UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

November 24, 2023

Mr. Daniel H. Dorman
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: INTERIM LETTER ON LEVEL 3 PROBABILISTIC RISK ASSESSMENT – VOLUMES 3 AND 4, PERTAINING TO REACTOR AT-POWER EVENTS

Dear Mr. Dorman:

During the 710th meeting of the Advisory Committee on Reactor Safeguards (ACRS), November 1-2, 2023, we completed our review of two of the planned eight volumes of the Level 3 Probabilistic Risk Assessment (L3PRA): Volume 3 - Reactor at-Power, Internal Events and Floods; and Volume 4 - Reactor at-Power, Internal Fires and External Events. Our Subcommittee on Reliability and Probabilistic Risk Assessment also reviewed these volumes during its meetings on June 22, 2022, and October 19, 2023. During these meetings, we had the benefit of discussions with representatives of the U.S. Nuclear Regulatory Commission (NRC) staff and other stakeholders. We also benefited from the referenced documents.

CONCLUSIONS AND RECOMMENDATIONS

1. When completed, the L3PRA study will be the most comprehensive full-scope probabilistic risk assessment (PRA) performed by NRC. The coverage of the PRA subject matter, including risks associated with severe accidents, is extensive. It applies experience gained over the 30 years since NUREG-1150, providing new insights related to regulatory decision-making and Level 3 PRA documentation, technical feasibility, and cost.

2. Insights, assumptions, sensitivity runs, treatment of uncertainties, model limitations, deficiencies, and possible enhancements are found throughout Volumes 3 and 4. The forthcoming Volume 1 summary report should cover the important insights from these volumes, including and expanding upon the items identified in this letter.

3. Given that results from this work could provide important risk insights for regulatory decision-making, resources should be prioritized to ensure that the remaining documents are issued without significant delays.

BACKGROUND

The NRC is performing a full-scope site L3PRA project for a reference plant with two Westinghouse 4-loop pressurized-water reactors. The staff undertook this project in response to Commission direction in the staff requirements memorandum dated September 21, 2011, resulting from SECY-11-0089, "Options for Proceeding with Future Level 3 Probabilistic Risk Assessment Activities."

The objectives of the L3PRA project are:

1. Develop a Level 3 PRA, generally based on current state-of-practice methods, tools, and data, that: (a) reflects technical advances since the last NRC-sponsored Level 3 PRAs (NUREG-1150), which were completed over 30 years ago; and (b) addresses scope considerations that were not considered at that time (e.g., low-power and shutdown risk, multi-unit risk, and spent fuel storage).

2. Extract new insights to enhance regulatory decision-making, and to help focus limited NRC resources on issues most directly related to the agency's mission to protect public health and safety.

3. Enhance PRA staff capability and expertise as well as improve documentation practices to make PRA information more accessible, retrievable, and understandable.

4. Demonstrate the technical feasibility and evaluate the cost of developing new Level 3 PRAs.

A potential use of the methodology and insights generated from the L3PRA project is to inform regulatory, policy, and technical issues pertaining to advanced light-water reactor and non-light-water reactor applicants that are using the licensing modernization project (LMP) framework and are required to perform Level 3 PRA analyses.

The L3PRA project includes Level 1, 2, and 3 PRA models and results for internal events, floods and fires, seismic events, high winds, and other external hazards, as well as other plant operating states, and other site radiological sources (i.e., spent fuel pools and dry storage casks). Two cases are evaluated: the Circa-2012 case reflects the reference plant as designed and operated in 2012; and the 2020-FLEX case reflects the current reactor coolant pump shutdown seal design at the reference plant, as well as the potential impact of Diverse and Flexible Coping Strategies (FLEX).

The ACRS has reviewed the technical aspects of the L3PRA project since its inception in 2010. During our 584th meeting, we issued a letter dated June 22, 2011, supporting the performance of this work, encouraging explicit treatment of uncertainties and avoidance of excessively conservative assumptions or analytical simplifications. As the project entered its final completion phase, two subcommittee meetings were held covering the following volumes:

- Volume 3 documents the L3PRA project Level 1, 2 and 3 PRA models and analyses for internal events and internal floods, during power operation for the Circa-2012 and 2020-FLEX cases.

- Volume 4 documents the L3PRA project Level 1, 2 and 3 PRA models and analyses for internal fires, seismic events, and high winds during power operation for the Circa-2012 and 2020-FLEX cases.

DISCUSSION

Our prior meetings focused on technical aspects of the L3PRA and on the technical work for Volumes 3 and 4 being completed and documented. Our current review is focused on evaluating how well this work meets the objectives of the overall project, especially objective #2 (extracting new insights to enhance regulatory decision-making), and part of objective #3 (improving documentation practices to make PRA information more accessible, retrievable, and understandable).

The work documented in Volumes 3 and 4 is extensive, covering broad technical areas. However, important insights, assumptions, sensitivity runs, treatment of uncertainties, as well as model limitations, deficiencies, and possible enhancements are spread throughout these volumes. We expect these insights will receive better focus in Volume 1 - Summary Report, which will be published after all technical work for the L3PRA project has been completed and will incorporate the results and perspectives from all other reports prepared in support of the L3PRA project.

The insights from Volumes 3 and 4 that deserve special attention, and need to be well documented in the summary volume, are discussed below:

Limitations: Throughout these documents, there are a few cautions stating that “inclusion of approaches in the L3PRA project documentation should not be viewed as an endorsement of these approaches for regulatory purposes.”

Examples where this caution was provided include: (1) technical aspects of the study that were subject to simplifications or were not fully addressed; and (2) technical areas within the project scope that necessitated advancements in the state of practice (e.g., modeling of multi-unit site risk, modeling of spent fuel in pools or casks, and human reliability analysis (HRA) for other than internal events and internal fires). These technical aspects and technical areas should be specifically identified in the summary volume.

FLEX Strategies: The FLEX strategies considered in the 2020-FLEX case are limited and conservative, because they consider only Phases 1 and 2 FLEX strategies for coping with plant conditions resulting from an extended loss of alternating-current power (ELAP), relying on installed plant equipment, on-site resources, and on-site FLEX equipment. The potential for FLEX to mitigate the plant conditions resulting from a loss-of-coolant accident (LOCA) was not considered. In addition, Phase 3 FLEX, obtaining additional capability and redundancy from off-site equipment and resources, was not considered. While Phase 3 FLEX may not impact the core damage frequency, it can influence accident progression, containment response, and long-term fission product release.

Level 2 HRA: The Level 2 PRA HRA evaluates a variety of post-core damage actions to mitigate radiological releases. The credit for such actions is based on the reference plant’s accident management guidelines and severe accident MELCOR analyses. The Level 2 HRA is innovative and can provide valuable insights. It should therefore be well documented as a separate report or an appendix.

Level 3 PRA Results: The Level 3 PRA results show extremely low early fatality risk and low latent fatality risk. The low early fatality risk is at least partially due to characteristics of the reference site, such as sparse population density near the plant and low frequency of adverse meteorological conditions, that may not apply to other sites. To provide a level of confidence in the results, the discussion of the fatality risk levels should provide a complete characterization of the factors that lead to an extremely low risk to the off-site public. Sensitivity studies should be conducted for sites with different characteristics. We note that results from these calculations could provide important insights in the relationship between the quantitative health objectives (QHOs) and the subsidiary risk metrics.

Timelines: A forward-looking approach for defining mission time is introduced in the report, based on time to reach a stable end state. The basis for selecting mission times should be documented. Many other timelines are considered in the report: ELAP entry time; severe accident management guideline (SAMG) entry time; time when airborne radiological releases are terminated; general emergency declaration time; time available for evacuation; large early release frequency (LERF) threshold times; time to containment failure; etc. The technical bases for the selected times, and the sensitivity of the overall results to these selections, should be documented.

Uncertainties: Uncertainty evaluations in the L3PRA work provide many interesting and thought-provoking insights. It would be helpful to explain these in more detail, and document them in Volume 1 - Summary. A few examples are listed below:

- "…*the relatively large number of basic events and cut sets used in the parametric uncertainty analysis appears to dilute (mask) the effect of basic events with higher uncertainties."*

- Model uncertainty within the Level 2 PRA is characterized through *"alternative treatments about the default modeling assumption and explored using sensitivity analysis… [That] reflects limitations in the state-of-practice of uncertainty treatment, along with practicalities in how the overall PRA is constructed (as the combination of probabilistic and deterministic modeling)."*

- *"The approach here is to consider all parameter uncertainties in an integrated fashion, and to explore model uncertainties in groups (or categories). Accident analysis uncertainties are correlated/inter-related throughout the accident, so one should be cautious in thinking that this approach provides a comprehensive or holistic view of accident uncertainty. Once again, its limitations reflect the state-of-practice in uncertainty treatment and Level 2 PRA development.*"

In addition, many uncertainties were not analyzed, sometimes because of limited knowledge or software limitations. In general, all assumptions with potentially large impact on the results should be identified and included in Volume 1- Summary, even if they were not part of the completed sensitivity studies (i.e., sensitivity cases that could not be performed).

Finding a way to present more realistic uncertainty distributions could be an important suggestion for future work. The reported narrow uncertainty distributions should be explained.

Future Work: Candidates for future work are identified throughout the reviewed documents, including additional analyses that could be done for the reference plant and potential model enhancements. The more important suggestions requiring future research should be

emphasized in the summary volume. It would also be beneficial if the current work identified cases where more detailed analyses may not be a cost-effective means of improving risk insights.

SUMMARY

When completed, the L3PRA study will be the most comprehensive full-scope PRA performed by NRC. The coverage of the PRA subject matter, including risks associated with severe accidents, is extensive. It applies experience gained over the 30 years since NUREG-1150, providing new insights related to regulatory decision-making and to Level 3 PRA documentation, technical feasibility, and cost.

Not all the expected analyses and results could be completed due to unforeseen situations, including the Fukushima events that diverted staff resources. Nevertheless, the study has met its original objectives; in the case of FLEX, it continued the analysis beyond the original plan. The continuing value of the project will be enhanced by providing a clear statement of insights gained in its performance. A clear exposition of modeling assumptions, sensitivity analyses, treatment of uncertainties, modeling issues, deficiencies, and possible enhancements for future PRAs in the Volume 1 summary report would be valuable.

Sincerely,


Signed by Rempe, Joy
on 11/24/23

Joy L. Rempe
Chairman

REFERENCES

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5. U.S. NRC, SECY-12-0123, “Update on Staff Plans to Apply the Full-Scope Site Level 3 PRA Project Results to the NRC’s Regulatory Framework,” September 13, 2012 (ADAMS Accession No. ML12202B170).

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10. U.S. NRC Level 3 Probabilistic Risk Assessment (PRA) Project, Volume 3b: “Reactor, At-Power, Level 1 PRA for Internal Flooding,” April 2022 (ADAMS Accession No. ML22067A213).

11. U.S. NRC Level 3 Probabilistic Risk Assessment (PRA) Project, Volume 3c: “Reactor, At-Power, Level 2 PRA for Internal Events and Floods,” April 2022 (ADAMS Accession No. ML22067A214).

12. U.S. NRC Level 3 Probabilistic Risk Assessment (PRA) Project, Volume 3d: “Reactor, At-Power, Level 3 PRA for Internal Events and Floods,” April 2022 (ADAMS Accession No. ML22067A215).

13. U.S. NRC Level 3 Probabilistic Risk Assessment Project, Volume 4: “Overview of Reactor, At-Power, Level 1, 2, and 3 PRAs for Internal Fires, Seismic Events, and High Winds,” April 2022 (ADAMS Accession No. ML23194A015).

14. U.S. NRC Level 3 Probabilistic Risk Assessment Project, Volume 4a: “Reactor, At-Power, Level 1 PRA for Internal Fires,” April 2022 (ADAMS Accession No. ML23194A016).

15. U.S. NRC Level 3 Probabilistic Risk Assessment Project, Volume 4b: “Reactor, At-Power, Level 1 PRA for Seismic Events,” April 2022 (ADAMS Accession No. ML23194A017).

16. U.S. NRC Level 3 Probabilistic Risk Assessment (PRA) Project, Volume 4c: “Reactor, At-Power, Level 1 PRA High Winds and Other Hazards Project,” April 2022 (ADAMS Accession No. ML23194A012).

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