December 23, 2015

MEMORANDUM TO: John A. Nakoski, Chief
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Office of Nuclear Regulatory Research

FROM: Anders Gilbertson, Reliability and Risk Analyst ***/RA/***
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SUBJECT: SUMMARY OF THE U.S. NUCLEAR REGULATORY COMMISSION AND ELECTRIC POWER RESEARCH INSTITUTE CO-SPONSORED WORKSHOP ON THE TREATMENT OF UNCERTAINTY IN RISK-INFORMED DECISIONMAKING

On November 18 and 19, 2015, the U.S. Nuclear Regulatory Commission (NRC) and the Electric Power Research Institute (EPRI) conducted a co-sponsored workshop on the treatment of uncertainty in risk-informed decisionmaking. The NRC announcement of the workshop was issued on September 9, 2015, was made publicly available in the Agencywide Document Access and Management System (ADAMS) under accession number ML15252A433. The NRC and EPRI also posted publicly available announcements for the workshop on www.nrc.gov and www.epri.com, respectively. The workshop was announced by the NRC as a Category 3 public meeting and was held at the Hilton Hotel and Executive Meeting Center located in Rockville, Maryland.

The purpose of the workshop was to obtain feedback from internal and external stakeholders on the guidance in NUREG-1855, Revision 1, "Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decisionmaking," and the two companion EPRI documents, EPRI 1016737, "Treatment of Parameter and Model Uncertainty for Probabilistic Risk Assessments," and EPRI 1026511, "Practical Guidance on the Use of PRA in Risk-Informed Applications with a Focus on the Treatment of Uncertainty." The feedback obtained in this workshop will be used by the NRC staff to help determine how to proceed with the subsequent publication of NUREG-1855, Revision 1, and future work.

NUREG-1855, Revision 1, provides guidance on how to treat uncertainties associated with probabilistic risk assessments (PRAs) used by a licensee or applicant to support a risk-informed application to the NRC. Specifically, NUREG-1855, Revision 1, provides guidance on identifying and characterizing the uncertainties associated with a PRA; performing uncertainty analyses to understand the impact of the uncertainties on the results of the PRA; and how the results of the uncertainty analyses are considered in the NRC's decisionmaking process. EPRI 1016737 provides guidance on determining the importance of the state-of-knowledge correlation and identifying and characterizing sources of model uncertainty in an at-power reactor PRA for internal events and internal flood hazards. EPRI 1026511 provides guidance on identifying and characterizing sources of model uncertainty in a reactor PRA for the internal fire hazard, seismic hazard, low-power and shutdown operational modes, and Level 2 PRA.

A total of fifteen presentations were given during the workshop; eleven presentations were given on the first day and four presentations on the second day. A hardcopy version of all workshop presentations were made available to participants during the workshop and is electronically available to the public in ADAMS under accession number ML15327A182. The following provides a summary of each presentation and related discussions in the order in which they occurred. The italicized headings indicate the presentation number and the presentation title, as taken directly from the workshop handout.

Day 1 – Wednesday, November 18, 2015

The first day of the workshop focused on a review of the guidance documented in NUREG-1855, Revision 1, EPRI 1016737, and EPRI 1026511. Following the presentations on the guidance, two additional presentations were given. The first of the two additional presentations described an example of a risk-informed activity that demonstrated the application of the guidance and the second discussed the NRC risk-informed review process related to that example.

Presentation 1: "Workshop on the Treatment of Uncertainties in Risk-Informed Decisionmaking"

This presentation provided a welcoming to the participants and general introduction including an overview of the treatment of uncertainties in risk-informed decisionmaking, the workshop objectives, and the workshop agenda. The workshop objectives were to review and discuss the guidance in NUREG-1855, Revision 1, EPRI 1016737, and EPRI 1026511; present examples of the application of the guidance in those documents; and solicit participants for feedback on potential enhancements to the guidance in NUREG-1855, Revision 1. Participants were encouraged to ask questions and provide comments throughout the entire workshop.

Presentation 2: "Guidance on the Treatment of Uncertainty Associated with PRAs in Risk-Informed Decisionmaking (NUREG-1855)"

This presentation provided a general overview of the development history of NUREG-1855; the relationship between NUREG-1855, Revision 1, EPRI 1016737, and EPRI 1026511; and a general overview of the approach described in NUREG-1855, Revision 1. Issues discussed during the presentations related to the general scope of the guidance documents.

Presentation 3: "Detailed Discussion on Uncertainties"

This presentation provided an overview of the definition of the types of uncertainties considered in a PRA and how those types of uncertainty are treated in the development and use of a PRA. The following is a summary list of the presentation talking points:

- PRAs provide for an explicit characterization of uncertainties as opposed to an implicit characterization where uncertainties are incorporated into model conservatisms.

- When building a base PRA model, the analyst will need to make assumptions; however, the base model should accurately represent the plant configuration and operations.

- A base PRA model may need to be modified to conform to the current state-of-practice or to changes in the state-of-knowledge. For example, sump clogging was historically an issue assumed to be of little importance to plant risk, but has since been found to be a potential risk driver in PRA models.

- Technical adequacy is not the same as uncertainty. As discussed in Regulatory Guide (RG) 1.200, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities," technical adequacy is demonstrated through the assurance that the pieces of the PRA used in the application have been performed in a technically correct manner and that the assumptions and approximations used in developing the PRA are appropriate.

- Biases are unquantified uncertainties. Existence of biases are acceptable in risk-informed decisionmaking, especially when they do not affect the decision.

- Conservative assumptions can mask important risk impacts. One example of this is assuming perfect correlation of component failure during large earthquakes, which may result in optimistic estimates of the Fussell-Vesely (FV) and risk achievement worth (RAW) importance measures due to the fact that having redundant components would no longer result in a risk decrease.

- Most parameter estimates are derived from statistical models that are based on an underlying probabilistic model. Once parameter uncertainties are characterized, the analyst propagates the uncertainties through the PRA model. The analyst must be sure to consider the state-of-knowledge correlation (SOKC) when propagating parameter uncertainties. NUREG-1855, Revision 1, describes what an analyst needs to do when SOKC is important and EPRI 1016737 describes how an analyst determines if SOKC is important.

- Model uncertainties relate to the uncertainty associated with some aspect of a PRA model that can be represented by any one of several different modeling approaches, none of which is clearly more correct than another, e.g., using the MAAP thermal hydraulics code as opposed to the MELCOR thermal hydraulics code. The focus should be on modeling choices that impact the overall decision.

- The effect of model uncertainty is examined through sensitivity studies, which requires viable model alternatives with a demonstrated applicability to the PRA framework. Model uncertainty relates to the uncertainty associated with some aspect of a PRA model that can be represented by any one of several different modeling approaches, none of which is clearly more correct than another. Deciding whether to use a higher fidelity model versus a lower fidelity model is not a model uncertainty issue, and the higher fidelity model should always be used in the base PRA model. However, a lower fidelity model is sometimes all that is needed to obtain the necessary results. An example is the calculations of hot gas layer thickness in fire PRAs. The key question that should be asked is whether all models result in meeting the same capability category in the PRA standard.

- Completeness uncertainty can be categorized as either known, e.g., a scope or level of detail item that is knowingly excluded from the PRA, or unknown, i.e., an undiscovered source of uncertainty. If contributors are excluded from the base PRA model, the analyst must demonstrate that the excluded contributors are not significant and that protective measures are in place. Unknown completeness uncertainties are protected against by implementing performance monitoring, adherence to the defense in depth philosophy, and safety margins.

Issues discussed during this presentations include the following:

- The meaning of the term base PRA – The term base PRA was defined as being either a single integrated model that evaluates all hazards and plant operating states or multiple individual PRA models that address specific hazards and plant operating states. In general, the various parts of an integrated base PRA or the multiple individual PRA models are not always derived from an internal events PRA model.

- Performance monitoring, as related to Stage F in NUREG-1855, Revision 1.

- Generation of parameter uncertainties in a fire scenario model that has a structure to characterize parameter uncertainty – This can potentially be accomplished by bringing together constituent models.

- Conservative assumptions that can produce non-conservative impacts – It is conservative to assume full correlation between the failure of multiple redundant components (i.e., if one fails, all are assumed to fail). The non-conservative impact of this assumption is that removing one of the components from service does not result in an increase in the absolute risk. In contrast, if the same components were not assumed to be fully correlated, removing one component from service would result in an increase in the absolute risk.

- The assumption that parameter uncertainty is always epistemic and whether that assumptions is applicable across all fields – Is aleatory uncertainty always characterized in the model and epistemic uncertainty always characterized in the parameter? Context will be needed when an application involves different engineering fields and disciplines, e.g., an annual exceedance probability as compared to an initiating event frequency. NUREG-2122, “Glossary of Risk-Related Terms in Support of Risk-Informed Decisionmaking,” might be able to close this gap and provide clarity on the definition of a given term in various contexts.

- Applicability of guidance as it relates to the use of computer codes and the outputs of those codes – Where does the uncertainty in the outputs of computer codes get introduced to the cause-effect relationship? Code output uncertainty likely appears in the application as model uncertainty. Different analyses that produce different results will appear as a sensitivity study. There are studies in numerical chaos in MAAP results for example. NUREG-1855, Revision 1, should be relevant to the various aspects of a Level 2 PRA.

Presentation 4: "Stage A – The Approach for Treating Risk Analysis Uncertainties"

This presentation provided an overview of the guidance in Section 3 of NUREG-1855, Revision 1, which relates to determining whether the guidance in NUREG-1855, Revision 1, is applicable to a given risk-informed activity under consideration. Depending on whether the activity generally relies on a PRA; what risk metrics are needed to support the risk-informed activity; and how those risk metrics are used, the guidance in NUREG-1855, Revision 1, may or may not be applicable to the activity. NUREG-1855, Revision 1, also describes how the specific guidance can be applied generically.

Presentation 5: "Stage B – Assessing PRA Scope and Level of Detail"

This presentation provided an overview of the guidance in Section 4 of NUREG-1855, Revision 1, which relates to determining whether the scope and level of detail in the base PRA is adequate for the risk-informed activity under consideration. If the scope and level of detail in the base PRA is not sufficient to support the risk-informed application, the application can be redefined, the missing items can be shown not to be risk significant, or the PRA can be revised to address the missing scope and level of detail items.

Presentation 6: "Stages C, D, and E – Assessing Completeness, Parameter, and Model Uncertainties"

This presentation provided an overview of the guidance in Sections 5, 6, and 7 of NUREG-1855, Revision 1, which relates to the process of assessing completeness, parameter, and model uncertainty, respectively, in a risk-informed application. The completeness uncertainty assessment is used to determine whether a scope or level of detail item that is missing from the base PRA is significant to the decision and how it should be treated if it is significant. Parameter uncertainty is assessed through the propagation of parameter uncertainty during the risk metric quantification process. The model uncertainty assessment is used to identify the potential sources of model uncertainty and determine which of those sources of model uncertainty are key to the application.

Presentation 7: "Step 6/Stage F: Use of PRA Results in RIDM; Addressing Modeling Assumptions & Sources of Uncertainty in Licensee Applications"

This presentation provided an overview of the guidance in Section 2.2.6 of EPRI 1026511. The guidance discusses how to present the impacts of model assumptions and uncertainties in a given risk-informed application. This process provides confidence in the PRA model inputs that are needed by the decisionmakers in order to use the outputs of the PRA.

This presentation also discussed risk aggregation, including the following high level insights:

- Adding mean values is mathematically correct.
- Disaggregation of results is needed to understand what drives the risk results.
- Reasonableness of sensitivity studies are important.
- Sensitivity studies will likely produce results both above and below the mean value.
- Sensitivity studies move the entire distribution, including the mean value.

Presentation 8: "NUREG-1855 Stage F: Licensee Application Development Process"

This presentation provided an overview of the guidance in Section 8 of NUREG-1855, Revision 1, which discusses the process of ensuring adequate justification is provided to demonstrate the acceptability of a risk-informed application and that the justification is appropriately documented. The process of developing a risk-informed application may involve redefining the application, refining the PRA, or developing compensatory measures or implementing performance monitoring.

Presentation 9: "Stage G – NRC Risk-Informed Review Process"

This presentation provided an overview of the guidance in Section 9 of NUREG-1855, Revision 1, which discusses the NRC's review process for risk-informed applications. This process includes the NRC's review of the treatment of completeness, parameter, and model uncertainty, consistent with the guidance in NUREG-1855, Revision 1. In general, the level of justification needed in the risk-informed application is largely dependent on the proximity of the application risk results to the acceptance guidelines for the related risk-informed activity. The level of review by the NRC is similarly dependent on the proximity of the application risk results to the acceptance guidelines.

Presentation 10: "Example 1a: Example Implementation of the Process for Treatment of PRA Uncertainty in a Risk-Informed Regulatory Application"

This presentation discussed an example that describes the development of a license amendment request (LAR) application. The LAR application relates to a revision of a technical specification allowed outage time from three days to seven days for a residual heat removal/suppression pool cooling system at a two-unit boiling-water reactor, Mark II-type containment nuclear power plant. The motivation for developing the LAR is to allow periodic replacement of piping over a period of several years when one unit is shutdown and the other unit is operating. The presentation goes through each of the six steps described in EPRI 1026511 and, in doing so, illustrates the application of guidance in NUREG-1855, Revision 1.

Presentation 11: "Industry Example Stage G – NRC Review"

This presentation discussed the NRC risk-informed review process as related to the LAR example from the previous presentation. This presentation included a discussion of the NRC staff considerations for the application; assessment of the adequacy of the scope and level of detail and the technical adequacy of the model; comparison of the risk results to the acceptance guidelines; the impact of parameter and model uncertainties on the risk results; and the NRC's determination of whether the application is adequately justified.

Day 2 – Thursday, November 19, 2015

Four presentations were given on the second day that further demonstrated the application of the guidance in NUREG-1855, Revision 1, EPRI 1016737, and EPRI 1026511. These presentations were followed by an open discussion session with the workshop participants to solicit feedback on the guidance. The first two presentations discussed examples LARs related

to the National Fire Protection Association (NFPA) standard NFPA 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants;" the third presentation discussed an example related to the NRC's Significance Determination Process (SDP); and the last presentation discussed an example related to a new reactor application.

Presentation 12: NFPA 805 Example #1 Point Estimate of ΔCDF Meets RG 1.174 Acceptance Guidelines but Mean Does Not

This presentation discussed an example of a risk-informed activity related to RG 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis." The example describes the NRC review of an LAR in support of bringing a license into conformance with the requirements in NFPA 805 where the point estimate value of the change in CDF (ΔCDF) meets the acceptance guidelines in RG 1.174, but the mean value of the ΔCDF does not. The example included hypothetical requests for additional information (RAIs) and sensitivity studies from the NRC as well as a discussion of hypothetical NRC staff considerations from the risk-informed review. Issues discussed during the presentation included the following:

- Incorporation of risk mitigation capabilities affected by plant modifications should be incorporated in the PRA for the license application.
- How the NRC risk-informed review would differ if the ΔCDF was slightly below the threshold.
- Use of more realistic modeling when conservative fire PRA modeling yields unacceptable results.
- Use and treatment of conservative modeling when the risk results approach or exceed acceptance guidelines, in particular as related to LARs related to NFPA 805 and the NRC SDP.
- Use and review of unapproved new methods in risk-informed license applications.
- Inclusion of all targets and ignition sources in a fire PRA, as related to completeness uncertainty.
- Extension of insights from an internal hazards scenarios, e.g., internal fire, to external hazard scenarios.

Presentation 13: "NFPA 805 Example #2 Sensitivity Analysis for Crediting Westinghouse RCP Shutdown Seal (SDS) Shield Package Prior to NRC Review and Operational Verification"

This presentation discussed a second example of a risk-informed activity related to RG 1.174. The example describes the NRC review of an NFPA 805-related LAR for the installation of new Westinghouse shutdown seal (SDS) package in the reactor coolant pumps at a two-unit site where both units had mean CDF values ranging from 10^{-4} to 10^{-5} per year. The example included a hypothetical resolution for the LAR. Issues discussed during the presentation

included how to address situations where there is limited or a complete lack of operating experience, in particular, as related to sensitivity studies.

Presentation 14: "Stage G Significance Determination Process Example"

This presentation discussed the treatment of uncertainty in the NRC SDP related to an example external flooding scenario assessment, which included consideration of uncertainties on external flood frequencies; the performance of sensitivity studies; and the results of a phase 3 risk assessment. Issues discussed during the presentation included the following:

- Characterization of level of effort associated with the various portions of the SDP analysis.

- The impact that NUREG-1855, Revision 1, might have had on the risk assessment if it had been available at the time the subject SDP was being conducted.

- The treatment of and general perceptions related to large uncertainties.

Presentation 15: "New Reactor Example – A Key Assumption"

This presentation discussed an example application for a new reactor where the internal fire risk contributes more to the overall risk profile from any other hazard. The general NRC staff assessment of the application and a proposed resolution was presented.

Workshop Observations and Comments

This portion of the workshop was focused on soliciting feedback from participants related to suggested enhancements to the guidance in NUREG-1855, Revision 1, EPRI 1016737, and EPRI 1026511. The NRC will consider these observations and comments in determining how to proceed forward with the subsequent publication of NUREG-1855, Revision 1. The following observations and comments were shared and discussed:

- A review of the definition of the term base PRA should be performed to determine how that definition is influenced by the internal events PRA.

- A broader technical audience should be engaged, including but not limited to those involved in the analysis of external hazards, to help ensure that future document revisions adequately communicate the guidance to the intended audience.

- The NRC is currently looking at Level 2 and Level 3 PRA and cost-benefit analysis which extends beyond the CDF and large early release frequency (LERF) risk metrics. The concepts in NUREG-1855, Revision 1, should be broadened beyond the CDF and LERF risk metrics. Review relevant documentation from the workshop on Level 2 PRA modeling uncertainties.

- There is currently an effort to revise Inspection Manual Chapter (IMC) 0609, Appendices A and M, which is intended to further integrate risk-informed qualitative criteria with the existing framework. Consider eliminating IMC 0609, Appendix M, to be replaced with a process that involving a detailed treatment of uncertainties based on guidance in NUREG-1855. Consider establishing a joint working group to accommodate such a change.

- Consider developing an appendix which evaluates performance deficiencies and mitigating strategies.

- Publication of NUREG-1855, Revision 1, is beneficial and publication should not be delayed. However, the next revision of NUREG-1855 would be improved by including explicit guidance for the example risk-informed activities in Tables 3-1 and 3-2 as well as lessons learned from pilot studies.

- Evaluate whether the guidance in NUREG-1855, Revision 1, adequately describes the NRC expectations related to detailed information licensee's need to provide in the documentation for a risk-informed submittal. Also, consider developing guidance on a standardized way of documenting routinely communicated information.

- Decisionmakers generally do not have time to read NUREGs. Consider using different communication tools, such as a shortened version of this workshop, to inform managers about the guidance in NUREG-1855, Revision 1. Additionally, consider actively involving NRC staff in communicating the guidance to management.

- More guidance is needed related to scenario formulation and completeness uncertainty in external events.

- Reproduce the EPRI external events example in NUREG-1855, Revision 1, to clarify the NRC's expectations in a license application.

- Additional guidance may be needed on the selection of sensitivity studies beyond the related guidance in EPRI 1016737. Consider developing a list of sensitivity studies and reasonable alternatives for common assumptions, to be correlated with the EPRI list of sources of uncertainty.

- EPRI and the NRC have signed a memorandum of understanding (MOU) to share data collected on external event hazards, but analysis based upon that data will not be shared. EPRI is currently focused on characterization of low frequency floods.

- Future revisions of NUREG-1855, Revision 1, should address sensitivity studies that involve the analysis of large numbers of model uncertainty combinations.

- Conduct a review of Section 7.2.1 in NUREG-1855, Revision 1, to ensure consistency with the advanced light-water reactor interim staff guidance document DC/COL-ISG-028, "Interim Staff Guidance on Assessing the Technical Adequacy of the Advanced Light-Water Reactor Probabilistic Risk Assessment for the Design Certification Application and Combined License Application."

- Conduct a review of NUREG-1855, Revision 1, to ensure that the terms upgrade, update, and refine are used consistently and appropriately.

- Consider additional outreach to help external stakeholders better understand the tools, processes, and vernacular in NUREG-1855.

- The Pressurized-Water Reactor Owner's Group is considering expanding their pilot of the EPRI 3002003116, "An Approach to Risk Aggregation for Risk-Informed Decision-Making," to include the use of NUREG-1855, Revision 1.

- Consider developing training that focuses on the use of guidance in NUREG-1855 and the EPRI documents. Two to three levels of training is needed. Such training should be used to complement existing training for management, from line management up through the Commission. The training should take 15-20 minutes and include links to additional information that can be accessed at the user's discretion.

- The NRC should consider piloting the guidance in NUREG-1855, Revision 1, using one or more examples of risk-informed decisions. This pilot would be less rigorous than a formal pilot of an actual application, but more rigorous than a tabletop exercise, in order to exercise the practical implementation of the guidance in NUREG-1855, Revision 1.

Enclosures:
1. List of Meeting Attendees
2. Presentation Handouts (ADAMS Accession No. ML15327A182)

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