U.S. Department of Energy

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

Seismic Fragility of Structures, Systems and Components

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Fragility Evaluation

- **Determines conditional probability of unacceptable seismic performance (failure) vs. appropriate ground motion parameter (e.g., spectral acceleration)**
- **Unacceptable performance (failure) is:**
  - **The inability of an SSC to perform or provide its intended safety function**
  - **Defined in terms of Limit States per ASCE 43-05**

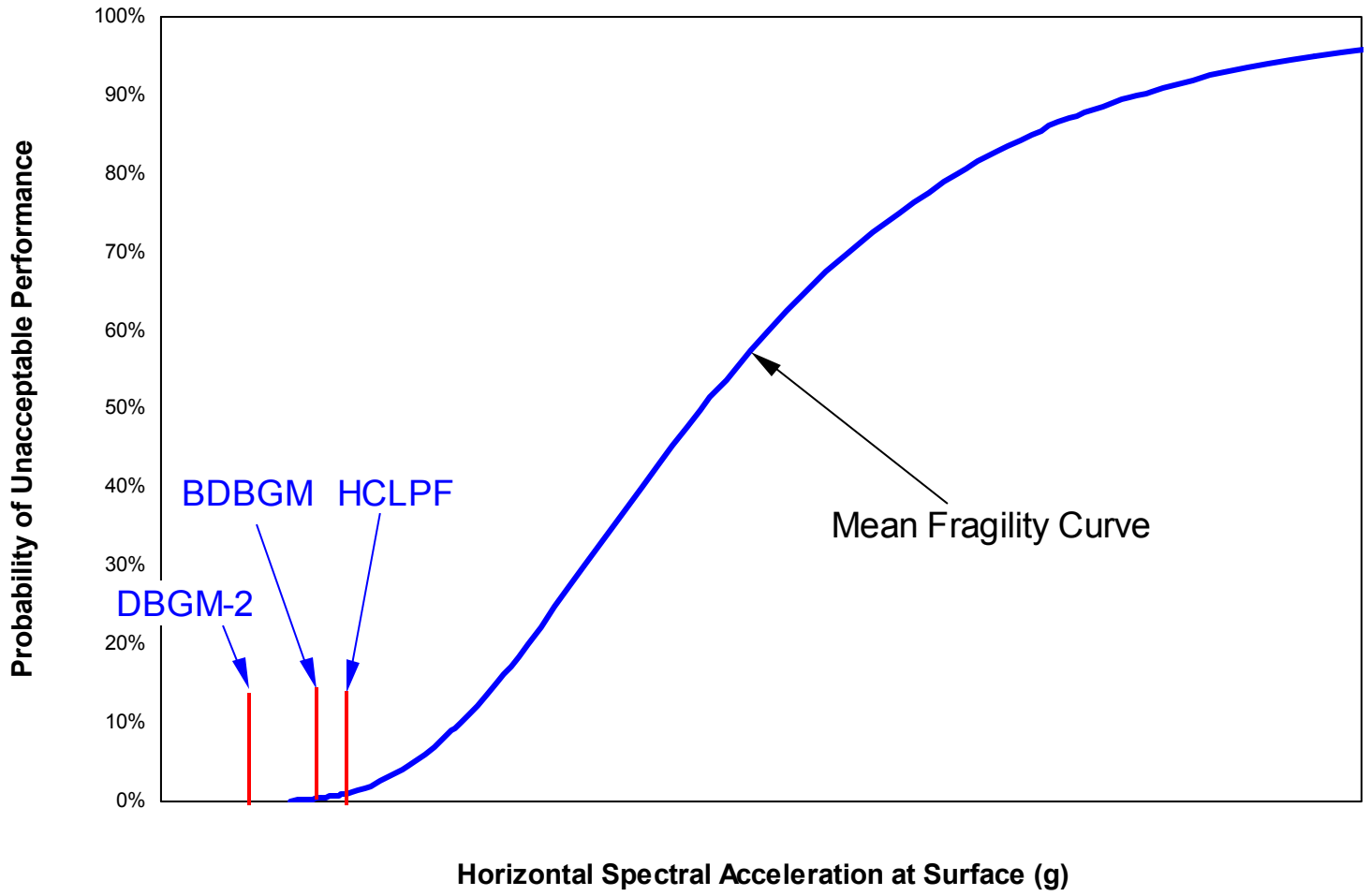
SSCs = Structures, Systems and Components
ASCE 43-05 = American Society of Civil Engineers, Standard 43-05

Hybrid Method

Mean Fragility Curve defined by:

- **High-Confidence-of-Low-Probability-of-Failure (HCLPF) capacity**
- **β - fragility logarithmic standard deviation**

Example – Mean Fragility Curve



DBGM-2 = Design Basis Ground Motion 2; g = acceleration due to gravity
BDBGM = Beyond Design Basis Ground Motion
HCLPF = High-Confidence-of-Low-Probability-of-Failure

Definition of HCLPF

High-Confidence-of-Low-Probability-of-Failure (HCLPF)

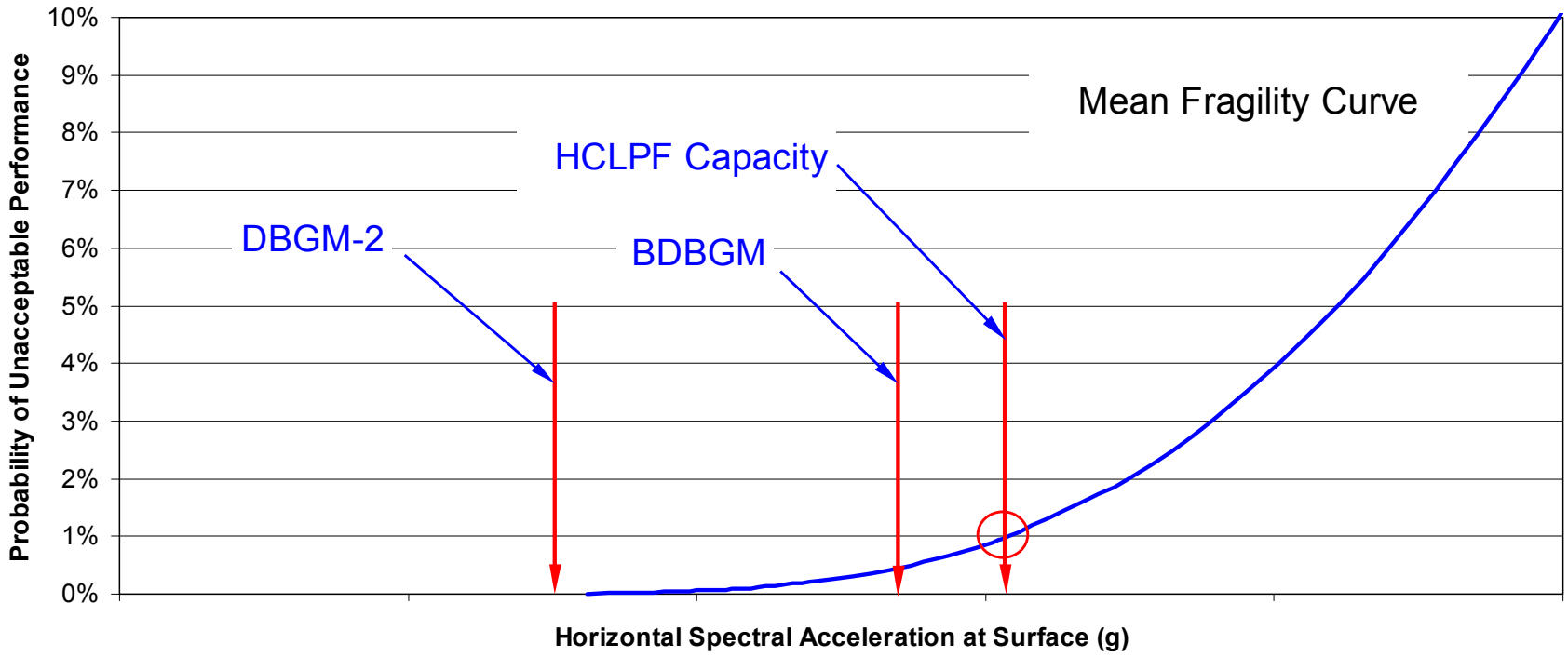
- **Seismic capacity of SSC described in terms of a specified ground motion parameter (e.g., spectral acceleration) corresponding to 1% probability of unacceptable performance on a mean fragility curve**
- **Deterministically computed using Conservative-Deterministic-Failure-Margin (CDFM) methodology**

CDFM References

Conservative-Deterministic-Failure-Margin (CDFM) Methodology described in the following:

- EPRI (Electric Power Research Institute) 1991. A Methodology for Assessment of Nuclear Power Plant Seismic Margin (Revision 1). EPRI NP-6041-SL, Rev. 1. Palo Alto, California: Electric Power Research Institute.
- Budnitz, R. J., et al., An Approach to the Quantification of Seismic Margins in Nuclear Power Plants, NUREG/CR-4334, U. S. Nuclear Regulatory Commission, August 1985
- NRC (U.S. Nuclear Regulatory Commission) 2004. Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design, Docket No. 52-006, NUREG-1793, U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation.
- ASCE 43-05, Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities

HCLPF Factor



Uncertainty Parameter, β

β - Fragility Logarithmic Standard Deviation

- Estimated based on published information, e.g.,
  - ASCE 43-05 Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities
  - *Methodology for Developing Seismic Fragilities*, EPRI TR-103959, Electric Power Research Institute, June 1994
- β ranges from 0.3 to 0.5 for structures and equipment mounted at ground level
- β ranges from 0.4 to 0.6 for equipment mounted high in a structure

Results

Fragility Curves for Seismic Probabilistic Analysis

- **Structures**
  - Calculate specific fragility curves
- **Components**
  - Analyze for components such as cranes
  - Use “experience-based” (generic) information
  - Future qualification testing if required

Structural Margin

For Risk Significant Structures, Margin Demonstrated by:

- **DBGM-2 Demand significantly less than Code Capacity**
  - **DBGM-2 PGA: 0.58g horizontal and 0.52g vertical**
- **BDBGM Demand < HCLPF Seismic Capacity**
  - **BDBGM PGA: 1.19g horizontal and 1.49g vertical**
- **Structural Capacity that ensures that the probability of unacceptable seismic performance of the structure (or complete event sequence) is less than 1 in 10,000 over the preclosure period**

PGA = Peak Ground Acceleration

MAPE = Mean Annual Probability of Exceedance

Additional References

- Chen, J.T.; Chokshi, N.C.; Kenneally, R.M.; Kelly, G.B.; Beckner, W.D.; McCracken, C.; Murphy, A.J.; Reiter, L.; and Jeng, D. 1991. *Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities.* NUREG-1407. Washington, D.C.: U.S. Nuclear Regulatory Commission.
- Kennedy, R.P. 2001. "Overview of Methods for Seismic PRA and Margin Analysis Including Recent Innovations." *Proceedings of the OECD/NEA Workshop on Seismic Risk, Committee on the Safety of Nuclear Installations PWG3 and PWG5, Hosted by the Japan Atomic Energy Research Institute under the Sponsorship of the Science Technology Agency, 10-12 August,1999, Tokyo, Japan. NEA/CSNI/R(99)28, 33-63.* Paris, France: Organization for Economic Cooperation and Development, Nuclear Energy Agency.