Seismic Probability Analyses Overview

Presented to:
NRC/DOE Technical Exchange/Management Meeting

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June 7, 2006
Las Vegas, Nevada

Introduction

- Overview
  - Discussion of NRC letter of January 24, 2006
  - DOE path forward
  - Seismic probability analyses
- Seismic Hazard Analyses
- Fragility Analyses
- Systems Analyses
- Summary

NRC January 24, 2006 Letter

- States the following:
  - Seismic design bases, and design codes and standards, appear consistent with regulatory requirements of §63.112(f)(2)
  - Seismic Margins Analysis (SMA) approach is useful but is not a substitute for demonstrating compliance with the performance objectives in §63.111(b)(2)

NRC January 24 Letter

(Continued)

- **Additional supporting analyses required to demonstrate compliance**
  - **Develop probability of occurrence of event sequences through convolution of hazard curves and fragility curves**
  - **Reference to mixed oxide fuel fabrication facility at the Savannah River Site analyses and American Society of Civil Engineers Standard 43-05 approaches**
  - **The preclosure safety analysis requirements are met if the calculated probability of unacceptable seismic performance values of individual SSC ITS is less than 1 in 10,000 over the preclosure period, as defined in §63.111(b)(2)**

ITS =Important to Safety
SSCs = Structures, Systems, and Components

NRC January 24 Letter

(Continued)

– If probability of occurrence of unacceptable seismic performance of individual SSCs ITS is greater than or equal to 1 in 10,000 over the preclosure period, DOE may demonstrate compliance with § 63.111(b)(2) by:

i. Showing that dose consequence is within 5 rem;

ii. Showing that probability of complete event sequence is less than 1 in 10,000 over the preclosure period; or

iii. Modifying the design

DOE Path Forward

- **DOE understands the letter is limited to seismically-initiated events**
- **DOE believes that elements of the SMA approach in addition to probabilistic seismic analysis will demonstrate compliance with regulations**
- **DOE will perform additional supporting evaluations and seismic probability analyses to demonstrate compliance for risk-significant SSCs**
- **Seismic approach will be documented in revised seismic methodology report**

DOE Path Forward
(Continued)

- **Continue to use two-levels of seismic design bases ground motions (DBGM-1 and DBGM-2)**
- **Continue to use Conservative Deterministic Failure Margin (CDFM) method to define seismic HCLPF capacities for structures**

DBGM-1 = Design Basis Ground Motion #1 = 10^{-3} MAPE
DBGM-2 = Design Basis Ground Motion #2 = 5×10^{-4} MAPE
HCLPF = High-Confidence-of-a-Low-Probability-of-Failure
MAPE = Mean annual probability of exceedance

DOE Path Forward
(Continued)

- Modify current seismic approach to incorporate elements of probabilistic risk technology to demonstrate compliance for risk-significant SSCs – probabilistic seismic analyses
- Screening analysis will be used to focus analyses on risk-significant SSCs

Seismic Probability Analyses

- **Apply to risk-significant structures and equipment, having DBGM-2 design basis**
- **Demonstrate probability of unacceptable seismic performance is:**
  - **Less likely than one-chance in 10,000 during the preclosure period for individual ITS SSCs or for complete event sequences**

Otherwise

- **Dose consequence is less than 5 rem; or**
- **Modify the design**

Seismic Probability Analyses Clarification

- **Probabilistic seismic analyses are not a full probabilistic risk assessment (PRA)**
  - **Analyses based on individual event sequences and individual ITS SSCs**
  - **Failure of individual ITS SSCs or individual event sequences will be shown to have probabilities of less than 1 in 10,000 over the preclosure period and therefore below the regulatory threshold or consequences of the event sequences will be shown to be less than 5 rem**
  - **Consistent with the NRC Letter of January 24, 2006, DOE will not sum the failure probabilities of individual ITS SSCs or probabilities of individual event sequences**

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Integration

- **Screening and quantification will require coordination of various technical inputs:**
  - **Seismic hazard analyses**
  - **Fragility (vulnerability) evaluations**
  - **System analyses**

Additional Slides

Performance Objectives Table

Performance Objectives Applied to Seismic Preclosure Safety	Dose Receptor	Consequences of Loss of SSC Safety Function Single Sequence Dose Limit (TEDE)	DBGM Assigned to ITS SSCs
Category 1 Event Sequences 10 CFR 63.111(b)(1) 10 CFR 20.1201-1204 10 CFR 20.1207-1208 10 CFR 20.1301-1302 10 CFR 20.1101	Radiation Worker	>5 rem (0.05 Sv)	DBGM-1
	Controlled Area Worker Beyond the Geologic Repository Operations Area Or Member of the Public Onsite and Beyond the Geologic Repository Operations Area Or Nevada Test Site and Nellis Workers in an Unrestricted Area	>100 mrem (1.0 mSv) or >2 mrem (0.02 mSv) in one hour Or >10 mrem (0.1 mSv) from air emissions	DBGM-1
	Member of the Public Beyond the Site Boundary in the General Environment	>15 mrem (0.15 mSv)	DBGM-1
Category 2 Event Sequences 10 CFR 63.111(b)(2)	Individual at or Beyond the Site Boundary	=>5 rem (0.05 Sv)	DBGM-2
Criticality Condition 10 CFR 63.112(e)(6)	N/A	N/A	DBGM-2

NOTE: Values are for TEDE (a measure of body dose). Higher dose equivalents for the lens of the eye, skin, and extremities are not included in the table, but are subject to separate limits per 10 CFR 63.111(b)(2), 10 CFR 20.1101, 10 CFR 20.1201 to 1204, 10 CFR 20.1207 to 1208, and 10 CFR 20.1301 to 1302.

Definition – Basic Terms

Seismic Risk:

- The probability that the undesirable consequences, harm or unacceptable performance due to a seismic event (earthquake) will be realized

Definition – Basic Terms
(Continued)

Probabilistic Seismic Analysis:

- The development of a quantitative estimate of unacceptable seismic performance based on engineering evaluation and mathematical techniques for combining estimates of incident likelihood and consequences for risk-significant SSCs

Risk-Significant SSCs:

- *Risk-significant* SSCs are SSCs that are credited to mitigate/prevent seismically-initiated event sequences that potentially could result in a dose from unmitigated release that exceeds the performance objective of 10 CFR 63.111(b)(2)

Definition – Event Sequence

*Event sequence (*10 CFR 63.2):

"***Event sequence*** means a series of actions and/or occurrences within the natural and engineered components of a geologic repository operations area that could potentially lead to exposure of individuals to radiation. An event sequence includes one or more initiating events and associated combinations of repository system component failures, including those produced by the action or inaction of operating personnel. Those event sequences that are expected to occur one or more times before permanent closure of the geologic repository operations area are referred to as Category 1 event sequences. Other event sequences that have at least one chance in 10,000 of occurring before permanent closure are referred to as Category 2 event sequences"

Definition – Convolution

Convolution:

In functional analysis, convolution is a mathematical operator that (in effect) represents the amount of overlap of one function, f, as it is shifted over another function, g. It therefore "blends" one function with another. If X and Y are two independent random variables with probability distributions f and g, respectively, then the probability distribution of the sum X + Y is given by the convolution f * g.

For seismic analyses, the convolution can be expressed as:

$$\bar{f} = \int_0^{\infty} \left| \frac{d\overline{H}}{da} \right| P_{f:a} \, da$$

$$\frac{d\overline{H}}{da} = \textit{derivative of hazard curve}$$

$$\overline{P}_{f:a} = \textit{fragility given a}$$

U.S. Department of Energy

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

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Seismic Probability Analyses Summary

- **Credible potential seismically-initiated event sequences will be identified and associated consequences estimated**
- **Appropriate design basis ground motions will be assigned to ITS SSCs credited to prevent or mitigate event sequences, based on potential dose due to unmitigated release**
- **Event tree quantification (including convolution) will be used to demonstrate compliance for individual ITS SSCs or each seismically-initiated event sequence as appropriate**

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Seismic Probability Analyses Summary
(Continued)

- The failure probability of each risk-significant SSC or the probability of each seismically-initiated event sequence where dose consequence could exceed 5 rem will be demonstrated to be less than 1 chance in 10,000 over the preclosure period