Recommendations from the Working Group on
Qualitative vs. Quantitative PRA Methods

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I. Charter:

The charter for the working group is to recommend a framework by which qualitative standards and quantitative methods can be addressed in future ASME and ANS Probabilistic Risk Assessment (PRA)[1] standards so that these standards can support risk-informed decision-making.

II. Background

RISC and others have been struggling with how certain methodologies (e.g., SMA for seismic risk standard, FIVE for fire risk standard and the qualitative part of the low power and shutdown risk standard) fit into the framework of risk standards. The Working Group on Qualitative vs. Quantitative PRA Methods (WGQQPM) realizes and recognizes that there is not universal understanding and agreement on concepts and definitions on this topic. Central to this topic are the following questions:

1) When is an analysis PRA?
2) What is a qualitative analysis?
3) What is the distinction between a qualitative analysis and a quantitative analysis?
4) What are the defining characteristics of an analysis which, when applied to a decision-making process, make that decision risk-informed?
5) Does qualitative mean non-quantitative?

In order to define some distinctions, the following table may be useful:

PRA & Quantitative	Non-PRA & Quantitative
PRA & Qualitative	Non-PRA & Qualitative

It is now possible to try to populate each box in this table with specific examples of methodologies and/or analyses. Also, we could attempt to put pieces of our risk standards into these boxes.

The following sections provide some Definitions, Status of Methods in Standards, Potential Roles for Qualitative Methods, and Recommendations for RISC Consideration.

III. Definitions

A. PRA

- The ANS Glossary is being revised and the proposed definition for PRA (there was not one in the past) is, "Probabilistic risk assessment (PRA)

[1] Probabilistic Risk Assessments (PRA) are also referred to as Probabilistic Safety Assessments (PSA).

technology provides a quantitative assessment of nuclear power plant accident risk. Models delineate the [note that some words are missing here in the text of the draft glossary, possibly the word "operation"] of systems and operators response to accident initiating events. Additional models identify component failure modes required to cause the accident mitigating systems failure. Nuclear power plant PRA data analysis estimates the parameters used to determine the frequencies and probabilities of the various events modeled in PRA. (ANSI/ANS 53.1-200x Draft)" However, the most recent draft of ANSI/ANS 53.1 defines PRA to be, "A qualitative and quantitative assessment of the risk associated with plant operation and maintenance that is measured in terms of frequency of occurrence of risk metrics, such as the frequency of a radioactive material release and its effects on the health of the public [also referred to as a probabilistic safety assessment (PSA)]." These definitions express the opinion that PRA can be qualitative or quantitative in the assessment of risk.

- The IAEA glossary defines PSA as probabilistic safety assessment (PSA) as "A comprehensive, structured approach to identifying failure scenarios, constituting a conceptual and mathematical tool for deriving numerical estimates of risk."

- IAEA Requirements document Safety of Nuclear Power Plants: Design, NS-R-1, is the base design document for nuclear power plants sort of like ANS-51.1 is for PWRs, ANS-52.1 is for BWRs, and ANS-53.1 is for HTGRs. This IAEA document in section 5.73 identifies a mixed bag of elements (listed below) for probabilistic safety analysis to be carried out in order:
  1. to provide a systematic analysis to give confidence that the design will comply with the general safety objectives;
  2. to demonstrate that a balanced design has been achieved such that no particular feature or postulated initiating event (PIE) makes a disproportionately large or significantly uncertain contribution to the overall risk, and that the first two levels of defense in depth bear the primary burden of ensuring nuclear safety;
  3. to provide confidence that small deviations in plant parameters that could give rise to severely abnormal plant behavior ('cliff edge effects') will be prevented
  4. to provide assessments of the probabilities of occurrence of severe core damage states and assessments of the risks of major off-site releases necessitating a short term off-site response, particularly for releases associated with early containment failure;
  5. to provide assessments of the probabilities of occurrence and the consequences of external hazards, in particular those unique to the plant site;

6. to identify systems for which design improvements or modifications to operational procedures could reduce the probabilities of severe accidents or mitigate their consequences;
7. to assess the adequacy of plant emergency procedures; and
8. to verify compliance with probabilistic targets, if set.

This list of elements can be accomplished with either qualitative or quantitative methodologies.

- ASME standard

  Probabilistic risk assessment (PRA) is defined as,:"A qualitative and quantitative assessment of the risk associated with plant operation and maintenance that is measured in terms of frequency of occurrence of risk metrics, such as core damage or a radioactive material release and its effects on the health of the public."

B. Risk

Risk is typically recognized as a formulation of the product of likelihood (probability) and consequences. More generally, it can be a probability vs. consequence plot or an array of probability vs. related consequences (for a particular event or an aggregate of events)

C. Risk-Informed

NRC has defined risk-informed in several places; e.g.,

- COMSAJ-98-003, February 20, 1998, from NRC Chairman Shirley Jackson
- NUREG-1614, Strategic Plan
- NRC glossary
- March 11, 1999 Commission White Paper on Risk-Informed and Performance-Based Regulation

The NRC definitions all tend to have their genesis from what is in the white paper, i.e.,

> Risk-Informed Approach: A "risk-informed" approach to regulatory decision-making represents a philosophy whereby risk insights are considered together with other factors to establish requirements that better focus licensee and regulatory attention on design and operational issues commensurate with their importance to public health and safety. A "risk-informed" approach enhances the deterministic approach by: (a) allowing explicit consideration of a broader set of potential challenges to safety, (b) providing a logical means for prioritizing these challenges based on risk significance, operating experience, and/or engineering judgment, (c) facilitating consideration of a broader set of resources to defend against these challenges, (d) explicitly identifying and quantifying sources of uncertainty in the analysis (although such analyses do not necessarily reflect all important sources of uncertainty), and (e) leading to better

decision-making by providing a means to test the sensitivity of the results to key assumptions. Where appropriate, a risk-informed regulatory approach can also be used to reduce unnecessary conservatism in purely deterministic approaches, or can be used to identify areas with insufficient conservatism in deterministic analyses and provide the bases for additional requirements or regulatory actions. "Risk-informed" approaches lie between the "risk-based" and purely deterministic approaches. The details of the regulatory issue under consideration will determine where the risk-informed decision falls within the spectrum.

In addition, the NRC in Regulatory Guide 1.174 states that PRA quality needs to be "commensurate with the application for which it is intended and the role the PRA results play in the integrated decision process."

The NRC makes no explicit determination of qualitative or quantitative risk tools. In addition, conventional language would suggest that "risk-informed" would be any decision where the conclusion of the decision is "informed" not necessarily "based entirely" on information that comes from a "risk" study. Thus "risk-informed can be from qualitative or quantitative sources and the NRC allows both.

D. Summary

Qualitative risk methods for risk-informed decision-making are methods (primarily non-numerical, but sometimes supported by numerical information) that identify specific attributes of probability and consequences to provide information to make decisions.

Quantitative risk analysis methods for risk-informed decision-making are methods (primarily numerical) that determine with some appropriate degree of exactness (i.e. with related estimates of uncertainties) the quantities of attributes of probability and consequence to provide information to make decisions.

E. Conclusion

Given the above definitions, <u>all the methods employed currently in the nuclear industry to estimate risk are quantitative to a certain degree</u>. The industry has used the term qualitative to apply to some quantitative methods as a means of distinguishing between degrees of resolution of results accuracy.

In both qualitative and quantitative methods the measures of risk, probability, and consequences should be the same. The distinction comes in translating the measures into metrics. For quantitative methods the metrics are numerical. For qualitative methods they are non-numerical (e.g. linguistic metrics like high, medium, and low). The following section summarized the methods endorsed in the current PRA standards.

Thus qualitative is a special case of quantitative; a first step in any quantitative PRA that is done right. For a qualitative analysis to be the basis for risk-informing, it should be the best that one can reasonably do, in term of likelihoods and consequences. It should recognized dependencies to the extent possible and it should give a clear statement of uncertainties in both likelihoods and consequences, even if these are presented in terms of qualitative descriptors or linguistic variables (e.g. H, M, L).

IV. Status of Methods in Standards:

- Full Power Internal Events: The ASME standard endorses more quantitative methods; however, section 3.6 does endorses and provides examples of supplementary methods stating, "These supplementary analyses will depend on the particular application being considered, but may involve deterministic methods such as bounding or screening analyses, and determinations made by an expert panel."
- External Events: The standard deals with all external events, but the focus in on seismic. SMA takes a prominent role in the standard but there is a caveat that requires enhancements (provided in Appendix D) to allow SMA to play that role.
- Fire: The standard contains a non-mandatory appendix discussion on FIVE but does not explicitly endorse its use; however, the Fire PRA process described in NUREG/CR-6850 includes both quantitative and qualitative screening tasks. In fact, the whole approach of NUREG/CR-6850 is a process that limits the extent of detailed fire modeling by a series of qualitative and quantitative screening steps.
- LP/SD: This standard is in draft; however, the decision was made by ANS RISC to allow the use of qualitative methods in the standard as a screening method to determine if further quantitative analysis is needed. This decision will not be revisited as part of this Working Group effort.

V. Potential Roles for Qualitative Methods:

Role 1
Use qualitative methods as analysis tools equivalent with quantitative methods when the need for technical adequacy of quantitative methods is not required or supported by data. This is justified when the risk contributor is judged to be low for the existing design and site.

Role 2
Use qualitative methods as screening tools to judge if risk is significant enough to require further evaluation with more quantitative means. This approach is an extension of screening techniques already employed in quantitative risk assessments. Initial screening should be performed in all risk assessment to separate the insignificant from what remains to be analyzed in detail. Note that a degree of "significance" must be predetermined by the analyst. It effectively establishes a metric for the underlying measure.

The difference between role 1 and 2 is that role 1 means a judgment of low risk or very large uncertainty already exists and the qualitative tool is necessary to gain risk insights. Role 2 is employed when the qualitative tool can do an adequate job of screening risk scenarios at a low enough level to justify that quantitative tools are needed only for analysis of the higher risk scenarios. As noted above, quantitative approaches may be difficult where uncertainties a large and difficult to quantify.

VI. Recommendations for RISC Consideration:

In the Background section, five questions were posed. These questions have been answered. The following two recommendations are for the consideration of the ANS RISC.

A. The Use of Qualitative Tools in the Combined Standard (ASME/ANS RA-S-series)

The purpose of the combined standard is to combine the existing standards without changing any technical elements or judgments. Thus, the combined standard must incorporate all the methods already employed in the individual standards.

B. The Use of Qualitative Tools in the Future Integrated Standard

At some time in the future, having gained experience with the combined standard and resolved some technical integration problems, an integrated standard will be produced. This standard may include other risk contributors such as fires during shutdown. Roles 1 and 2 are appropriate for incorporation of qualitative tools in to PRA standards.