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SUBJECT: Comments on Draft NUREG-1855

Thank you for the opportunity to review the draft of NUREG-1855. It looks to be a very useful report for the industry. Please consider our attached comments in preparation of the final report.

If you have any questions, please do not hesitate to call.

Sincerely,

Vincent M. Andersen
Rishi Narain

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Comments on Draft NUREG-1855

The Draft NUREG-1855 report is a well-written useful evolving document. The information provided in the report will be useful in addressing the uncertainty requirements of the ASME PRA Standard and RG 1.200. The following comments relate to potential enhancement for consideration.

1) Consider including an upfront section (right after the Abbreviations and Acronyms list) of definitions of key terms in the report. Obvious candidates for key definitions are: aleatory, epistemic, parametric uncertainty, modeling uncertainty, completeness uncertainty, assumption, consensus model. Many of these terms are discussed in the body of the report, but it would be useful to have short definitions of key terms in an upfront section. The reader may also be referred to Appendix D of NUREG/CR-6823 for definitions; however, Appendix D of NUREG/CR-6823 does not address this list of key terms.

2) The Abstract, and other sections of the report state that the focus of the report is on epistemic uncertainty; yet, Section 4 of the report discusses parameter uncertainty. In addition, the report even specifically defines parameter uncertainty as epistemic. There is no industry debate that parametric uncertainty has a substantial basis in aleatory uncertainty. Oberkampf, W.L., et al., "Challenge Problems: Uncertainty in System Response Given Uncertain Parameters", states *"Sources of aleatory uncertainty can commonly be singled out from other contributors to uncertainty by their representation as randomly distributed quantities that can take on values in an established or known range...The mathematical representation most commonly used for aleatory uncertainty is a probability distribution...Propagation of these distributions through a modeling and simulation process is well developed and is described in many texts."* Should not the text of the report be revised to state that both aleatory and epistemic uncertainty are treated in the report, and that parametric uncertainty is substantially aleatoric in nature? This is a taxonomy issue, and not necessarily key to the approaches outlined in the report.

3) Section 1.1, Background and History, discusses the history of PRA and uncertainty as starting from the 1995 PRA Policy Statement. Consider enhancements at the beginning of this section to recognize that PRA development, and uncertainty considerations in PRA, were evolving decades before the 1995 PRA Policy Statement. Such additional discussion may mention:

   - 1975 WASH-1400 uncertainty approach
   - 1981 Apostolakis, "Pitfalls in Risk Calculations", Reliability Engineering
   - 1981 Parry and Winter, "Characterization and Evaluation of Uncertainty in PRA", Nuclear Safety
   - 1986 Burns, Andersen, et al., IDCOR IPE Uncertainty Report
   - 1989 NUREG-1335 IPE uncertainty expectations
   - 1990 NUREG-1150 uncertainty approach

4) NUREG-1855 states that the focus of the report is on "epistemic" uncertainty. The NRC contractor Sandia National Laboratories formed the Epistemic Uncertainty Project in 2002 to "evaluate, develop and apply the most useful theories to reliability engineering, risk analysis, and system safety assessment". No mention of this project is made in

NUREG-1855. Does the work and products of the Sandia Epistemic Uncertainty Project not apply to the purpose and application of NUREG-1855?

5) Section 4 of the report directs the reader to consult other industry reference sources in the determination of parameter probability distributions. The Lognormal distribution has been assumed as a typical practice for most, if not all, basic events in PRAs for many decades due to its good fit to rare events. For example, NUREG/CR-0400, Risk Assessment Review Group Report to the US NRC, states the following: *"we accept the log-normal as an acceptable summary of most data."* The recent NUREG/CR-6923 study recognizes the increasingly wide-spread use of the log-normal distribution, as well as recognizes that often multiple distributions are reasonable fits for data sets.

   Recent NRC/INEL data studies have employed the Beta and Gamma distributions. Assuming a Beta for demand failures, Gammas for run failures, Lognormals for HEPs, etc. may be a purist desire for perceived rigor, but pursuit of such assumed rigor has no significant impact on risk metric results or propagated uncertainty distributions. Both at the EPRI R&R Workstation conference in January 2008 and at the BWROG IRIR meeting in Carolina Beach, NC in January 2008, the consensus of the meeting members was that assuming Betas and Gammas instead of Lognormals is not believed to be a requirement of the ASME Standard and not significant to results and insights. Jeff Riley (EPRI) presenting at the EPRI R&R Workstation referred to NUREG/CR-3263, A Comparison of Methods for Uncertainty Analysis, as a study that shows that assumed basic event distributions have non-significant impacts on model results and propagated uncertainties. Using all Lognormals in an EPRI R&R Workstation UNCERT calculation of an example plant CDF, the resulting CDF propagated uncertainty analysis takes <10 minutes to calculate; using Betas, Gammas, and Lognormals in the same UNCERT analysis takes 10-20 hrs to calculate and produces a CDF "range factor" that differs only in the first decimal point from the all Lognormal case. As can be seen, the impact on results and insights is negligible.

   Consider incorporation of a discussion in Section 4 of NUREG-1855 that identifies the issues above, and recognizes that the historical assumption of the log-normal distribution for all or most PRA basic events is reasonable and not precluded by NUREG-1855.

6) Monte Carlo is the most prevalent method for parametric uncertainty analysis in the US commercial nuclear power PRA industry. Section 4.2.1 of the report refers to "at least 1000" when discussing the number of sampling trials. One thousand is indeed the minimum number of samples that should be used in CDF and LERF uncertainty propagation analyses. Consider providing additional guidance on this issue, such as referring the reader to EPRI 1008905, or by suggesting use of the Standard Error of the Mean (SEM), which measures the fluctuation of a statistic as a function of sample size, to test the stability of the propagated mean as a function of sampling size. The text, Basics of the Monte Carlo Method with Application to System Reliability, also refers to tests for "Monte Carlo error", but such rigor may be over kill. It is reasonable (given current computer speed) to simply recommend use of 10,000 trials or greater, but allow the analyst the option to show that lesser trials are suitable if for some reason they have a need for fewer trials. Alternatively, if the EPRI Uncertainty report also under-development is to be the guidance document for this issue, then consider referring the reader to that document.

7) Section 4.2.1 appropriately presents the concept of a "seed" value, but then directs the analyst to verify that the propagated results are not sensitive to the choice of the seed value. It is true that the choice of seed value can impact the resulting propagated uncertainty distribution of a risk metric. Monte Carlo uncertainty analysis purists would assert that the proper way of performing a formal uncertainty propagation analysis is to perform hundreds of separate analyses, each analysis with a different seed value and thousands of sampling trials, and then the family of hundreds of propagated uncertainty distributions then integrated to determine the overall uncertainty distribution. As can be seen, guidance is needed in this regard so as not to imply that analysts need to pursue such rigor. Consider providing guidance to the analysts to define and constrain the level of effort that may be necessary to address the sensitivity of seed value selection. Alternatively, if the EPRI Uncertainty report also under-development is to be the guidance document for this issue, then consider referring the reader to that document.

8) Section 4.3 provides good discussions of different approaches to considering parametric uncertainty in the comparison to acceptance guidelines. However, the section does not appear to come to a recommendation. It appears to indicate that the recommended approach is to use the mean of the propagated uncertainty distribution of the risk metric (e.g., CDF). Is that the correct interpretation of the recommendation of Section 4.3?

9) As discussed in the previous comment, it appears that the recommended approach to use when considering parametric uncertainty in comparison to acceptance guidelines is to use the mean of the propagated uncertainty distribution in comparison to risk metric acceptance guidelines. Section 7.3.2.1 seems to indicate that this is the preferred approach, but then states that a formal propagation of uncertainty may not be required if it is demonstrated that the state-of-knowledge correlation is unimportant. It is unclear to the reader how one would determine that the state-of-knowledge correlation is unimportant without performing a formal propagation of uncertainty analysis, or what rules of thumb or criteria apply to the determination of the importance of the state-of-knowledge correlation to the propagated uncertainty distribution. Any guidance on these aspects would be useful. Alternatively, if the EPRI Uncertainty report also under-development is to be the guidance document for this issue, then consider referring the reader to that document.

10) Frequency sub-section of Section 6.2: Clarify that the collective frequency refers to the collective frequency of the missing items/scenarios in question.

11) Section 7.3.2.1 references a Section 4.3.2. There is no such section. Should this be Section 4.2.4?

12) NUREG-1855 is a good compendium of information related to treatment of the various pieces of uncertainty inherent in PRAs. It is recognized that there are multiple facets of uncertainty, multiple methods for treating them, and different methods for comparison to acceptance guidelines. The labyrinth of information and approaches may not be easily followed by many users of this useful document. Consider adding a short appendix that would act as an easy user manual with a flow chart guiding the analyst through the steps and referring the analyst to the appropriate section in the report.