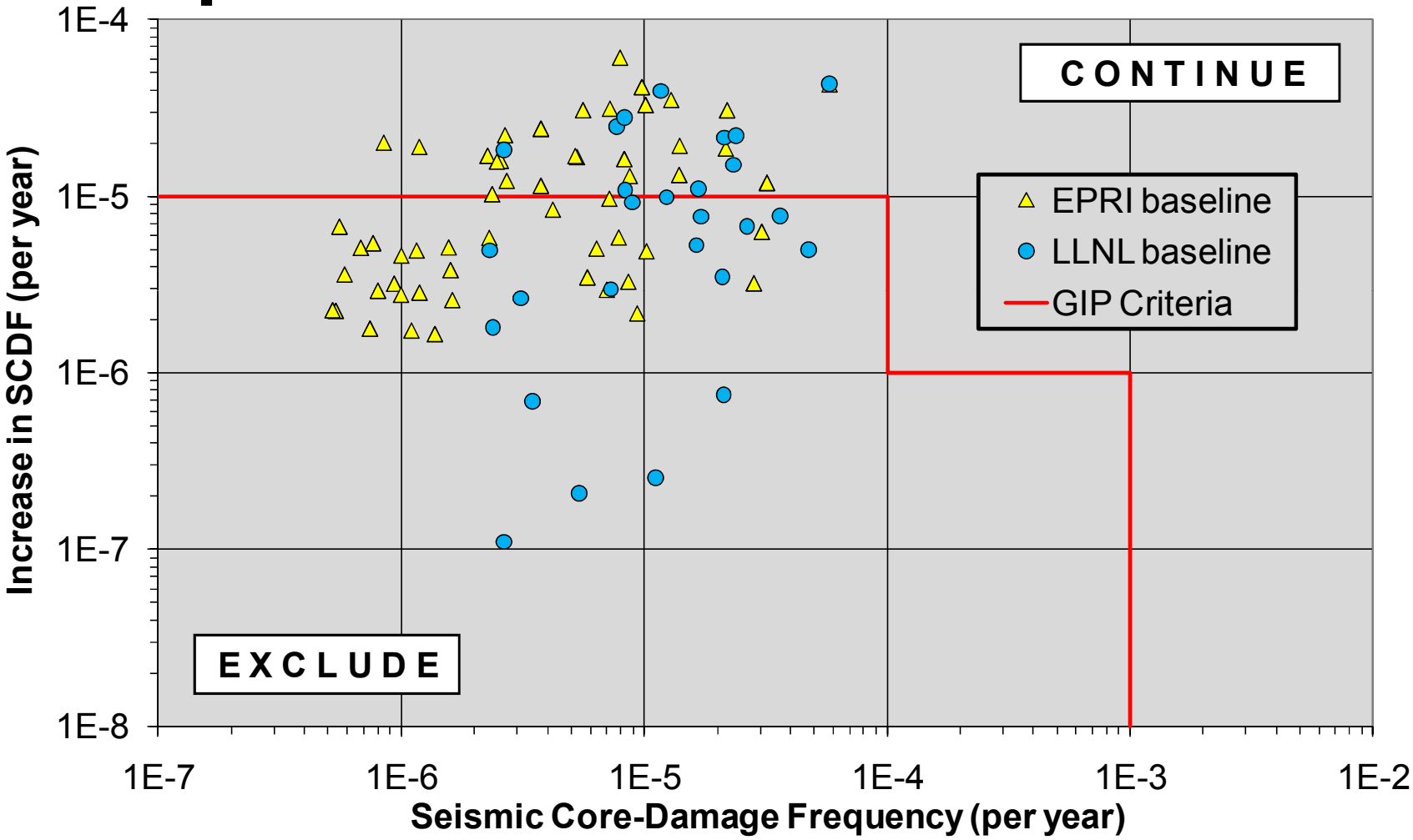
Comparison to GIP Criteria



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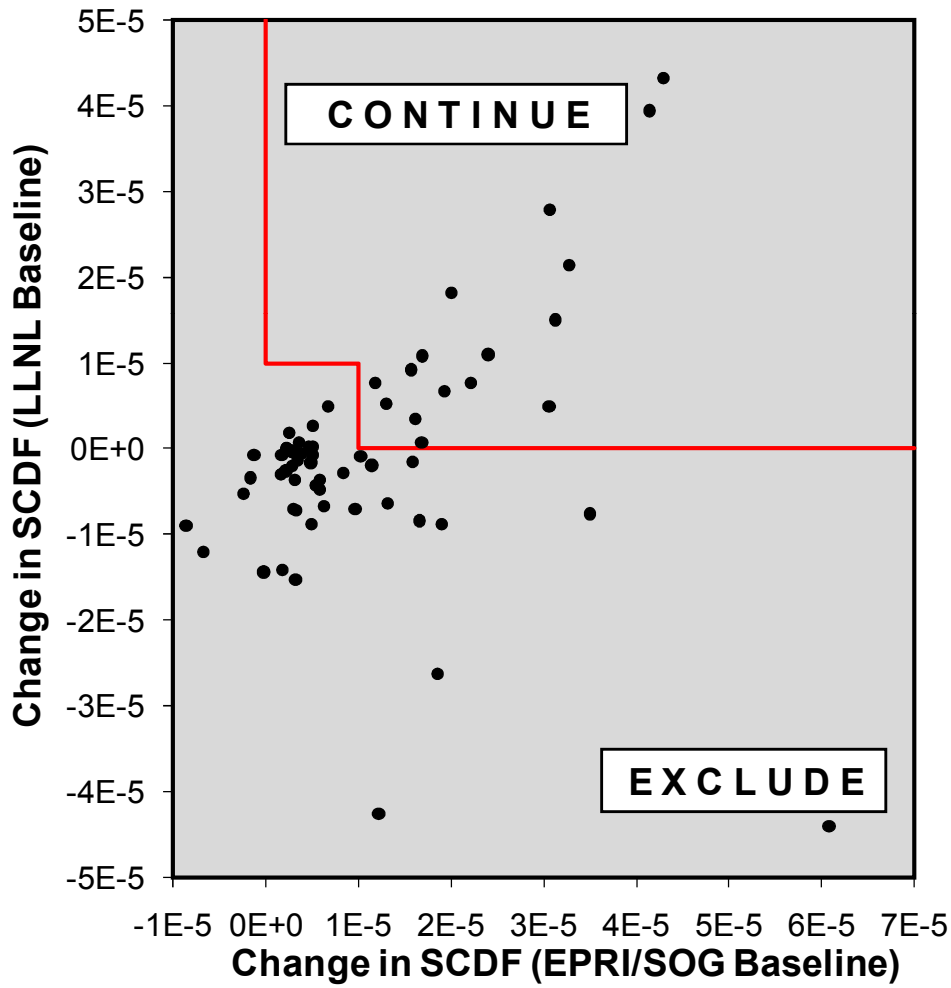
Delta-Delta Plot



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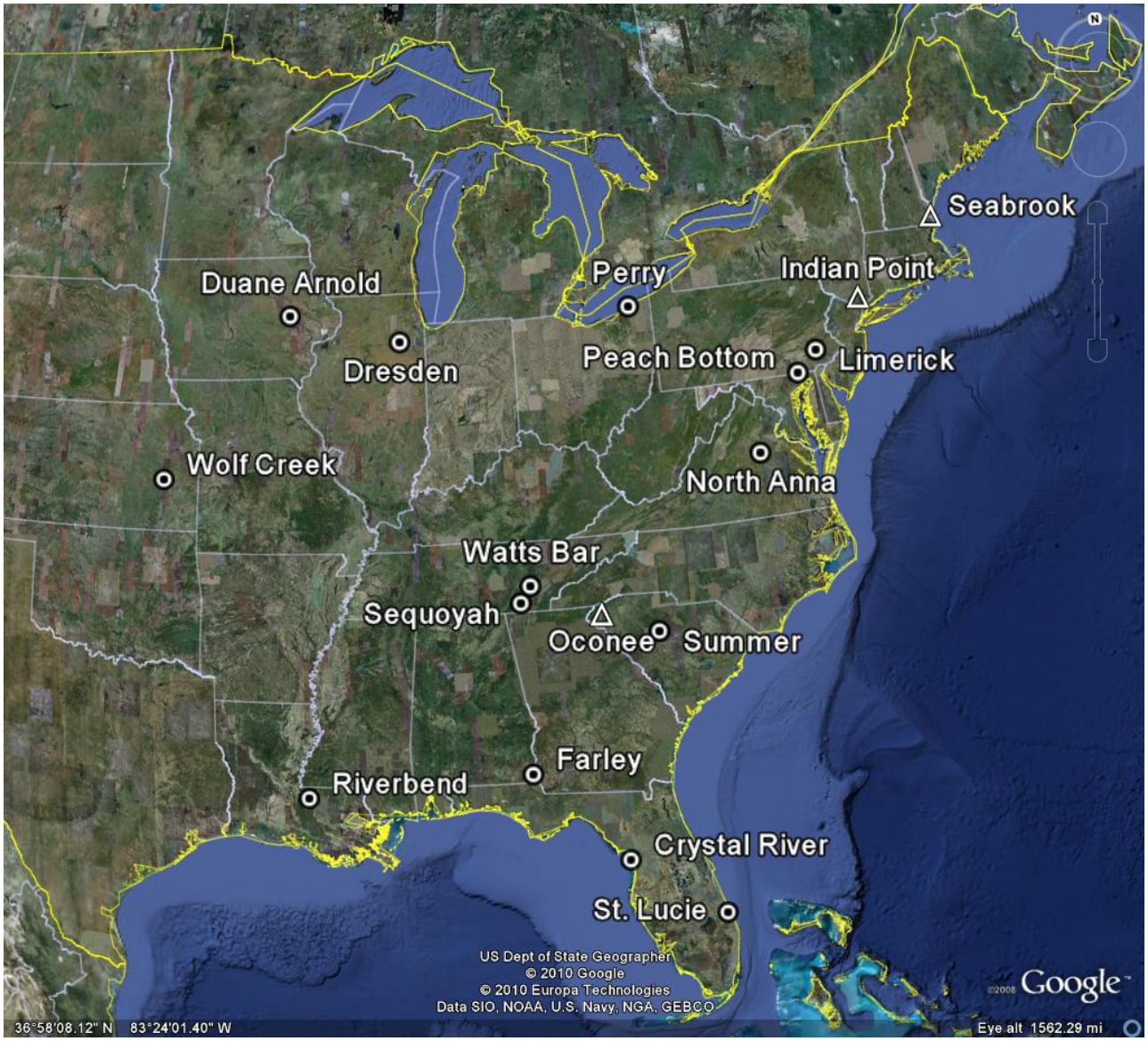

Plants in the "Continue" Zone

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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

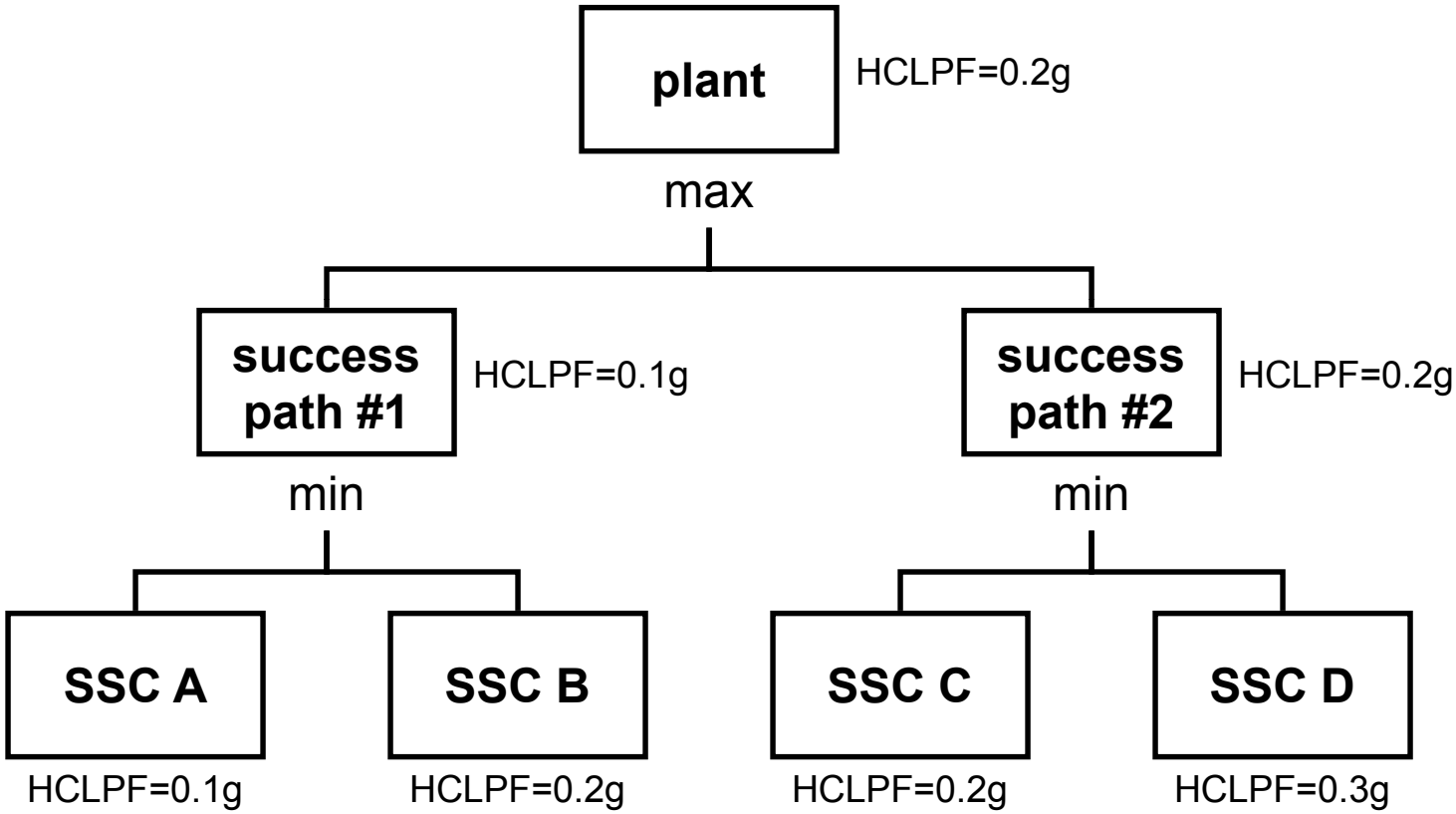
2E-6

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

Improving the Plant-Level HCLPF



Which SSC should be improved to increase the plant-level HCLPF?

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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 and 2010-019 to inform licensees of the GI-199 Safety/Risk Assessment results
  - Develop a generic communication to request needed data
  - RES will work with EPRI on method for plants that used Seismic Margins Analysis (SMA)
  - RES will develop inputs for GI-199 regulatory analysis under a user need request

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GI-199 Key Points

- Operating power plants are safe
- Seismic hazard estimates have increased at some sites
- Assessment of GI-199 will continue
  - Information is needed to perform regulatory assessments
  - NRC will request the needed information

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Thanks

QUESTIONS?

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Backup Slides

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

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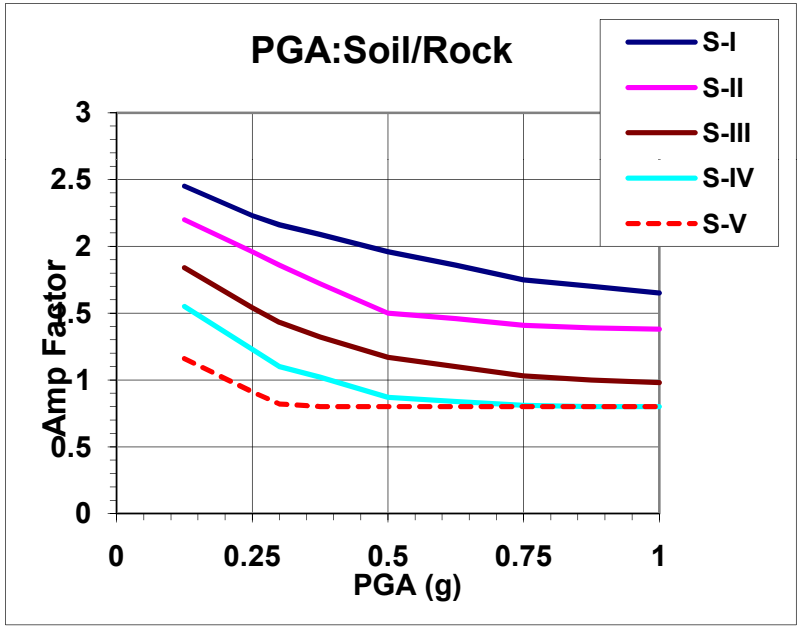
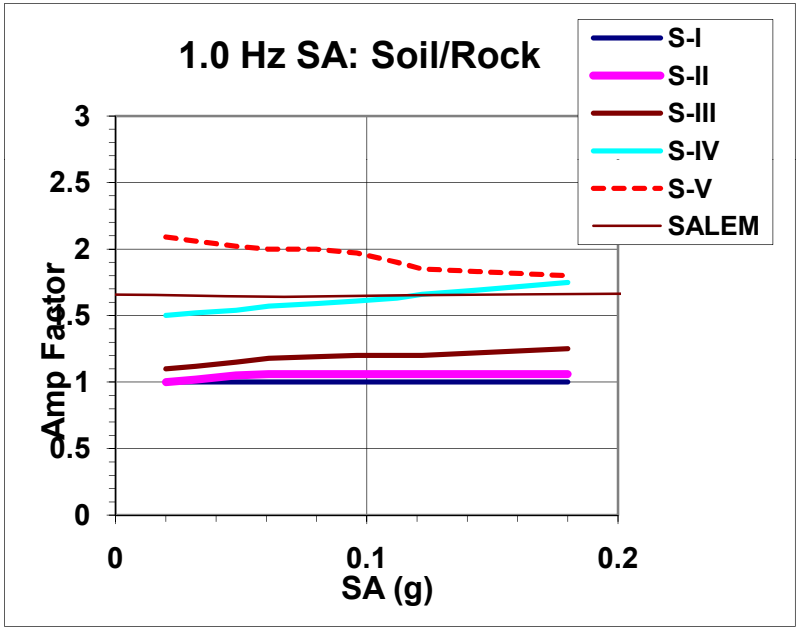
Example Soil Amplification Functions





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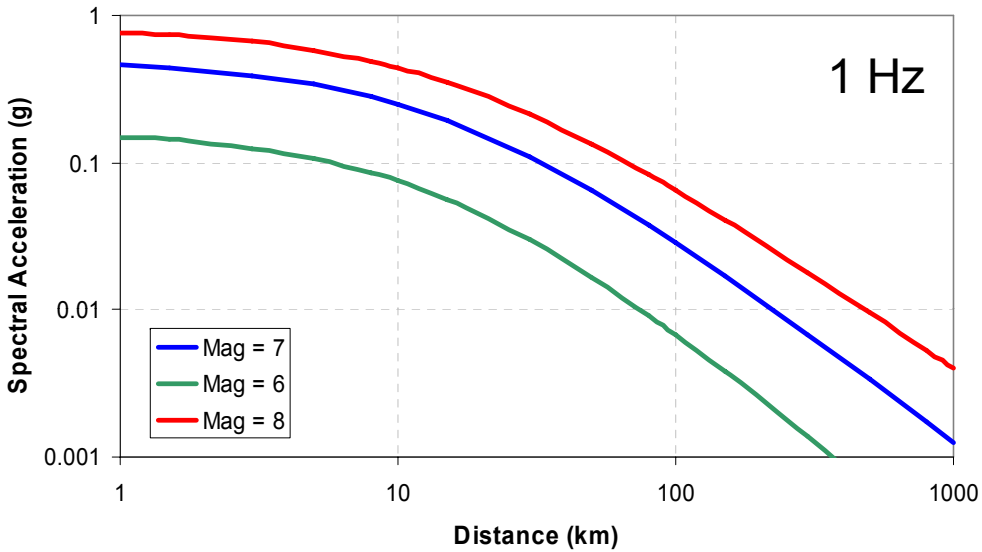
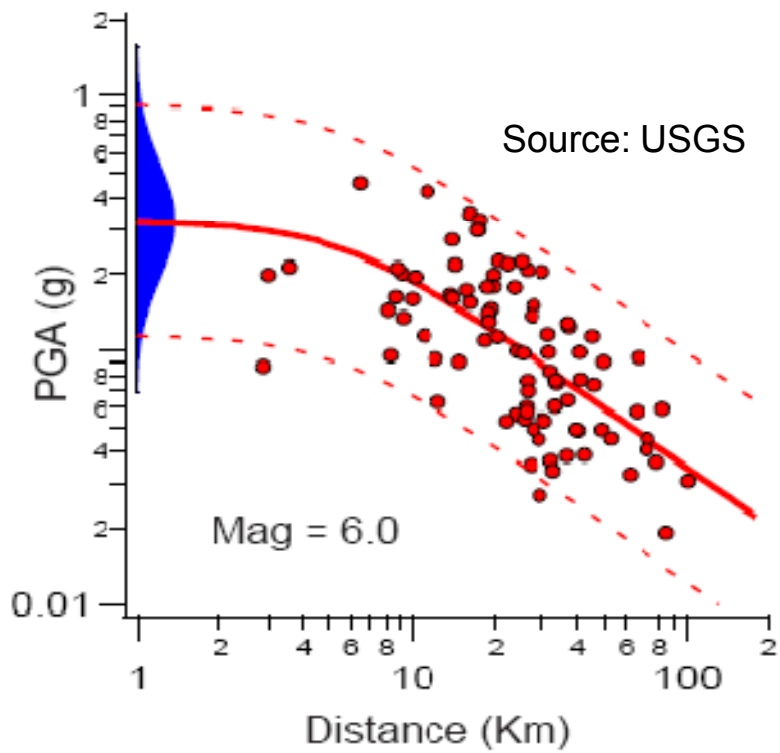
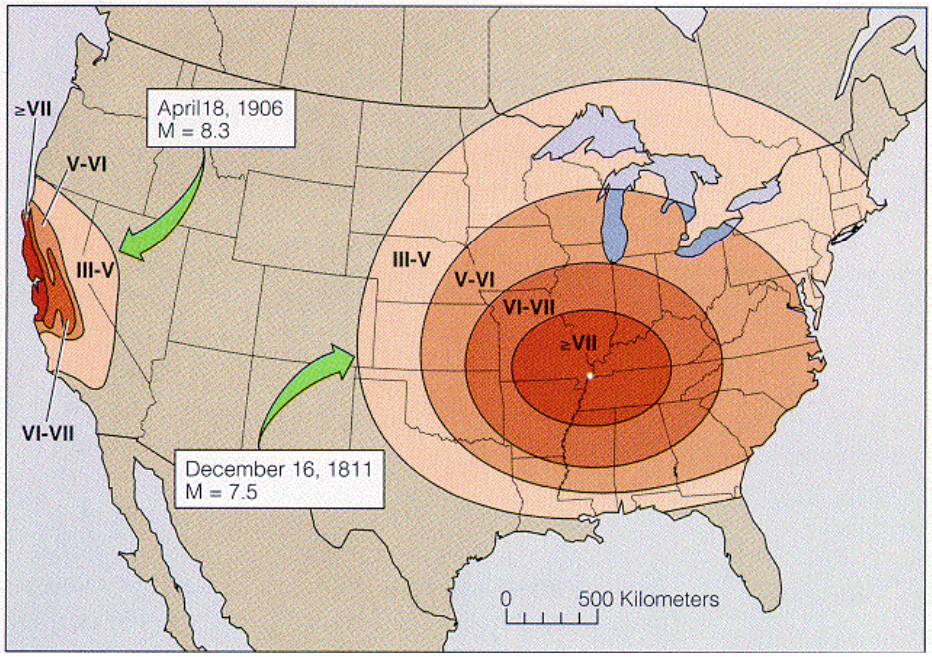
Seismic Wave Amplitudes vs. Distance





Ground Motion Prediction Models

- **Seismic attenuation is region specific**



- **Different ground motion prediction models are used for western and eastern United States**

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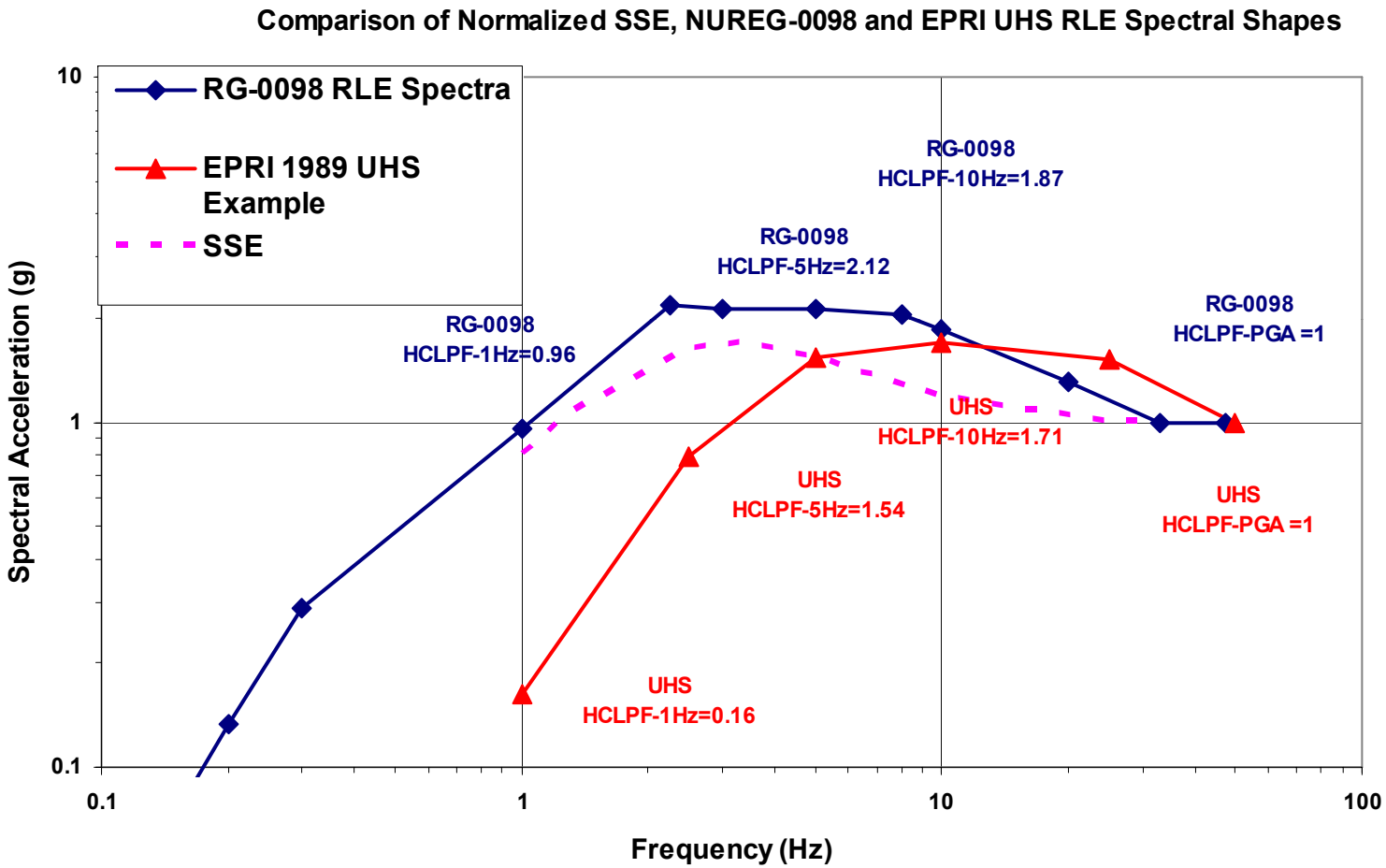
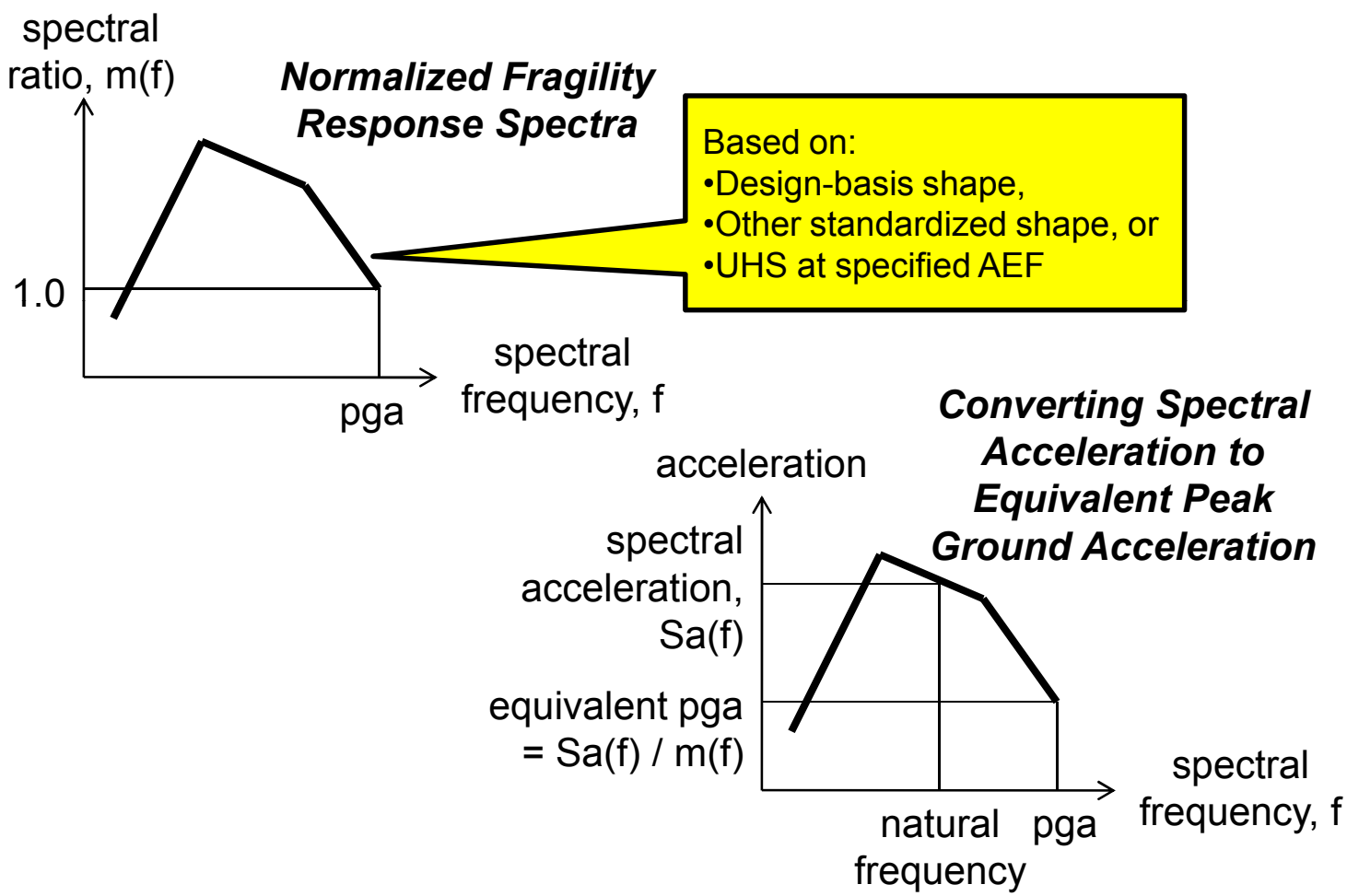
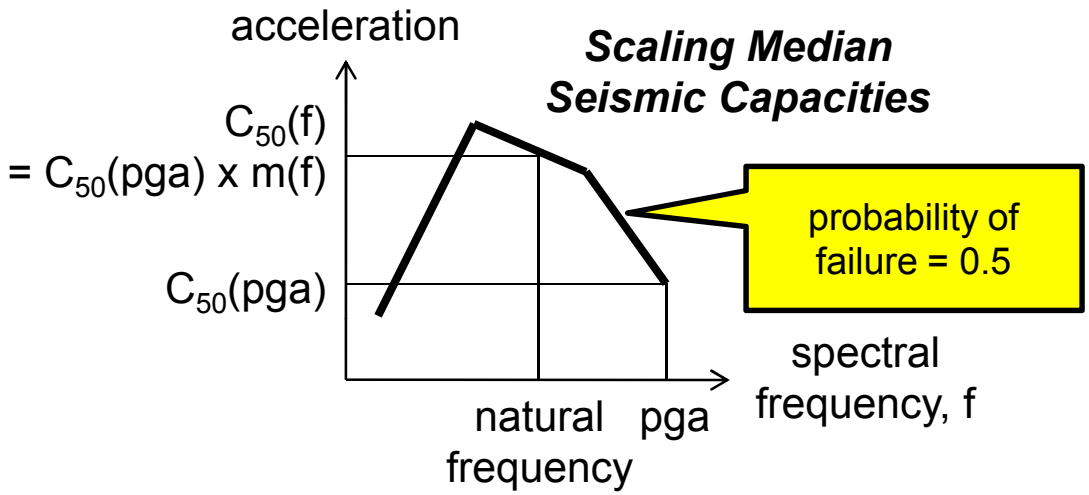
Response Spectral Shape

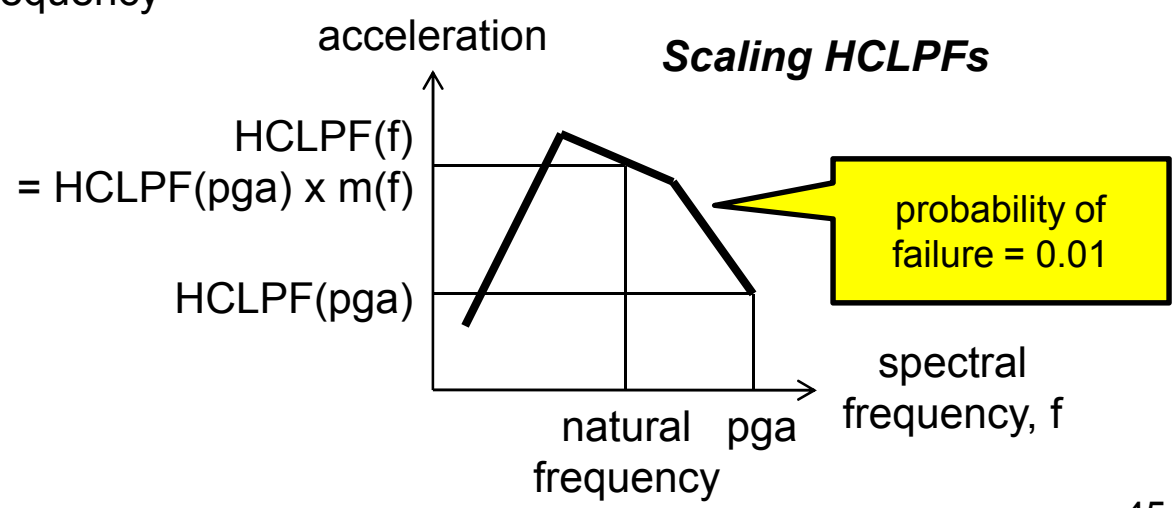


Spectral Ratios

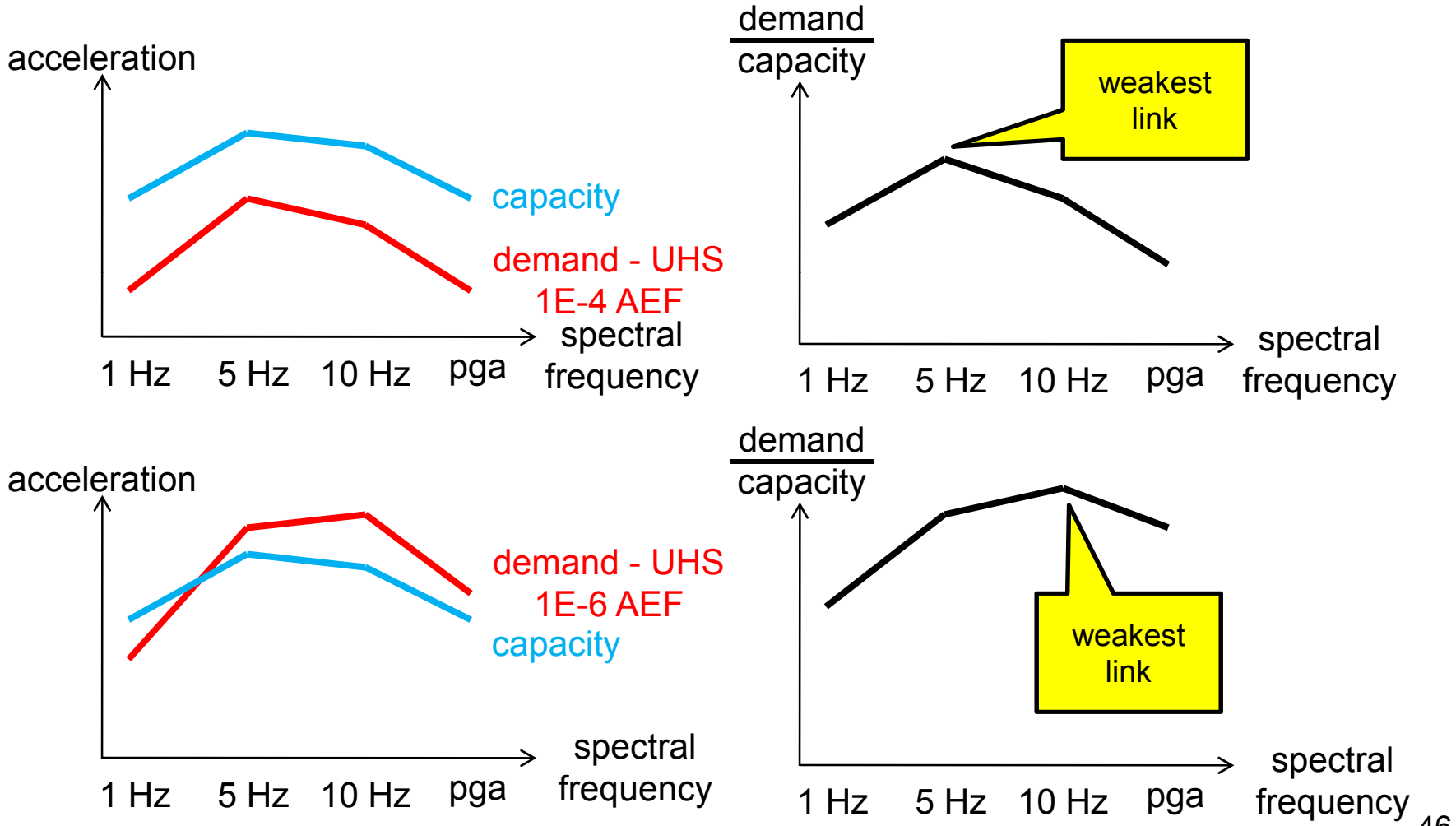


Spectral Fragility





The Weakest Link Model



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Algorithm for the Weakest Link Model

- Pick a value of peak ground acceleration (pga).
- Find the corresponding spectral accelerations from the spectral seismic hazard curves (i.e., find the UHS for the given pga).
- For each spectral frequency, compute the ratio of the spectral acceleration (demand) to the median seismic capacity at that spectral frequency.
- Over all spectral frequencies, find the maximum ratio of spectral acceleration to the median seismic capacity (i.e., the weakest link).
- Compute the probability of core-damage

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RESULTS

- For each CEUS plant, we determined 8 SCDFs for each hazard curve:
  - SCDF(pga)
  - SCDF(1 Hz), SCDF(5 Hz), and SCDF(10 Hz)
  - Simple average of SCDF(pga), SCDF(1 Hz), SCDF(5 Hz), and SCDF(10 Hz)
  - IPEEE-weighted average: 1/7th of SCDF(pga) plus 2/7th each of SCDF(1 Hz), SCDF(5 Hz), and SCDF(10 Hz)
  - The maximum of SCDF(pga), SCDF(1 Hz), SCDF(5 Hz), and SCDF(10 Hz)
  - The weakest link model
- Implemented in MS Excel® with Visual Basic® macros.
- Calculation time of the entire workbook is several minutes.

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The Generic Issues Program (GIP)

- Description
- Purpose
- Resources
  (http://www.internal.nrc.gov/RES/projects/GIP/index.html)
  (http://www.nrc.gov/about-nrc/regulatory/gen-issues.html)
- Improvements

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The Seven GIP Criteria

1) Significant implications for public health and safety
2) Applies to two or more facilities
3) Not readily addressable through other established regulatory processes
4) Can be resolved by regulation, policy, or guidance
5) Risk or safety significance can be adequately determined or estimated
6) Well defined, discrete, technical
7) May involve review, analysis, or action by the licensee