Technical Advisory Committee of the Nuclear Risk Research Center
Central Research Institute of Electric Power Industry
1-6-1 Otemachi, Chiyoda-ku, Tokyo, 100-8126 Japan

February 16, 2021

Dr. George Apostolakis
Head, Nuclear Risk Research Center
Central Research Institute of Electric Power Industry
1-6-1 Otemachi, Chiyoda-ku
Tokyo, 100-8126 Japan

SUBJECT: PROPOSED NRRC RESEARCH PLAN FOR FISCAL YEAR 2021

Dear Dr. Apostolakis:

We will remember the year 2020 as no other. As did individuals, families, and organizations worldwide, the Nuclear Risk Research Center (NRRC) and its Technical Advisory Committee (TAC) developed creative ways to adapt to the ever-changing challenges and uncertainties. We commend the entire NRRC staff for their efforts to continue progress on their important research during these very difficult conditions.

Since we could not meet with your team in our usual format, we used an alternative approach to conduct our review of the research plan for fiscal year 2021. In November, the NRRC research teams provided us with presentations that summarize the projects in each major research area. We reviewed that material and prepared our individual comments and questions on specific topics, as we would normally do before our meeting. In lieu of the active meeting discussions that clarify our understanding of each topic, we sent those individual member comments and questions to you for consideration by each research team. The researchers provided detailed and thoughtful responses to each question. We then deliberated on those responses and developed the Committee's consensus observations, conclusions, and recommendations that are provided in this letter report. The purpose of our review was to provide comments on the technical merit of the research plan and its relevance for supporting NRRC's current mission.

Our experience from this effort has reinforced the vital importance of the dynamic interactions during our face-to-face meetings. While the approach we used for this review achieved our basic objectives, the in-person technical exchanges provide clarification and understanding that benefit each of us in ways that cannot be accomplished through written questions and answers. We sincerely hope that we can return to our normal meetings in 2021.

CONCLUSIONS AND RECOMMENDATIONS

1. We did not identify any major gaps in the overall technical research plan for fiscal year 2021.

2. The development of increasingly detailed computational models for specific hazards and damage mechanisms may lead to a belief in the numerical precision of the results that is not justified for an evaluation of the risk from phenomena that have inherently large uncertainties. Before more detailed analytical tools are developed further, each research team should describe and document how important sources of aleatory and epistemic uncertainty will be identified, characterized, and quantified as an integral part of the applied methods and models.

3. Most of the NRRC research activities have achieved a level of maturity that allows practical demonstrations of how they are integrated into a plant-specific probabilistic risk assessment (PRA). A fully-integrated PRA will demonstrate the importance of a balanced assessment and understanding of risk and its contributors. That integrated perspective provides practical insights for plant-specific risk-informed decision-making and risk management that cannot be realized through stand-alone examinations of individual issues. It also provides a risk-informed framework to organize priorities for focused research to further improve specific methods and models. The currently-available methods and models for each NRRC research topic should now be included in the pilot plant PRAs that are in progress for Ikata Unit 3 and Kashiwazaki-Kariwa Unit 7.

4. During our review, we identified a few individual research activities that merit additional attention in the plans for fiscal year 2021 and subsequent years. Our recommendations for specific activities are summarized in the Discussion section of this report. We have also issued a separate companion letter report on "Proposed NRRC Research on Selected Seismic Issues for Fiscal Year 2021." That report contains more detailed discussions and recommendations for two specific areas of the seismic research program.

BACKGROUND

Since 2014, the NRRC research has made important advances in the scientific and engineering state of knowledge about events, phenomena, and accident scenarios that contribute to the risk from a nuclear power plant. That knowledge significantly improves realism in the methods and models that are used to evaluate risk. It also improves our understanding of risk and its contributors, and it supports confidence in the scientific basis for each utility's risk management activities. Those benefits are achieved through implementation of the research in the framework of an integrated probabilistic risk assessment (PRA) that provides a comprehensive and balanced evaluation of the risk from all internal events, internal hazards, and external events. The PRA is a vital tool to support effective risk-informed decision-making (RIDM) programs and practices that focus on the most important sources of risk at each nuclear power plant site. Therefore, it is essential that the scope and details of each research project are carefully tailored to meet the utilities' needs for integrated risk management. We will comment on the current status of the integration of NRRC research activities with the utilities' RIDM programs in a separate letter report.

One of the most important objectives of the research plan is to present the technical context of the research needs, including the rationale, current state of knowledge, and potential contributions and significance of the research to the goals of the center. Our review of the research plan focused on the objectives of each research project and its supporting tasks, the technical relationships and relative priorities among those activities, and any major needs for additional research. We did not review the technical details of individual research activities or their completion milestones, except as needed to understand how those activities are integrated throughout the plan. We will comment separately on the technical elements of individual research projects in our future detailed reviews of those projects.

DISCUSSION

The overall scope of research and the technical objectives of the individual projects within each major research area remain consistent with the NRRC short-, intermediate-, and long-term goals. We did not identify any major gaps in the overall technical research plan for fiscal year 2021. The discussion of Individual Research Activities contains our recommendations for specific elements of a few research projects.

Research Extensions

Several research projects are now focusing on refinements and extensions of analytical methods and models that have been developed during the six-year history of the NRRC, often continuing from earlier research programs. We have noted a distinct trend toward the development and use of increasingly detailed finite-element models, thermal-hydraulic models, fire simulation models, etc. to evaluate specific hazards and damage mechanisms. Based on our own experience and our discussions with the research teams, we understand that those tools typically provide only "point-estimate" results that are determined by the input parameters and the selected models for physical phenomena and functional interrelationships. Because those results are derived from very detailed and computationally-intensive calculations, they may lead to a belief in numerical precision that is not justified for an evaluation of the risk from phenomena that have inherently large uncertainties. Explicit identification, characterization, and quantification of uncertainty is a fundamental element of the risk assessment process. It is integral to understanding the overall level of risk from a facility, its contributors, and how that risk can be managed most effectively.

We have questioned the research teams about how the proposed analytical methods quantify the effects from inherent uncertainties in the controlling parameters and uncertainties in the applied models, and how the results account for those uncertainties. We have also noted that it is not appropriate to simply retrofit a nominal uncertainty distribution around the "point-estimate" result. To appropriately account for complex physical and functional interrelationships, the uncertainties must be quantified as an integral part of the computation process. Thus, models and analyses that do not provide a fully-integrated quantification of uncertainty are of limited value to support modern full-scope risk assessments. In practice, simpler models that facilitate a rigorous treatment of the uncertainties often provide more meaningful and realistic support for risk assessment than the implied precision of complex computations. Before more detailed analytical tools are developed further, each research team should describe and document how important sources of aleatory and epistemic uncertainty will be identified, characterized, and quantified as an integral part of the applied methods and models.

Research Applications

The Japanese industry is actively supporting the development of good quality PRAs for two pilot plants: Ikata Unit 3 and Kashiwazaki-Kariwa Unit 7. These PRAs are very important to the overall goals of the NRRC and the industry. They demonstrate how current state-of-the-practice methods and models are implemented to achieve a comprehensive assessment of the plant-specific risk and its contributors. They also provide important experience and lessons for PRA practitioners at all Japanese utilities, as they update and extend their current models and analyses to achieve the desired level of quality. The scope of each pilot project is currently focused primarily on the development of Level 1 and Level 1.5 PRA models to evaluate the risk from internal events that occur during full-power operations. We understand that the pilot plants have also developed preliminary PRA models that evaluate the risk from internal events that occur during low power and shutdown modes, but excluding the risk from damage to stored spent fuel.

Most of the NRRC research activities have now achieved a level of maturity that allows practical demonstrations of how the methods and models are integrated into a full-scope PRA. In several cases, the developed methods and models are functionally consistent with the international state-of-practice. In some cases, the research is still at a relatively preliminary stage, retaining some inherent sources of conservatism and rather large uncertainties. However, even those preliminary methods and models are sufficiently well-understood to be examined in the context of a full-scope PRA.

The current research program includes plans to demonstrate each analytical technique through the use of separate "model plant" PRAs which are selected from a variety of plant sites and are currently developed to varying degrees of technical quality. In our previous reviews, we have strongly recommended that practical demonstrations of the methods and models for each research project should use the best available Japanese PRAs; i.e., the current versions of the good quality PRAs for Ikata Unit 3 and Kashiwazaki-Kariwa Unit 7. We continue to strongly recommend that practice instead of the "model plant" approach.

We certainly understand and are sensitive to the resource constraints of the NRRC, the Japanese nuclear industry, and the individual utilities that are supporting these important initiatives. However, we are also obligated to explain the technical rationale for our recommendation.

Risk assessment is not a disjointed mathematical exercise. The power of risk assessment is realized through a comprehensive evaluation of a broad spectrum of internal events, internal hazards, and external events that can challenge plant safety during all operating modes. The PRA provides the framework for an integrated, objective, and balanced evaluation of those sources of risk, including their inherent uncertainties. That integrated perspective provides practical insights for plant-specific risk-informed decision-making and risk management that cannot be realized through stand-alone examinations of individual issues.

Integration of the evolving methods and models into a good quality full-scope PRA also provides vital risk-informed feedback to identify research priorities for focused improvements to specific analytical techniques. In practice, PRA always involves an iterative refinement process that systematically examines the most important contributors to risk. In some cases, sources of significant conservatism or uncertainty may be reduced by performing more refined analyses. In other cases, modifications to plant hardware, operating procedures, or maintenance practices may provide the most beneficial risk management option.

In the context of an integrated risk perspective, further refinements to potentially conservative analyses are not justified or needed if the respective issues are a small contribution to the overall plant risk. In principle, those analyses might be improved further. However, in practice, there is no reason to spend additional effort on those improvements, because they would not have a meaningful effect on the understanding of plant risk and its contributors. Thus, for example, even though a specific damage mechanism might account for 90% of the risk from a particular hazard, further refinements to those models and analyses are not warranted if that damage contributes to only 1% of the overall plant risk.

The use of diverse "model plant" studies to demonstrate the application of each research topic and to inform priorities for further research refinements is not consistent with the Japanese industry and NRRC goals to develop integrated risk assessment tools and capabilities for balanced risk-informed decision-making. Use of the pilot plant PRAs for Ikata Unit 3 and Kashiwazaki-Kariwa Unit 7 would support those goals and reinforce the importance of an integrated perspective on plant risk and risk-informed decision-making.

Individual Research Activities

The following items summarize our recommendations for re-examination of a few individual research activities.

(1) Scope of Multi-Unit PRA Research

We continue to recommend that the scope of the multi-unit PRA (MUPRA) research activities should include an integrated evaluation of Level 1 and Level 2 risk, beginning in fiscal year 2021.

We understand that some Level 2 PRA modeling and analysis methods are not currently as well-developed as Level 1 PRA techniques. However, the entire topic of integrated multi-unit risk assessment is an evolving discipline in the international PRA community. The NRRC research teams have acknowledged that it is important to examine the risk from offsite releases that may occur when multiple units are damaged. Thus, this research should be focused on that objective. Although the current Level 2 PRA models may be improved in the future, this research should now include explicit consideration of contributions to containment failure and offsite releases as key metrics of the MUPRA models and analyses. The research can address well-understood accident scenarios, failure modes, and phenomena that contribute to offsite risk, despite limitations in specific Level 2 PRA models.

As we noted in our report on the research plan for fiscal year 2020, a focus on only Level 1 core damage frequency may result in unforeseen technical challenges, iteration, and research inefficiency. More importantly, it may subtly influence decisions about applied analytical methods, techniques to consolidate or truncate complex models, and other practices that may inappropriately overlook or suppress important contributions to multi-unit accident scenarios that affect offsite releases. To avoid these potential pitfalls, we recommend that the MUPRA research activities should explicitly evaluate integrated Level 1 and Level 2 risk from fiscal year 2021 forward.

(2) Methods and Models for Evaluating the Risk from Seismically-Caused Tsunamis

In our report on the research plan for fiscal year 2020, we recommended that the seismic and tsunami research should be expanded to include an additional activity beginning in fiscal year 2021 to develop a site-specific demonstration of how to model and quantify the risk from seismically-caused tsunamis. We explained why this issue is important for completeness of the analyses of the risk from external events and why development of coherent models for the frequency and consequences from these correlated hazards is technically challenging.

We were informed that NRRC is considering inclusion of this topic in the research plan. We recommend that the external natural events research plan for fiscal year 2021 should include a specific project and schedule to develop a practical hazard analysis methodology for seismically-caused tsunamis, and to perform a trial PRA application that evaluates the risk from correlated seismic and tsunami damage.

(3) Evaluation of Volcanic Ash-Fall Contribution to Loss of Offsite Power

The proposed research plan for volcano risk assessment includes a task to develop models and analytical methods to evaluate the conditional probability that volcanic ash deposition on electrical insulators will result in sufficient arcing to cause a loss of offsite power at a particular site. We recommend that this research activity should not be continued.

In practice, there are many reasons why offsite power may be lost during a severe volcanic event with associated seismic activity and substantial regional or localized ash-fall. Development of numerical analysis methods to estimate the thickness of ash that may accumulate on insulators and bushings will not provide a meaningful estimate for the conditional probability that offsite power is lost during these events. In fact, those analyses might provide only an approximate estimate of the absolute minimum lower bound for that conditional probability. Furthermore, there is substantial uncertainty in the models for ash transport, ash deposition, moisture content, latent insulator contamination, arc development, and the consequences from flashovers of insulators on multiple transmission lines, transformers, and circuit breakers in a variety of geographic locations, physical arrangements, and electrical configurations.

Considering the frequency of severe volcanic eruptions, multiple possible causes for power failures, and the substantial analytical uncertainties, it seems that a reasonable bounding evaluation of the risk from a severe volcanic event could simply assume that offsite power will be lost for an extended period of time (e.g., longer than 24 to 48 hours). The PRA models and analyses would then focus on how the ash affects plant-specific equipment that is needed to mitigate the resulting event scenarios (e.g., air supplies for emergency generators, building ventilation, cooling water systems, etc.). Methods and models for conducting those analyses are appropriately included in the current scope of this research.

Of course, the assumed loss of offsite power might involve considerable conservatism for a specific eruption, a particular nuclear power plant site, and its surrounding electrical grid. However, in practice, more complex and detailed analyses to estimate the conditional probability for loss of offsite power, and its duration, from all causes that are related to the eruption would be justified only if these events are important contributors to overall plant risk.

(4) PRA Peer Review Guidance and Implementation

Comprehensive, independent peer reviews are vital for establishing confidence in the technical quality of a PRA and its use for risk-informed applications. Those reviews provide the utility engineers and managers with objective feedback on how each element of the plant-specific PRA models and analyses conforms with well-defined technical capability criteria. Understanding the capabilities and limitations of the PRA is essential for effective use of that tool to support day-to-day decisions about plant operations, maintenance, proposed modifications, and emergent issues. In the U.S., consistently applied peer reviews also provide regulatory confidence that a licensee's PRA can be used to support proposed risk-informed changes to the plant's licensing basis. Use of standardized peer review guidance, criteria, and assessments for every PRA also enhances regulatory confidence for industry-sponsored risk-informed initiatives that apply to all licensees or selected cohorts of plants.

The NRRC has had a lead role in developing the current draft PRA peer review guidance. We understand that the Japanese nuclear industry, and ultimately each nuclear power plant, is responsible for implementing the peer reviews. Experience from the U.S. has demonstrated the importance of technical consistency in those reviews, performed by trained and experienced PRA experts. The U.S. experience has also shown that development of those review capabilities and the necessary technical expertise requires considerable effort and time.

The NRRC and other organizations currently conduct training sessions that are focused on expanding the capabilities of Japanese utility engineers in a variety of PRA technical disciplines and methods. Beginning in fiscal year 2021, we recommend that the NRRC should develop a specific peer review training program to provide assurance that peer reviews will be conducted according to consistent technical practices for every Japanese nuclear power plant PRA.

We look forward to our continuing interactions with the NRRC research team to review the overall research program and individual research projects, and to help the NRRC and the Japanese nuclear industry achieve their goals of comprehensive risk-informed decision-making.

Sincerely,

John W. Stetkar
Chairman

REFERENCES

1. "NRRC Overview: Research Program for FY2021, Risk Assessment," Presentation to NRRC Technical Advisory Committee, November 4, 2020, Proprietary.

2. "NRRC Overview: Research Program for FY2021, External Natural Events," Presentation to NRRC Technical Advisory Committee, November 4, 2020, Proprietary

3. "NRRC Overview: Research Program for FY2021, RIDM Promotion," Presentation to NRRC Technical Advisory Committee, November 4, 2020, Proprietary

4. Technical Advisory Committee individual members' comments and questions on "NRRC Overview: Research Program for FY2021, Risk Assessment," December 4, 2020, Confidential.

5. Technical Advisory Committee individual members' comments and questions on "NRRC Overview: Research Program for FY2021, External Natural Events," December 4, 2020, Confidential.

6. Technical Advisory Committee individual members' comments and questions on "NRRC Overview: Research Program for FY2021, RIDM Promotion," December 4, 2020, Confidential.

7. NRRC Research Team responses to comments and questions on "NRRC Overview: Research Program for FY2021, Risk Assessment," January 30, 2021, Confidential.

8. NRRC Research Team responses to comments and questions on "NRRC Overview: Research Program for FY2021, External Natural Events," January 30, 2021, Confidential.

9. NRRC Research Team responses to comments and questions on "NRRC Overview: Research Program for FY2021, RIDM Promotion," January 30, 2021, Confidential.

10. Technical Advisory Committee of the Nuclear Risk Research Center, "Proposed NRRC Research on Selected Seismic Issues for Fiscal Year 2021," February 16, 2021.

11. Technical Advisory Committee of the Nuclear Risk Research Center, "Proposed NRRC Research Plan for Fiscal Year 2020," November 19, 2019.