NRC/NEI RISK-INFORMED STEERING COMMITTEE UNCERTAINTY WORKING GROUP

ISSUE DESCRIPTION

As risk results and insights have been increasingly relied upon to support licensee and regulatory decisions, the appropriate treatment and consideration of uncertainties in the PRAs supporting the decision-making processes have also become more important. Considerable work has been done on this topic by the nuclear community and others, and there are several guidance documents and standards used in current applications.[1] However, recent experiences indicate that practical applications can be hindered by: (a) different levels of detail and assumptions made in the development of the supporting PRA models; (b) the lack of sufficient guidance to address important issues, including decision making in the presence of very large, irreducible uncertainties; and (c) the implications of the differentiated treatment of uncertainty when considering the risk profile from multiple hazards.

OBJECTIVE

The objective of this working group is to identify options for follow-on activities needed to develop near- and longer-term solutions to improve the treatment of uncertainty in risk-informed decision making.

APPROACH

In order to identify the best path forward, the first step was to identify the specific causes for why PRA uncertainties are not consistently characterized in a manner that supports decision making in current risk-informed applications. After establishing causes that inhibit the appropriate, consistent treatment of uncertainty in risk-informed decision-making, the existing approaches and the associated guidance for the identification and representation of uncertainty in the estimates of risk metrics were evaluated in order to determine the gaps. A number of relevant resources already exist, including RG 1.174, NUREG-1855, NRR Office Instruction LIC-504, and various EPRI documents, including EPRI 1026511. The goal is to identify the key areas where additional guidance and/or training may be beneficial in order to focus the near-term efforts. In order to achieve this, several public meetings were held and a public workshop was held on November 20, 2014. These public interactions yielded a number of insights, and recommendations were generated as presented below.

ASSESSMENT OF CURRENT STATUS

Nature of PRA models

Understanding uncertainties in PRA models requires an understanding of the fundamental and necessary limitations, which can be summarized as follows:

- PRA models are approximate and are constructed by creating a discrete set of scenarios that encompass a range of scenarios. This is typically done in a bounding manner (e.g.,

[1] Key documents include RG 1.174, the ASME/ANS PRA Standard, NUREG-1855, and EPRI 1026511, the guidance document that is a companion to NUREG-1855.

choosing an initiating event that is bounding in terms of required plant and operator response to represent a group) to limit complexity in the PRA and to make the process more manageable. Thus there is a bias that is not readily measurable. While this may not be a significant issue for internal events, because the methods are relatively mature, characterizing these uncertainties can be resource intensive for fire and seismic PRAs due to lack of mature consensus methods and the larger associated uncertainties.

- Some approximations are driven by technological considerations (computer limitations), others by resources (the ability to trace all cables that might be relevant to a fire PRA). The latter, while not strictly fundamental, is an important consideration.
- Not all potentially relevant elements are included (e.g., errors of commission (EOCs), inter-system common cause failures (CCFs), recovery actions that are not explicitly covered in procedures, some mitigation capability), either because methods do not support their inclusion (EOCs and inter-system CCFs) or they don't have a significant impact on the results (e.g., fire water as a source of injection in a BWR). These approximations introduce a mixture of non-conservative and conservative bias.
- Some phenomena are not well understood or models are crude (e.g., fire growth modeling, fragility evaluation).
- Some assumptions are unstated and, while not significant for the base case assessment, could be relevant for specific applications, e.g., recovery actions.

As a consequence, PRA results are by their nature approximate and contain biases that cannot be captured in an uncertainty analysis. The best that can be done to address this situation is to identify the sources of those biases and either develop more detailed models or demonstrate that the impact is not significant (as has been done for EOCs in some studies).

<u>What does PRA Uncertainty Analysis do and what does it not do?</u>

Uncertainty is classified as either parametric, model, or completeness. These uncertainties are addressed in different ways, such as:

- Parametric uncertainty is typically addressed in the quantification of models and is reflected as a probability distribution on the assessed risk metrics. The mean of this distribution is used as the representative value of the metric.
- Model uncertainties are typically addressed through the use of sensitivity studies to explore how the mean value and insights change when alternate assumptions are made. However, some model uncertainty may be incorporated in the probability distribution on the risk metrics, but only when the estimation approaches have a means for doing so (e.g., SSHAC approach for seismic hazard assessment).
- Completeness uncertainties cannot be quantified. This has been recognized in guidance (e.g., RG 1.174) as an uncertainty that has to be addressed by considering factors such as defense in depth and safety margins.

Conclusion: the mean value and the characterization of uncertainty are conditional on all the assumptions that went into the PRA model. However, not all of the effects of the sources of uncertainty are captured in the mean. In particular, the biases introduced by the approximations and modeling assumptions are not included.

<u>Assessment of Current Treatment of PRA Uncertainty in Decision Making</u>

The acceptance guidelines are intended to be compared with the mean value of the probability distribution for the corresponding risk metric(s). However, as stated in RG 1.174,

> *"…the state-of-knowledge, or epistemic, uncertainties associated with PRA calculations preclude a definitive decision with respect to the region in which the application belongs based purely on the numerical results."*
>
> *"…comparison of the PRA results with the acceptance guidelines must be based on an understanding of the contributors to the PRA results and on the robustness of the assessment of those contributors and the impacts of the uncertainties, both those that are explicitly accounted for in the results and those that are not."*

Implementation of this guidance has been challenging for a number of reasons including the following:

- There is a tendency to focus on absolute numbers and not enough on the insights, i.e., the risk drivers and what their implications are.
- The mean values derived from the propagation of parameter uncertainty include biases that are the result of modeling approximations and are not quantified. These biases may be conservative or non-conservative.
- The increased scope of PRA models to include fire, seismic, and flood events as initiating hazards has exacerbated this concern because of the differing levels of approximation and resulting biases in the modeling. The acceptance guidelines require a comparison with the aggregated results of the risk assessments for the contributing hazards. The processes for effectively aggregating and interpreting aggregated results are not well defined.
- Existing guidance is unclear concerning when and how to address the sources of uncertainty that are not captured in the mean value, but have been shown to potentially challenge the acceptance guidelines by using the other principles of risk-informed decision making (RIDM) (e.g., defense-in-depth).
- Existing guidance is unclear on how to deal with very large uncertainties that cast doubt on the relevance of the mean values generated (see EPRI 1026511 for a discussion of dealing with very large uncertainties).
- There is a lack of understanding of the expectations for addressing model uncertainties, despite the publication of NUREG-1855 and EPRI 1016737.
- Some practitioners have expressed concerns that the expectations for addressing uncertainty are too onerous due to limited guidance and the potentially large number of sensitivity analyses that may be required.
- Lack of a specific framework for communication of the uncertainties and their significance to decision-makers is challenging, partly due to a lack of understanding of how PRAs are developed and the limitations on what they can and cannot address.

RECOMMENDATIONS

The working group (WG) has developed the following recommendations. They fall into two categories: (1) the enhancement of the existing guidance for addressing uncertainty, and (2) identification of potential education mechanisms (e.g., training, communications), for both PRA practitioners and broader audiences, with respect to the treatment of uncertainty in the context of decision-making.

Enhancements to Existing Framework

These enhancements need to be consistent with, and based upon, the principles for good decision-making. The enhanced framework will also continue to focus on maintaining the unique advantage of PRAs, i.e., their ability to develop a quantitative perspective using appropriate data and methods and while also producing qualitative insights from a systematic process.

Recommendation 1: Clarify Expectations for the Treatment of Uncertainty

In general, the existing guidance that addresses the treatment of uncertainty does not provide clear expectations on what information is needed and how the information should be interpreted in the context of risk-informed decision-making. This is applicable at both the practitioner and decision-maker levels. RG 1.174 is written at a very high, almost philosophical level and lacks details needed concerning the practical application of this concept. NUREG-1855 and the related EPRI documents are more specific, but the guidance is still somewhat generic in nature. Some specific explanations would be beneficial in clarifying the way the decision-making "regimes" (that are tied to specific expectations for what needs to be addressed) described in NUREG-1855 should be interpreted with respect to the manner in which Reg. Guide 1.174 characterizes the acceptance guideline "regions". In addition, other risk-informed regulatory guidance and industry application guides should be reviewed and updated, as appropriate, to adopt these expectations and to clarify how they should be applied in a particular application.

Recommendation 2: Provide Guidance on Aggregation

Guidance on aggregation of different risk contributors is needed. On-going EPRI work in this area may provide benefit to the WG activities. This same EPRI work provides some initial concepts for providing decision-makers the information necessary for a risk-informed decision. Sharing of the EPRI work with NRC should be expedited.

Recommendation 3: Develop Guidance on Integrating PRA Results into a Decision-Making Framework

The relationship to the integrated decision-making process and the interrelationship between the assessments of the different principles of RIDM are not clearly discussed in the current guidance documents. The lack of specific guidance on what information needs to be included and how it should be presented results in inconsistency in how the information is characterized. This results in failing to provide information concerning uncertainties in a way that it can be appropriately considered when making a decision. Existing guidance addresses this issue in a piecemeal manner. For example, EPRI 1026511 provides guidance on the use of the PRA insights to inform the assessment of defense-in-depth. LIC-504 provides a framework to document an assessment of all the principles for communication with decision-makers. Appendix M of IMC 609 provides a risk-informed framework for evaluating performance deficiencies, but the guidance is quite high-level and is only applied in cases where quantification of risks is difficult. Some of the concepts in Appendix M may be beneficial to consider in risk-informed decisions, even when quantification is possible. In addition, other parts of the Reactor Oversight Process (ROP) are largely risk-based and would benefit from the use

of more risk-informed concepts in Appendix M. EPRI has on-going work related to aggregation and risk-informed decision-making that should be shared with the NRC.

Recommendation 4: Develop Additional Guidance on Addressing Specific Challenges

Two areas where additional guidance is warranted include:

- In some cases, the lack of data can make computation of a reliable mean value challenging, e.g., certain rare environmental conditions. Guidance is needed to address situations where the mean values are not as meaningful as other contributors.
- Conservatisms, although widely employed in traditional safety analysis, have the potential to skew risk results, make relevant insights harder to extract, and in some instances lead to non-conservative decisions. Additional guidance is needed to assist practitioners and decision-makers in addressing this.

Recommendation 5: Provide Guidance on Addressing Mitigating Strategies in RIDM

Creating a means to address Mitigating Strategies in risk-informed decision-making is important in the post-Fukushima era. This may be through incorporation in the PRA model, or through a separate means. This is becoming a pressing need as the implementation of EA 12-049 has already been completed at some sites, with the rest of the fleet following in the near term.

Recommendation 6: Continue to Improve NUREG-1855 and Supporting EPRI Guidance

A “pilot” of NUREG-1885 is recommended using one or more actual risk-informed decisions either prior to or shortly after issuance of Rev. 1. NUREG-1855 provides guidance and insights that may be beneficial to consider incorporating into IMC 609 for use in the significance determination process (SDP). Expediting the incorporation of the applicable insights and recommendations will require near-term resource commitments on the part of both industry and NRC.

Education on Uncertainty and Decision-making

Recommendation 7: Conduct Annual Industry-NRC meetings on RIDM

A regularly scheduled, joint NRC-EPRI meeting on risk-informed decision-making would raise awareness of key issues and help educate practitioners as well as decision-makers.

Recommendation 8: Provide Education for Practitioners on Current Guidance

A joint NRC-EPRI workshop is recommended upon issuance of NUREG-1855 to help practitioners understand the expectations and supporting EPRI guidance. Such a workshop was held when the original NUREG-1855 was issued.

Recommendation 9: Provide a Training Course on Risk-informed Decision-making and the Role of Uncertainty

The training should be focused on the needs of both PRA practitioners and decision-makers.