ENCLOSURE

COMMENTS ON DRAFT INTERIM STAFF GUIDANCE

HLWRS-ISG-01, "REVIEW METHODOLOGY FOR SEISMICALLY INITIATED EVENT SEQUENCES"

No.	Line Numbers / Page Number	Original Text	Comment	Discussion	Proposed Resolution
1.	Lines: 38 to 43 Page: 2	The mean fragility curve for an SSC ITS may be estimated using: (1) probability density functions for controlling parameters in a Monte Carlo analysis; (2) simplified methods outlined in Section 4 of Electric Power Research Institute, TR-103959 (Ref. 2); or (3) other methods that capture appropriate variability and uncertainty in parameters used to estimate the capacity of the SSCs ITS to seismic events.	If the methodology proposed by the U.S. Department of Energy (DOE) for calculating the mean fragility curve is acceptable to the U.S. Nuclear Regulatory Commission (NRC) staff, DOE requests that the Interim Staff Guidance (ISG) endorse this methodology for the development of a fragility curve, or, alternatively, provide the staff guidance on evaluation of alternative methods.	DOE proposes to develop a lognormal fragility curve by a method not identified in the draft ISG. DOE believes that this method captures appropriate variability and uncertainty in parameters used to estimate the capacity of the important to safety (ITS) structures, systems, and components (SSCs) to seismic events. Specifically, as outlined at the NRC/DOE Technical Exchange of 7 June 2006, DOE intends in many cases to define the mean lognormal fragility curve by calculating the 1% failure capacity of the SSC (also called the High-Confidence-of Low-Probability-of-Failure [HCLPF] capacity or $C_{1\%}$), using the Conservative-Deterministic-Failure-Margin (CDFM) methodology (EPRI 1991, pp. 2-45 to 2-56), and estimating the composite logarithmic standard deviation (β) value taken from ASCE/SEI 43-05. As discussed in Kennedy (2001, Section 5.3, p. 45), the annual probability of unacceptable performance for any SSC is relatively insensitive to the composite logarithmic standard deviation and therefore can be estimated. (Continued on next page)	DOE recommends that the sentence starting at Line 38 be re-phrased as: "The mean fragility curve for an SSC ITS may be estimated using: (1) probability density functions for controlling parameters in a Monte Carlo analysis; (2) simplified methods outlined in Section 4 of Electric Power Research Institute, TR-103959 (Ref. 2); (3) **a method that uses the Conservative Deterministic Failure Margin methodology to determine the 1% probability of failure, and an estimate of the composite logarithmic standard deviation, as described by Kennedy (2001, pp. 44 to 45) and Ravindra (2006, p. 132); or (4**) other methods...

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1. (Cont'd)	Lines: 38 to 43 Page: 2	(See prior page)	(See prior page)	(Continued from prior page) Including a specific discussion of, or reference to, this proposed methodology will provide greater clarity to the NRC staff reviewers of how they are to review the Yucca Mountain license application. The methodology is discussed in more detail in Note #1 directly following this comment.	(See prior page)

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Note 1: Further Description of DOE's Proposed Methodology To Develop Fragility Curves

As noted earlier, DOE's methodology will consider the fragility of structures, systems, and components, as lognormally distributed and defined for a specific mode of unsatisfactory performance. Various methods can be used to define a fragility curve. In the two examples shown, the ISG has used the median capacity of the curve (i.e., the capacity at 50% probability of unacceptable performance) together with the composite logarithmic standard deviation to characterize the curve. DOE proposes to use another point on the fragility curve, the capacity at 1% probability of unacceptable performance (also termed the High-Confidence-of-Low-Probability-of-Failure [HCLPF] capacity) together with the composite logarithmic standard deviation.

Given the lognormal representation, the median capacity can be expressed as a function of the 1% capacity as:

$$C_{1\%} = C_{50\%} \exp(-2.326\beta)$$

Where:

$C_{1\%}$ = seismic capacity of a SSC described in terms of a specified ground motion parameter corresponding to 1% probability of unacceptable performance

$C_{50\%}$ = median seismic capacity of a SSC described in terms of a specified ground motion parameter corresponding to 50% probability of unacceptable performance

β = composite logarithmic standard deviation

The Conservative Deterministic Failure Margin (CDFM) method can be used to estimate $C_{1\%}$. This method is deterministic but has been extensively benchmarked against the Fragility Method (Kennedy et al 1988; Kennedy et al 1989; Reed and Kennedy 1994). As shown in Appendix A of Kennedy (2001, p. 58), the ratio of $C_{1\%}$ / CDFM ranges from 0.93 to 1.20 with a median value of 1.07.

Per ASCE/SEI 43-05, the composite logarithmic standard deviation, β, will generally lie within the range of 0.3 to 0.5 for structures and equipment mounted at ground level. For equipment mounted high in structures, β will generally lie within the range of 0.4 to 0.6. As demonstrated in Kennedy (2001), the computed seismic risk at $\beta = 0.3$ is approximately 1.5 times that at $\beta = 0.4$ and the computed seismic risk at $\beta = 0.6$ is approximately 60% of that at $\beta = 0.4$. Since the annual probability of unacceptable performance is relatively insensitive to β, an estimated β value is adequate to define the mean fragility curve.

Thus, the methodology is a reasonable, accepted approach for the determination of the mean fragility curve, and captures the appropriate variability and uncertainty in parameters.

DOE believes this methodology is consistent with the requirements of 10 CFR 63.

Kennedy (2001) provides additional information on the use of $C_{1\%}$ (determined using the CDFM method) and an estimated value for β to define the mean fragility curve.

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2.	Lines: 38 to 43 Page: 2	The mean fragility curve for an SSC ITS may be estimated using: (1) probability density functions for controlling parameters in a Monte Carlo analysis; (2) simplified methods outlined in Section 4 of Electric Power Research Institute, TR-103959 (Ref. 2); or (3) other methods that capture appropriate variability and uncertainty in parameters used to estimate the capacity of the SSCs ITS to seismic events.	The acceptability of using existing databases, as a source of component and system fragilities for evaluating the logarithmic standard deviation (β) and the median seismic capacity ($C_{50\%}$), should be noted.	Fragility data has been developed and documented in several databases for various facilities (including licensed nuclear facilities). In addition, fragility data can also be found in specific license applications for nuclear power plants. These data have been developed for use in probabilistic risk analyses (including those for nuclear facilities) and have been documented by a number of sources, including national laboratories and in some cases in work sponsored by the NRC. This type of data was also used in the probabilistic analyses for the mixed oxide fuel fabrication facility at the Savannah River Site in South Carolina (Duke Cogema Stone & Webster, L.L.C. 2005, Section 5.1.6.1). Employing this fragility data is appropriate if the system (or component) described is relevant to the repository system (or component) under consideration. Specifically, fragilities have been developed for a number of systems and components, such as Campbell, et al (1988), Cover (1985), Merz (1991), Bandyopadhyay et al (1991) and Murray et al (1997).	DOE recommends that the following sentence be added at the end of the sentence on line 43: **"Where appropriate, assessment of fragility for a SSC may be based on fragility values for an identical or similar component as found in the literature."**

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2. (Cont'd)	Lines: 38 to 43 Page: 2	(See prior page)	(See prior page)	(Continued from prior page) Comparable components or system fragility data may be identified and utilized for the Yucca Mountain repository based on a review of the similarity of the components and the expected seismic load.	(See prior page)

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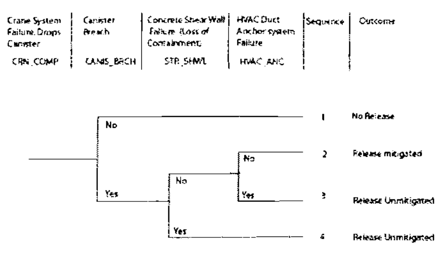
3.	Lines: 235 to 237, 240 to 241 Page: 8	For the closed-form solution, the seismic hazard curve is assumed to be linear in log-log scale and is approximated by a power law (Section 2.2.1.2 of Ref. 3): $H(a) = K_1 a^{-K_H}$, ... The slope used for this example is between probabilities of exceedance of 10^{-6} and 10^{-5}.	The text on the closed-form solution should be clarified to address why the selection of the slope of the hazard curve between probabilities of exceedance of 10^{-5} and 10^{-6} is appropriate.	As shown in Figure A-1, The hazard curve is a decreasing exponential curve when plotted using logarithmic scales for both axes (a log-log plot). The closed-form solution described in the ISG employs a power law equation as a basis, which becomes a straight line when graphed on a log-log plot with a slope parameter, K_H, from the equation on Line 237. In the example described, the slope of the hazard curve between 10^{-6} and 10^{-5} annual probability of exceedance was selected as the slope of the line used in the analyses, to obtain the value of 1.8×10^{-6}. However, given that the actual hazard is represented by a curve, the technical basis for the selection of a portion of this curve as representative is not provided. The text does not describe why the slope of the hazard curve between 10^{-5} and 10^{-6} annual probability of exceedance was selected or is appropriate to represent the entire hazard curve.	DOE recommends that an explanation be provided to address why the selection of this slope is appropriate. This explanation may include for example that this portion of the hazard curve was selected if it was the interval where the dominant contribution to risk arises. Text could be added at the end of the sentence on Line 241: **"The slope should be selected to focus on the portion of the curve where risk is expected to dominate the convolution."**

No.	Line Numbers / Page Number	Original Text	Comment	Discussion	Proposed Resolution
4.	Lines: 262 to 264 Page: 11	The evaluation typically would be performed at appropriate frequencies, based on the dynamic characteristics of the SSC ITS. It should be noted that the example evaluation is performed at 10-hertz (Hz) structural frequency.	The note on the "structural frequency" should be expanded to provide clarification of the selection of a 10-hertz (Hz) value for all SSCs in light of the fact that various SSCs can be expected to have differing natural frequencies.	The example in Appendix B assumes that a single "structural frequency" of 10 Hz is applicable to several SSCs. This frequency is understood to be the natural or response frequency of an SSC. Given that different SSCs can be expected to have different response frequencies, the selection of a single frequency for several SSCs in the example should be explained.	DOE suggests replacing the sentence starting on Line 263, with the sentence: **"For the purposes of illustration, a single response frequency of 10-hertz (Hz) is assumed for this evaluation."** DOE also suggests that an explanation why a single frequency is appropriate should be added.

No.	Line Numbers / Page Number	Original Text	Comment	Discussion	Proposed Resolution
5.	Lines: 256 to 338 Pages: 11 to 12	**Appendix B Example Methodology for Evaluation of Complete Event Sequences** ... Based on this example analysis, the crane components, concrete shear wall, and HVAC duct anchor system each have annual probabilities of failure greater than 10^{-6} for a Category 2 event sequence, assuming a 100-year preclosure period. Therefore, event sequences that include these SSCs ITS need to be evaluated further. ... Although evaluation of individual SSC ITS in an event sequence may indicate a probability of failure of greater than 10^{-6} during a seismic event, this example shows that appropriate consideration of these SSCs ITS jointly may result in an event sequence probability of occurrence less than 10^{-6}, which is not a credible event sequence for the preclosure safety analysis. ...	The discussion of the event sequences in Appendix B should be expanded to include factors associated with non-seismic events and/or conditions that may be important to the probability of the entire sequence.	Appendix B in the ISG considers the unsatisfactory performance of several SSCs in a single event sequence. However, other factors should be discussed in the ISG, as these factors can influence the probability computation for the complete event sequence. These factors are generally not directly related to the earthquake itself and hence, they are called *non-seismic* factors. Such non-seismic factors can include residency times, targeting factors, operational states, and design constraints. For example, the potential seismically-induced drop of a canister can only provide a dose to a worker or the public if the canister is present during the seismic event (a residency factor). If the canister is not present during the night shift, this can be considered in the event tree, reducing the probability of failure due to a seismic event. (Continued on next page)	DOE suggests that text be added to include discussion of other, non-seismic, factors that may influence/mitigate the probability of occurrence of the event sequence. At line 262, a sentence should be inserted to read: **"(Other non-seismic factors such as residency times, targeting factors, operational states, and design constraints, which may also influence the probability of occurrence of the complete event sequence, are not considered in this example.)"**

No.	Line Numbers / Page Number	Original Text	Comment	Discussion	Proposed Resolution
5. (Cont'd)	Lines: 256 to 338 Pages: 11 to 12	(See prior page)	(See prior page)	(Continued from prior page) Other factors can relate to operational considerations. For example, considering the potential seismically-induced drop of the canister, if the canister was suspended within the design basis drop height of the canister, the conditional probability of breach due to the drop is expected to be very small, perhaps less than 10^{-3}/year. When this probability is multiplied by the value of 3.2×10^{-6} per year for event CRN_COMP, all branches of the event tree in Figure B-1 after the event CANIS_BRCH would be well below 1×10^{-6} per year.	(See prior page)

No.	Line Numbers / Page Number	Original Text	Comment	Discussion	Proposed Resolution
6.	Lines: 308 to 323 Page: 12	As shown in figure B-1, in event sequence 3, unmitigated release may occur if both the crane system fails and drops the canister, and the HVAC duct anchor system supporting the duct fails. In this event sequence, the fragilities of the crane system and the HVAC duct anchor system are dependent on the spectral acceleration of the seismic event. However, the fragilities of these two systems are independent of each other. Therefore, the combined fragility of the two systems in the event sequence can be obtained by multiplying fragilities of each system at various seismic spectral acceleration values. To determine the probability of occurrence of the event sequence, the combined fragility curves for both SSCs ITS must then be convolved with the hazard curve. For example...	The computation described in the paragraph neglects to include the probability of "success" branches of the event tree.	In examining Sequence 3 of the event tree in Figure B-1, the sequence involves the success branch of the probability for event STR_SHWL (concrete shear wall failure (loss of containment)) as well as the failure branches for CRN_COMP (crane system failure, drops canister), CANIS_BRCH (canister breach), and HVAC_ANC (HVAC duct anchor system failure). However, the success branch of STR_SHWL is not discussed, nor is the CANIS_BRCH branch (it is assumed that this was set to 1.0). This could be confusing and is not mathematically accurate. Specifically, the STR_SHWL success probability is the complement of the fragility of the failure branch, and it is expected that the event sequence fragility and results of the convolution would be affected by including this probability. While the probability of success for non-seismic (random failures) is generally very close to 1.0, the seismic fragility in the range of accelerations of interest may range as high as 0.3 to 0.7. The complement (success probability) probability then ranges from 0.7 to 0.3. Including this would affect the frequencies calculated.	DOE recommends that the assumption made in the computation be clarified, and that each branch in the sequence be addressed in the description. For instance, at the end of the sentence ending on Line 310, the text should be expanded to mention the other branches: **"Tracing Sequence 3 across the event tree shown Figure B-1, this sequence also includes the STR_SHWL success branch and the assumed failure of the canister (CANIS_BRCH)..."** Additional text on Lines 310 to 323 should include: "... **the STR_SHWL success probability is the complement of the fragility of the failure branch...**" and "...Therefore, the combined fragility of the **three** systems in the event sequence can be obtained by..."

No.	Line Numbers / Page Number	Original Text	Comment	Discussion	Proposed Resolution
7.	Figure B-1, Page: 13		The figure headings and the conventions of the event tree shown in Figure B-1 should be changed to conform to other NRC documents and the literature on the topic.	The construction of Figure B-1 is not consistent with conventions for construction of event trees, such as NUREG-2300, pp. 3-11 to 3-12. For example, the initiating event for the event tree (an earthquake) is not shown. Also, the branch for the crane <u>not</u> dropping a waste form is not shown. Further, the event headings should describe the success or non-occurrence of the undesired event, with the event name (e.g. CANIS_BRCH) representing the unacceptable performance / failure.	DOE suggests that the figure be revised for clarity, making the figure consistent with conventions for the construction of event trees in other NRC documents, such as NUREG-2300. The following changes are suggested to Figure B-1: • The figure be revised to indicate that the initiating event of the sequence is an earthquake • The figure heading be revised to state the event in terms of success • The missing branch be shown for the event that the crane does not drop the waste form • The probability of canister breach, which has been assumed to be 1.0, be indicated.

No.	Line Numbers / Page Number	Original Text	Comment	Discussion	Proposed Resolution
8.	Lines: 218 to 222 Page: 7	The mean fragility curve of an SSC ITS for a defined failure mode is typically defined as being lognormally distributed, and can be expressed in terms of a median capacity level, C50%, and a composite logarithmic standard deviation, β. The technical basis for the development of the median capacity and the composite logarithmic standard deviation, β, should be available for staff review.	The guidance in the example should be moved to the main text of the ISG (Discussion section).	The sentence starting at Line 220 appears to be guidance that is included within an example of methodology in Appendix A. If the cited text is to instruct DOE to provide a technical basis for the development of the mean fragility curves, then the instruction should be moved into the main body of the document. If the text is not moved, the sentence could be read to have only limited applicability.	Assuming that the text has broader applicability than just as part of the example, DOE suggests that the sentence starting on Line 220 be deleted from Appendix A, moved to the Discussion section on page 1, and inserted into the text at Lines 54 to 63. (Please see next comment for suggested change in the wording of this text)

No.	Line Numbers / Page Number	Original Text	Comment	Discussion	Proposed Resolution
9.	Lines: 220 to 222 Page: 7	The mean fragility curve of an SSC ITS for a defined failure mode is typically defined as being lognormally distributed, and can be expressed in terms of a median capacity level, C50%, and a composite logarithmic standard deviation, β. The technical basis for the development of the median capacity and the composite logarithmic standard deviation, β, should be available for staff review.	The provision to provide the technical basis of the median capacity and the composite logarithmic standard deviation should be generalized so that it is applicable to other methods that may be employed in construction of a fragility curve.	The guidance appears inappropriate if alternative methods are used, and therefore should be generalized to require appropriate technical bases when alternative methods are employed. The guidance implies that if an analysis was performed using an alternative method (that may or may not involve the median capacity, $C_{50\%}$) that it is still necessary to provide a technical basis for the development of the median capacity. Given an alternate method where the median capacity may not be directly required for construction of the fragility curve (as when the curve is constructed using an assessment of the 1% capacity or HCLPF value, $C_{1\%}$), this guidance would not be appropriate, as DOE should only be required to provide justification for the technical basis of $C_{1\%}$ not of $C_{50\%}$.	Consistent with the prior comment indicating that this text be moved to the Discussion section on page 1, DOE also suggests that the sentence starting at Line 220 be re-phrased to state: "It is necessary in developing seismic fragilities that the **technical basis for the development of the applicable fragility parameters** be available for staff review."

No.	Line Numbers / Page Number	Original Text	Comment	Discussion	Proposed Resolution
10.	Lines: 276 to 277 Page: 11	— Canister is assumed to drop, and fails to perform the intended safety functions resulting in a release of radionuclide material.	As evidenced in the overall discussion in this appendix, it appears that the probability of canister breach is assumed to be 1.0 in this sequence. If this observation is correct, the assumption should be clearly stated in the analysis.	The potential for a canister breach is shown in Figure B-1 as a branch on the event tree. In discussing the overall sequence, the text reads, "Canister is assumed to drop, and fails to perform the intended safety function... ." As the canister failure is not discussed or evaluated further in the example, it is concluded that this statement indicates that the canister breach is assumed to occur in all cases, i.e., the probability of breach is 1.0. This assumption is fundamental to understanding the computations shown in this appendix. A canister breach (due to a drop within the design drop height for the canister) is not expected to occur in most instances. Therefore, it is recommended that the assumption (that canister failure is assumed in all instances) be clearly stated at the start of the analysis and related figures.	DOE recommends adding the following phrase to the end of Line 277: "... **and it is assumed that probability of breach is 1.0 in all cases**". In addition, DOE recommends adding in Figure B-1, "**(P_f = 1.0)**" on the branch indicating potential for breach. DOE also recommends adding text to state that when the probability of a breach (given a drop) is demonstrated to be less than 1.0, the appropriate conditional probability of breach may be factored into the quantification of the event sequence.

No.	Line Numbers / Page Number	Original Text	Comment	Discussion	Proposed Resolution
11.	Lines: 36 to 38 Pages: 1 to 2	The probability of occurrence of an event sequence leading to an SSC ITS failure, or seismic performance, is determined by convolution of the mean seismic hazard curve with the mean conditional failure probabilities (i.e., fragility) of the SSCs ITS.	This statement is a conservative simplification and should be clarified as such.	The convolution of the hazard curve and the SSC's fragility curve provides the probability of occurrence of a simplified event sequence, consisting of the initiating seismic event followed by the unacceptable performance of the specific SSC. It does not consider other SSCs and factors that can mitigate or prevent the complete event sequence. This underlying conservatism, implicit in this approach, should be clearly stated for readers unfamiliar with probabilistic risk.	DOE suggests adding the following text in the sentence starting on Line 36: "**As a conservative assessment of probability,** the probability of occurrence of an event sequence leading to an SSC ITS failure, or seismic performance, **can be** determined by...

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12.	Entire	--- All ---	The ISG should include a statement that while the examples in Appendix A and B were developed by simple numerical integration, alternative quantification methods may be used, such as the use of appropriate computer codes.	While hand computations can be performed for a simple event tree, for more extended event trees, the computational process can become complex and very cumbersome. A number of computer codes are available that can be used for the probability computation. For example, computer codes such as SAPHIRE or RISKMAN have built-in routines for computing probabilities and quantifying seismic hazard (e.g., using Monte Carlo or Latin Hypercube methods). DOE expects to use a computer code for quantification of event sequences and recommends that the ISG include a statement that these alternative means are acceptable.	DOE suggests that a brief statement be added stating that computations can also be performed using appropriate computer codes. DOE suggest that this statement could be added at the end of Line 232, and phrased as: **"Computations shown in the appendix can be performed either by hand computations or through the use of computer codes. A number of computer codes are available that can be used for probability computations."** It is also suggested that a similar statement be added to Appendix B as well.

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