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Methodology of Seismic Margin Assessment and Evaluation Examples in the US

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Outline of Presentation

- Motivation
- History of SMA
- SMA Concepts
- SMA Features
- Steps in Seismic Margin Methods
- Results from trial Plant SMAs
- IPEEE Insights
- Industry Standard and Regulatory Guides
- Summary and What is Next

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Motivation

- Seismic hazard analysis performed in the seventies indicated likelihood of earthquakes larger than the SSE
- ACRS raised the question of actual seismic margin beyond the design basis
- Large uncertainties in seismic PRA results
- Deterministic Process using probabilistic insights – easily understood and communicated

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History of SMA

- Seismic Safety Margin Research Program in early eighties
- NRC formed an expert panel to address the question of seismic margin
- NRC expert panel addressed easier task
  - review the plant against a specific earthquake level (i.e., SME) and determine whether plant has a high confidence of low probability of failure for SME
  - if less than SME, then calculate the plant "high-confidence low probability of failure (HCLPF)" capacity
- Fragility Analysis (FA) and Conservative Deterministic Failure Margin (CDFM) methodologies

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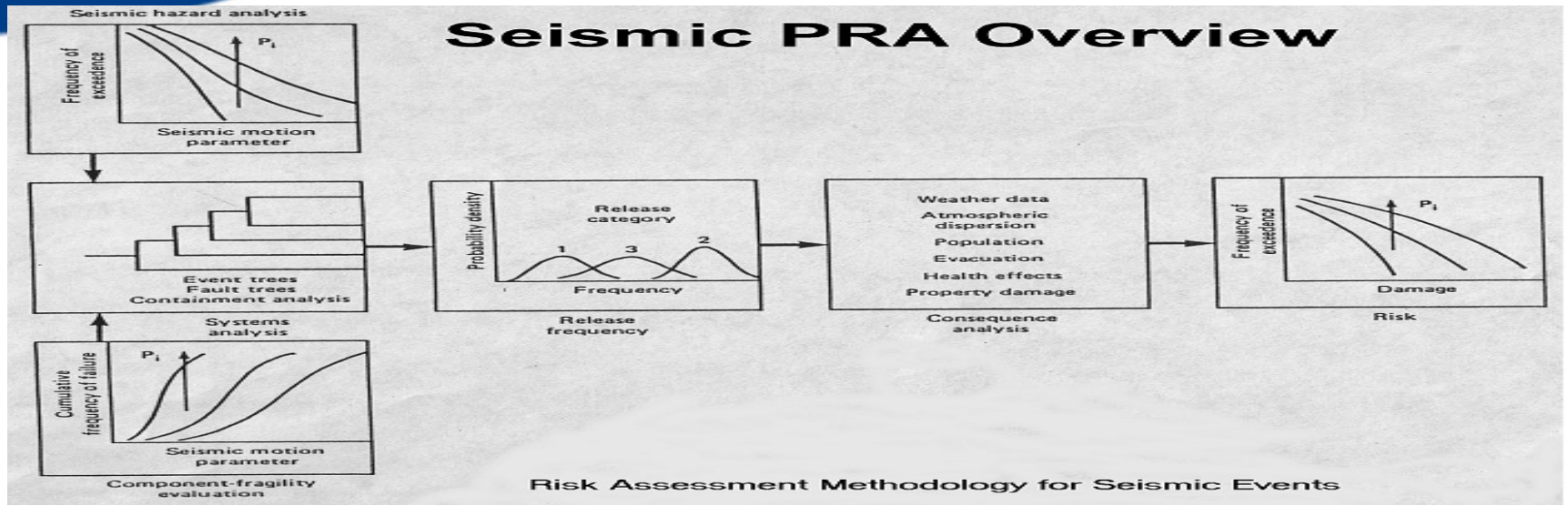
History of SMA (cont.)

- NRC expert panel (NRC Methodology – abbreviated system event tree/fault tree models)– NUREG/CR-4344
- Maine Yankee plant trial review using NRC method– NUREG/CR-4826
- EPRI Methodology (success path approach)- EPRI NP-6041
- Catawba trial review using EPRI method – EPRI NP-6359
- Hatch A-46/SMA trial review using EPRI method – EPRI-NP 7217-SL
- EPRI NP-6041, Revision 1
- IPEEE guidance document, NUREG 1407
- IPEEE Insights – NUREG - 1742
- ASME/ANS Standard (Including Augmented SMA)

Seismic Margin Concepts



Seismic Margin Overview

SYSTEM MODELING
Abbreviated system models for dominant initiators

IDENTIFICATION OF SSCs
System and Walk downs

SCREENING OF SSCs
Eq. exp., PRAs, Tests

CAPACITY OF COMPONENTS
Deterministic Fragility method

EARTHQUAKE (GROUND) MOTION
One fixed level (RLE)
> Design Basis

RESULTS
Plant capacity statement

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SMA Concepts

- Based on experience and insights from investigation of past earthquakes, shake table tests, past LWR PRAs and expert judgments
- Reliance on small team of responsible, trained seismic engineers to make on-site judgments of seismic ruggedness
- Pre-defined Review Level Earthquake (RLE)
- Component selection and screening by either fault/event tree or success path logic to achieve and maintain shutdown
- Deterministic plant seismic capacity in terms of lowest capacity components

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SMA Features

- Deterministic evaluation of components needed to achieve and maintain shutdown for 72 hours
- Most practical for RLE at or below 0.3g Peak Ground Acceleration (PGA)
- Does not require hazard data or fragility calculations
- Produces HCLPFs but does not give core damage frequency (CFD) directly, no uncertainty characterization
- Only transients and small-LOCA initiators considered
- Non-seismic failures, operator actions, and reliability not included directly in the success path approach

Steps in Seismic Margin Methods

- Selection of review level earthquake (RLE)
- Selection of assessment team
- Pre-walkdown preparation
- Selection of success paths and elements
- Ruggedness screening
- Seismic capability walkdown
- Evaluation of unscreened components
- Subsequent walkdowns (as needed)
- Documentation

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Selection for Review Level Earthquake (RLE)

- Prescribed ground motion response spectrum shape and PGA anchor
- For seismic IPE NRC prescribed RLE to be NUREG/CR-0098 median spectral shape anchored to 0.3g for most plants

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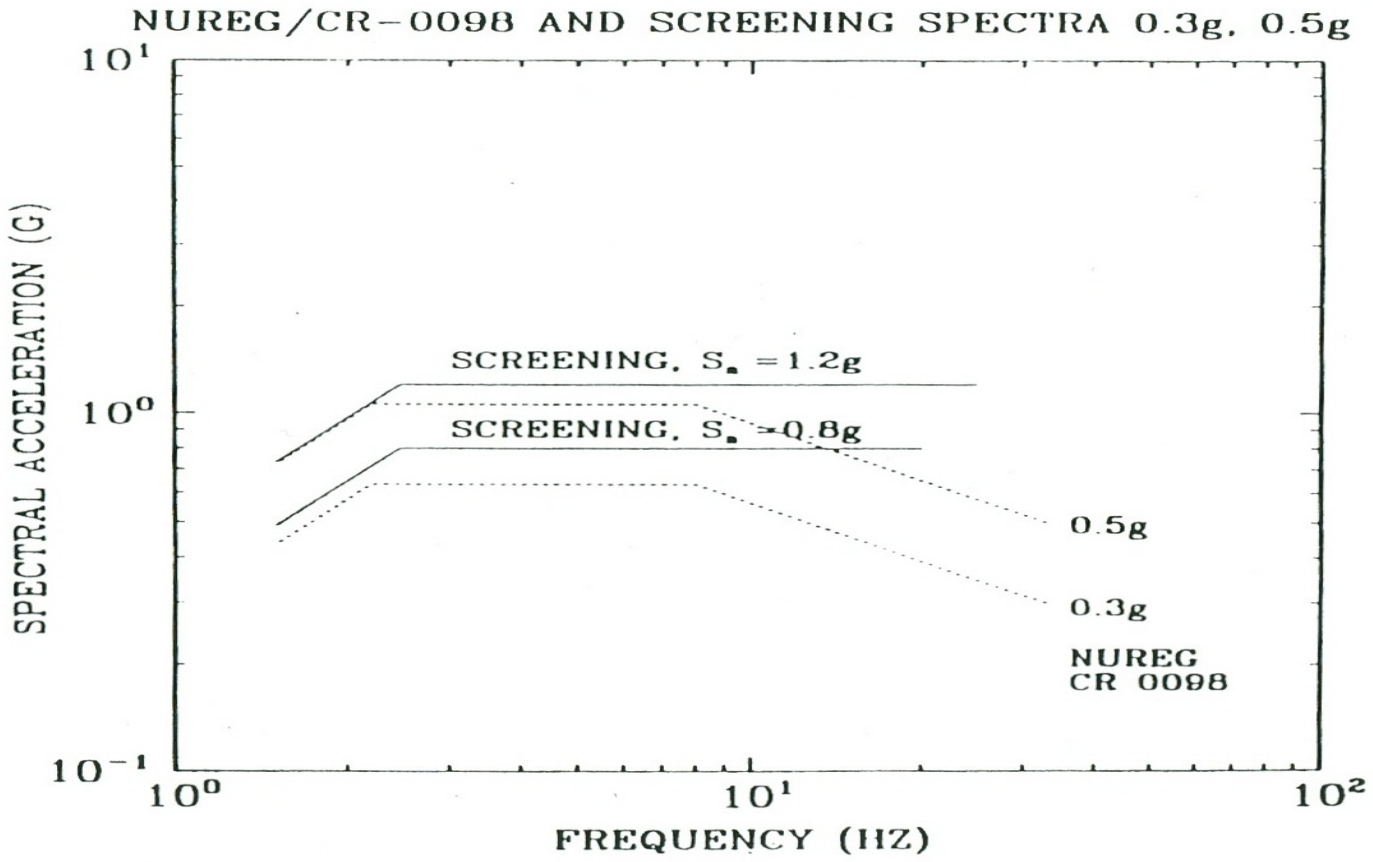
NUREG/CR-0098 and Screening Spectra 0.3g, 0.5g



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Success Path Conditions

- Assume loss of offsite power
- Minimum of two paths
- One path with SBLOCA mitigation
- Reliability of active components
- Operator preferred paths
- Procedure exit
- Sufficient instrumentation to allow use of each path

HCLPF Concept

- The result of a SMA review is the statement:
  - **The HCLPF for the plant exceeds the RLE, or**
  - **The HCLPF for the plant is "x"**
- HCLPF is defined as "high confidence of a low probability of failure"
- HCLPF can also be interpreted as: "approximately" a 95% confidence of about 5% or less probability of failure
  - **In the fragility analysis (FA) method HCLPF capacities are defined to be 95-5 values as an operation rule**

HCLPF Concept (Cont.)

- The Procedures for calculating HCLPFs in NP-6041 uses the Conservative Deterministic Failure Margin (CDFM) method
  - Analysis are similar to a design analysis, but using different factors
  - The CDFM procedures is understandable to design engineers
- The safety factors in NP-6041 have been calibrated to give similar results compared to using the FA method

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Results from Trial Plant SMAs

- Three plants completed — HCLPF
  - Catawba – Unit 2 — > 0.30g
  - Maine Yankee — 0.28g

    (Tank upgrade – no relay review)
  - Hatch – Unit 1 — >0.30g
- Predominant Outliers
  - Anchorage
  - Interactions
  - Design independent
- Relays not a significant problem

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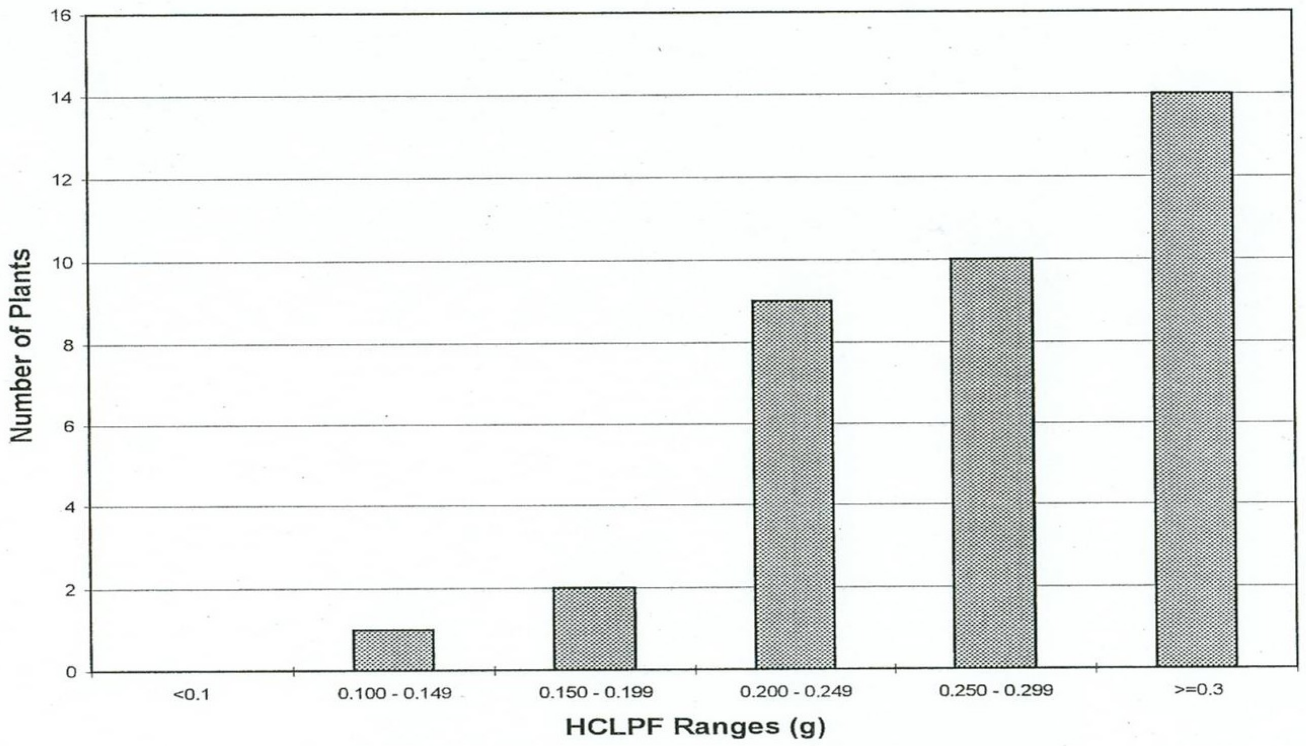
SMA Results from IPEEE (NUREG-1742)



Distribution of Plant HCLPF Values

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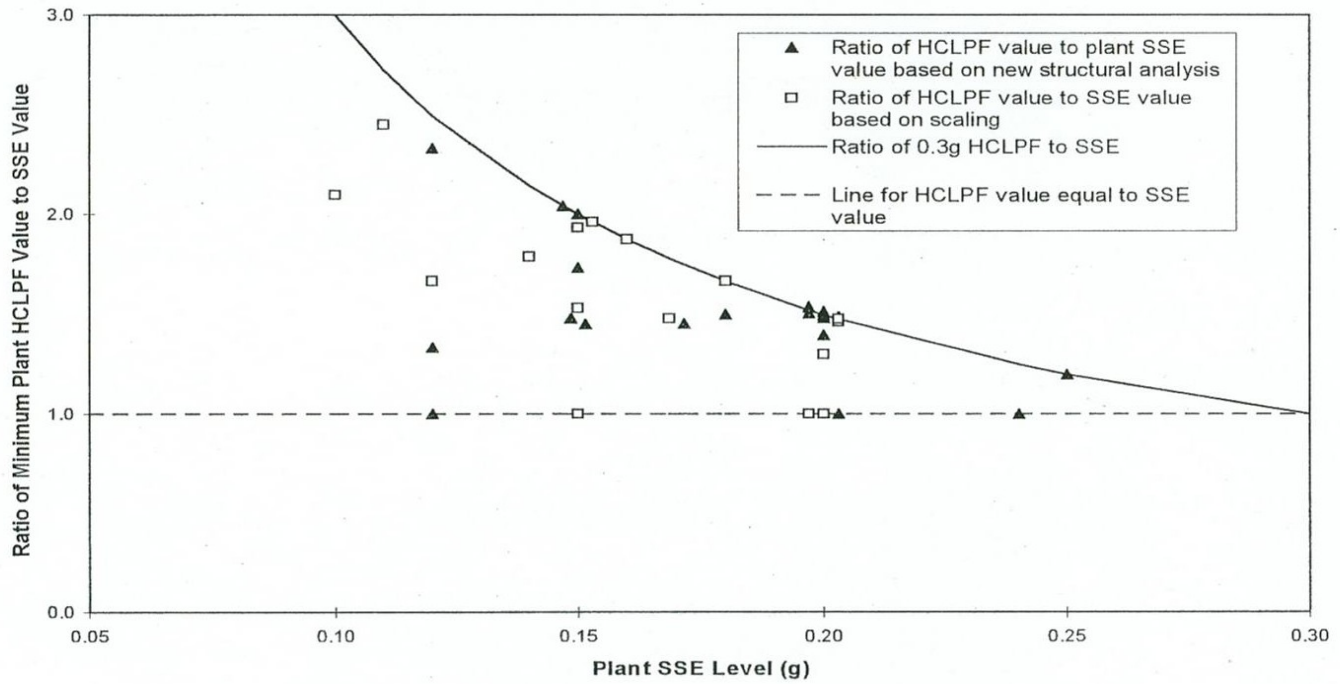
SMA Results From IPEE



Ratio of Plant HCLPF to SSE level plotted versus SSE level

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SMA Insights

- Electrical system components are frequently the governing outliers
- Building and structural failures, especially block walls, also significant
- Balance of weak links found among frontline and support systems and major tanks
- Seismic margins, in terms of RLE HCLPF values above SSE, vary significantly among plants

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SMA Insights (Cont.)

- No observable correlation between plant HCLPF values and plant vintage, i.e., with different seismic design standards (calculated HCLPF values cannot be higher than 0.3g because of screening)
- With proposed improvements taken into account, no plants reported HCLPF values below their SSE value
- Improvements identified by most licensees to enhance the seismic ruggedness
- Regardless of the approach used – a well planned, detailed walkdown is a key element

Industry Standard and NRC Regulatory Guides

- ASME/ANS RA-Sa–2009 - Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications:
- **Part 10 – Seismic Margin Assessment Requirements At-Power**

  "SMA methods can be used, as appropriate, for risk-informed applications".

  Nonmandatory Appendices:
  - 10-A Seismic Margin Assessment Methodology: Primer . . . . . .
  - 10-B Seismic Margin Assessment Applications Guidance, Including Seismic Margin Assessment With Enhancements . . . . . .
- RG. 1.200 – An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities

  "…..a seismic margins method is not an acceptable approach….."
- ISG – 20, PRA-Based Seismic Margin Analysis for New Reactors , defines positions for new reactors

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Summary

- Seismic margin methods provide a viable approach to evaluate plant capability beyond design basis
- Seismic margin methods are effective in identifying vulnerabilities
- SMA can provide limited risk insights with enhancements
- Thorough walk-downs are key element of any evaluation approaches