SEISMIC PRA METHODOLOGY:

OBTAINING INSIGHTS IN THE FACE OF

UNCERTAINTIES

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OPENING NOTES

"PRA" is the same as "PSA"

This talk will emphasize existing LWRs only

OBJECTIVES OF SEISMIC PRA
(or of PRA more generally)

- What is the risk from operating the NPP?

  [Core -Damage Frequency, CDF]
  [Large Release Frequency]

- What are the principal contributors to CDF?

- Weaknesses -- what to fix?

- How to fix the weaknesses?

- Does this aspect affect my safety decision?

AT A HIGHER LEVEL:

Quantitative Information (Analysis)

Qualitative Insights (Knowledge)

A Safety Decision

(ISSUE: UNCERTAINTIES IN THE ANALYSIS)

BUT:

Decision-making is almost always done in the face of Uncertainty !!

(This is an every-day experience for all of us !!)

THE MAJOR ATTRIBUTES OF PRA

- PRA is the only way to do a realistic evaluation of the safety performance of a facility.

- PRAs always have large numerical uncertainties.

MY ISSUE TODAY:

Given the uncertainties, how to use PRA?

OBJECTIVES OF THIS TALK

A. To describe the nature of the uncertainties

B. To describe the limitations caused by the existence of the uncertainties

C. To discuss how to overcome these limitations

LIMITATIONS OCCUR THROUGHOUT SEISMIC PRA:

Hazard Analysis

Fragilities Analysis

Systems Analysis

SEISMIC HAZARD ANALYSIS

[annual probability of EQs of different "sizes"]
[characteristics of the hazard]

(spectra, acceleration, velocity, displacement, etc.)

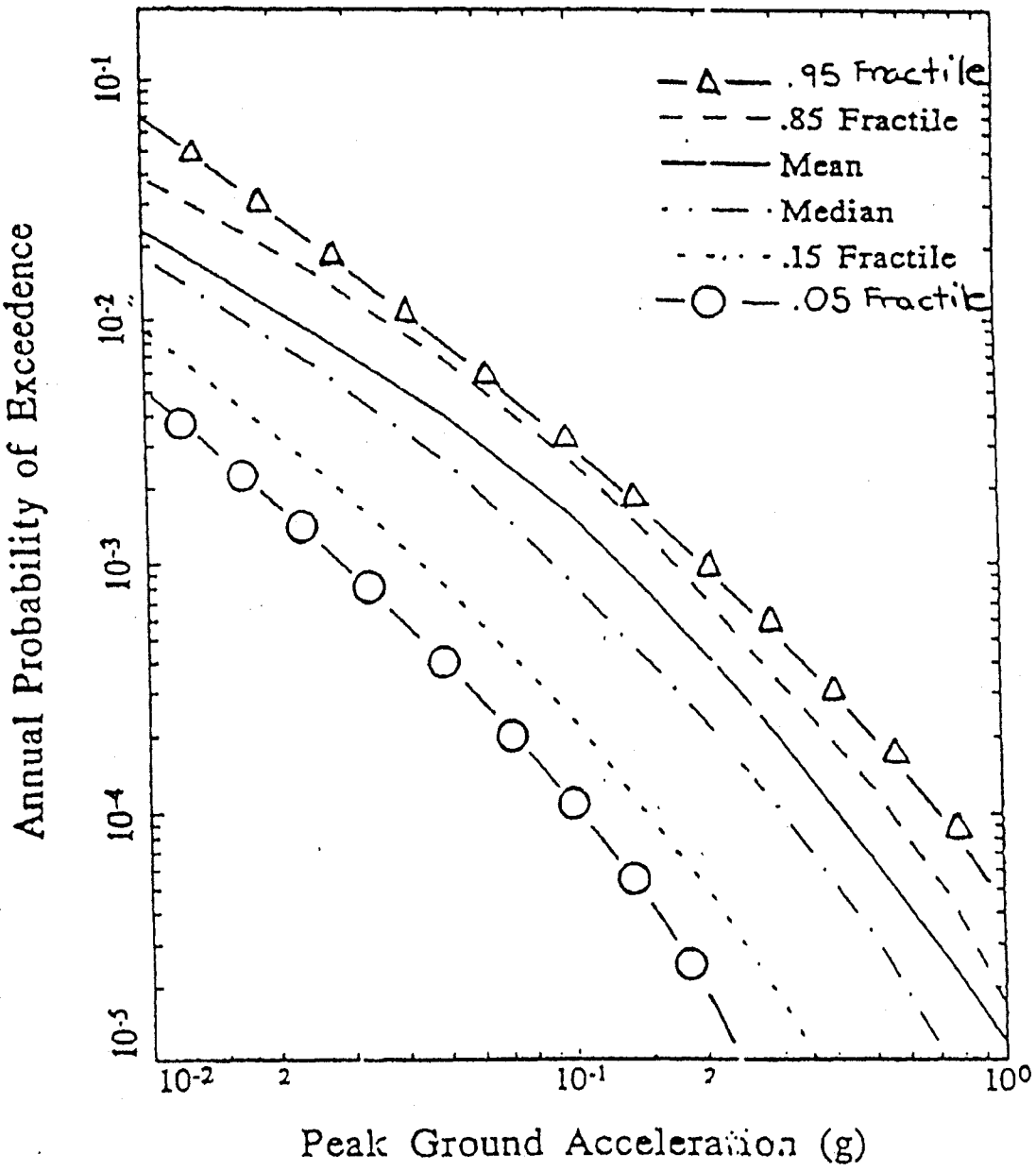


Figure 7-1 Total seismic hazard curves for PGA and rock site conditions.

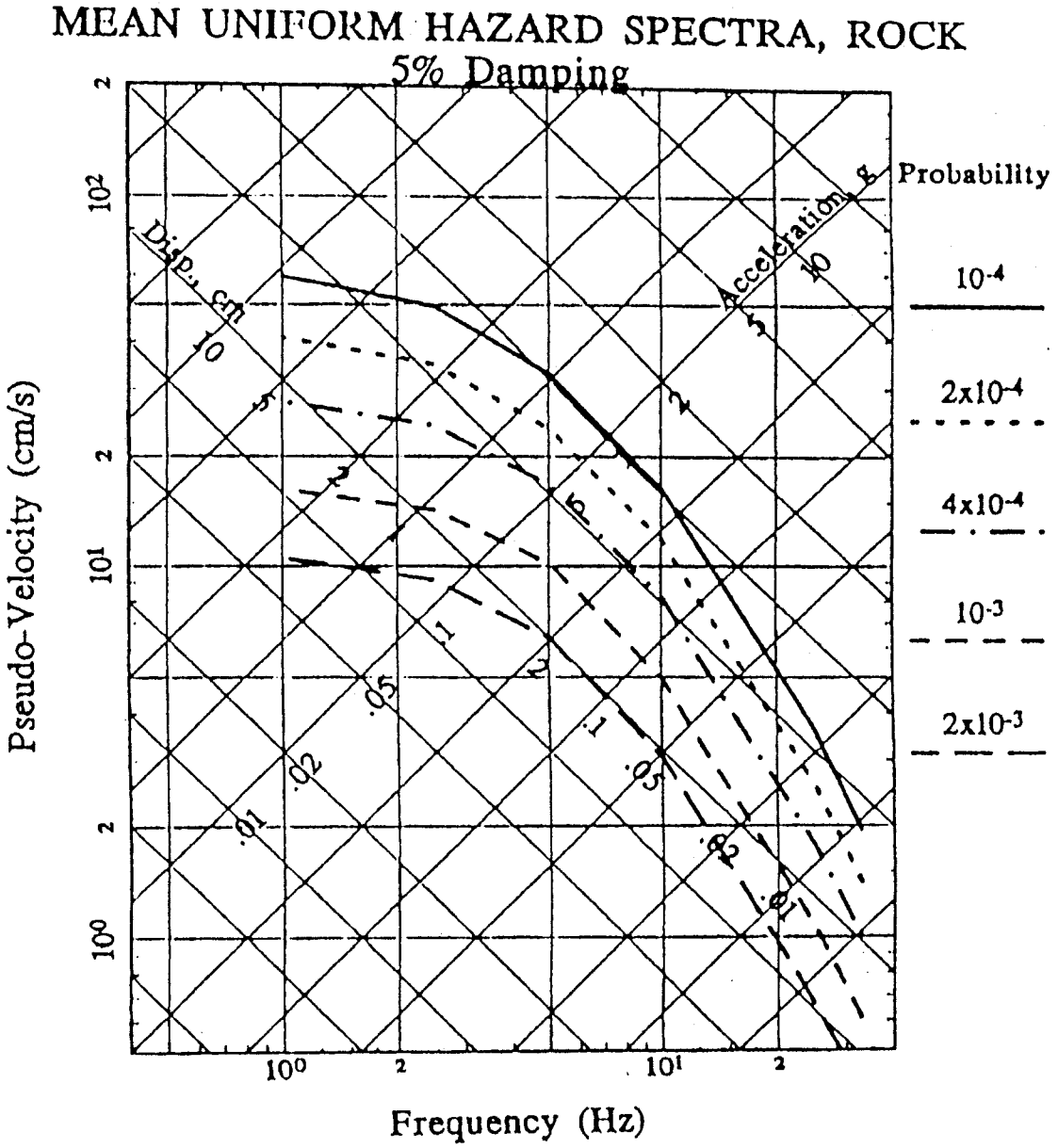


Figure 7-6 Mean uniform hazard response spectra for soil site conditions and annual probabilities of exceedance of $2x10^{-3}$, 10^{-3}, $4x10^{-4}$, $2x10^{-4}$, and 10^{-3} and a damping level 5% of critical.

SEISMIC HAZARD ANALYSIS

ORIGIN AND CHARACTER OF THE UNCERTAINTIES

- Location of the EQ source(s)
- Information about recurrence intervals
- Data on relative EQ "sizes"
- Maximum magnitude?
- Energy propagation: Attenuation vs. Distance
- (etc.)

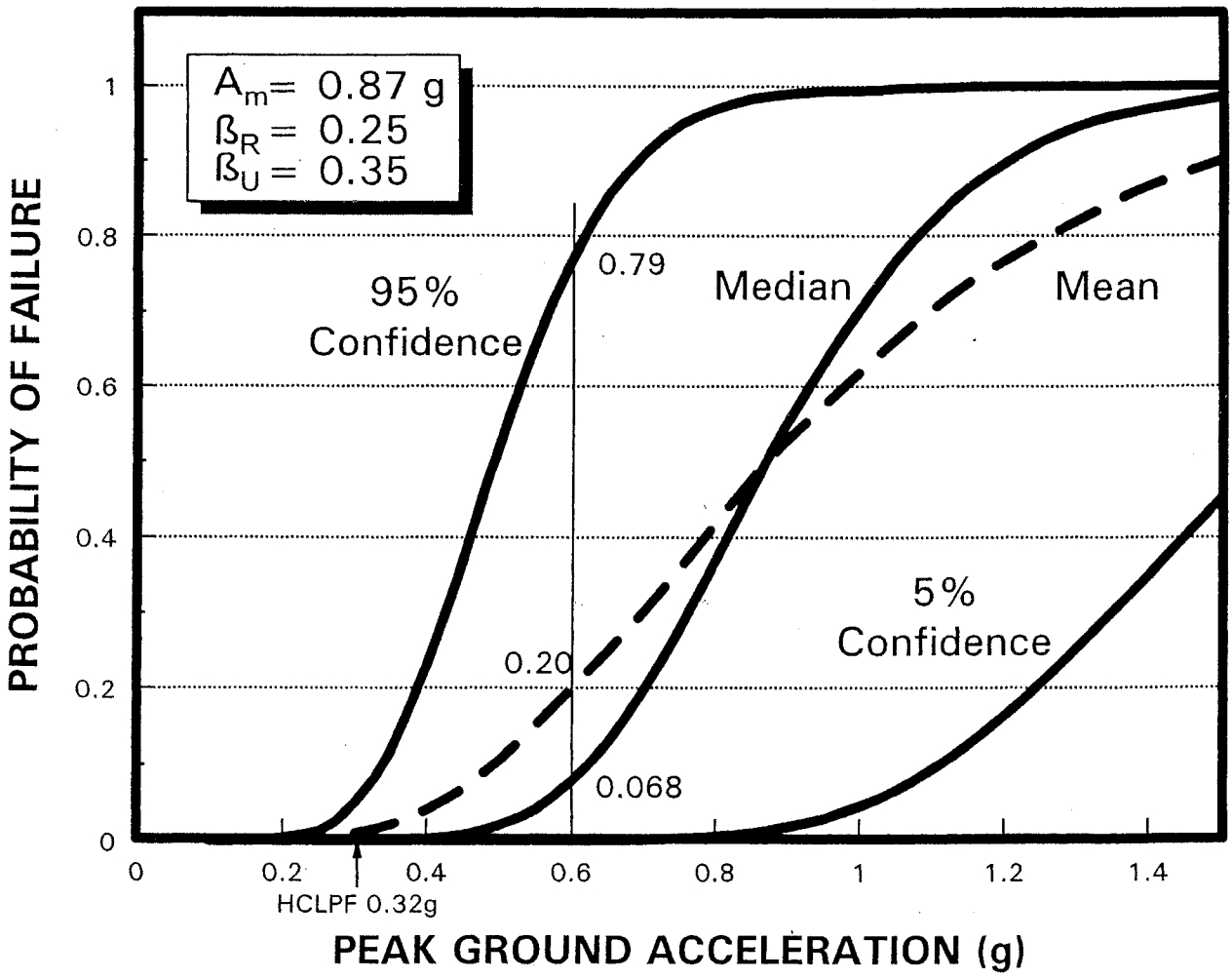
BUILDING/STRUCTURAL RESPONSE

- Soil-structure interactions
- Building energy absorption
- Floor response spectra -- modeling
- (etc.)

SEISMIC FRAGILITY ANALYSIS

SOURCES OF FRAGILITY INFORMATION

- Test data
- Analysis
- Earthquake experience information



EQE INTERNATIONAL

SEISMIC FRAGILITY ANALYSIS

ORIGIN AND CHARACTER OF THE UNCERTAINTIES

- Test Data (applicability)
- EQ experience data (applicability)
- Modeling is not exact
- Analyst judgment
- The EQ "size measure" is never fully applicable.

SYSTEMS ANALYSIS in SEISMIC PRA

- Human error probabilities after a large EQ
- Correlations among failures

These are major issues that limit the overall accuracy of seismic PRA.

PRA QUANTIFICATION

(Integration of Hazard and Fragilities)

(Folding in with the PRA Systems analysis)

OK ------ WHAT DO I MAKE OF ALL OF THIS?

I. The numerical uncertainties in the bottom-line CDF numbers turn out to be large:

± a factor of 10 or more is typical.

Claims of only ± factor of 3 to 5 are not facing the facts.

II. Which insights are robust?

- **Identification of the HAZARD RANGE that matters**
- **Identify the STRONG SSCs (and why)**
- **Identify the WEAK SSCs (and why)**
- **Identify COMBINATIONS OF FAILURES THAT COULD CAUSE PROBLEMS**
- **Identify EXTRA CONSERVATISMS that can help improve plant operations**

WHAT TO FIX??

The ACCIDENT SEQUENCE INFORMATION is crucial,

and

PRA IS THE ONLY WAY TO GET THIS INFORMATION.

An example:

Accident Sequence 101

Earthquake

+

A Seismic Failure of Equipment

+

A Non-Seismic Failure or Human Error

(about half of the seismic sequences are like this)