Technical Advisory Committee of the Nuclear Risk Research Center
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SUBJECT: PROPOSED NRRC RESEARCH PLAN FOR FISCAL YEAR 2020

Dear Dr. Apostolakis:

During the 12th meeting of the Technical Advisory Committee (TAC) of the Nuclear Risk Research Center (NRRC), November 11-15, 2019, we met with the NRRC staff to review the proposed research plan for fiscal year 2020. 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.

CONCLUSIONS AND RECOMMENDATIONS

1. We did not identify any major gaps in the overall research plan for fiscal year 2020.

2. A number of research activities will soon achieve a level of maturity that allows practical demonstrations of how they are used to accomplish NRRC's goal to support the development of good quality probabilistic risk assessments (PRAs) that evaluate the risk during all plant operating modes from internal events, internal hazards such as fires and floods, and external events. We are very encouraged by this progress.

3. During our review and discussions with the NRRC research teams, we identified a number of individual research activities that merit additional attention in the plans for fiscal year 2020 and subsequent years. Our recommendations for specific activities are summarized in the Discussion section of this report.

BACKGROUND

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 detailed reviews of those projects.

DISCUSSION

The NRRC staff provided a summary of the scope of a strategic plan and a phased approach for introduction of risk-informed decision-making (RIDM) in the Japanese nuclear industry. Comprehensive plant-specific PRAs of high technical quality provide the risk information and engineering insights that are an essential input for the RIDM process. Therefore, NRRC is conducting research on improved analytical methods, models, and data for the performance of good quality PRAs (i.e., state-of-practice fully-integrated Level 1 and Level 2 PRAs that evaluate plant-specific risk during all plant operating modes, with extensions to limited-scope Level 3 PRAs). The scope of those research activities covers a wide range of technical issues such as collection and analysis of plant operating experience and data, human reliability analysis, methods for analyzing internal fires and floods, improved modeling of severe accident phenomena, and evaluation of the risk from external hazards such as earthquakes, tsunamis, severe winds, and volcanic eruptions. In addition to supporting the development of good quality PRAs, the NRRC research team is also developing guidance for the use of PRA as a tool to support the RIDM process.

During this review, we were briefed on several important research projects, the major technical tasks in each project, the current status of each task, known or potential problem issues, and the estimated schedule for completion of each task. The project timelines and schedules were also useful to illustrate how each activity fits into the overall research scheme and the context of the NRRC short-, intermediate-, and long-term goals.

We did not identify any major gaps in the overall research plan for fiscal year 2020.

Furthermore, a number of research activities will soon achieve a level of maturity that allows practical demonstrations of how they are used to accomplish NRRC's goal to support the development of good quality PRAs that are consistent with the international state-of-practice. Those activities include:

- Use of the Senior Seismic Hazard Analysis Committee (SSHAC) methodology to perform a probabilistic seismic hazard analysis (PSHA) for the Ikata plant site.

- Development of a Fire PRA Guide.

- Development of a Human Reliability Analysis (HRA) Guide.

We are very encouraged by this progress.

Based on our review of the NRRC research plans and discussions with the research teams, we offer the following recommendations for extensions, applications, and further assessments of selected individual research activities. They should be integrated into the overall research program for fiscal year 2020 and the plans for subsequent years.

Research Extensions

The following items summarize our recommendations for extensions of the current research program and specific research activities.

(1) Methods and Guidance for Evaluating Risk during Low Power and Shutdown Modes

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.

Each pilot project has benefited substantially from interactive reviews that are being conducted by teams of international PRA experts. During this meeting, we received a summary briefing on a recent expert review of the Ikata Unit 3 PRA models for low power and shutdown (LPSD) modes. We were also informed that a similar review of the LPSD models for Kashiwazaki-Kariwa Unit 7 will be conducted in December of this year.

International experience has shown that events which occur during shutdown modes can be important contributors to the overall plant risk profile. That experience has also shown that the risk during shutdown and its contributors can be very plant-specific. Furthermore, the methods, models, data, and analysis techniques that are needed to evaluate that risk can present challenges that are different from those associated with the development of PRA models for full-power operation.

The NRRC research program does not currently include any distinct activities that are focused on development of methods, models, or guidance for evaluating risk during low power and shutdown modes. However, the scope of any research activities in this area should be tailored to the technical needs of the current Japanese analysis practices. We recommend that the research program for fiscal year 2020 should include an activity to interview the PRA analysts and examine the expert reviews of the Ikata Unit 3 and Kashiwazaki-Kariwa Unit 7 LPSD PRAs, identify research or guidance that may be needed to support the development of analytical methods and modeling techniques that are consistent with the international state-of-practice, and integrate those needs into the NRRC research program beginning in fiscal year 2021.

(2) Methods and Guidance for Evaluating Risk from Events that Affect Stored Spent Fuel

International PRA models for plant shutdown modes often include evaluations of the risk from events that affect the movement and storage of spent fuel during specific plant operating states (POSs). Some examples of those events include fuel handling accidents during POSs when fuel is being moved into and out of the pools, possible draining of water from the pools during fuel transfer operations, boron dilution, and loss of cooling during POSs when pool heat loads are high from fuel that has been recently removed from the reactor, including full core offloads. Damage from external events and internal hazards such as fires and floods may also affect the stored spent fuel. Some recent international PRAs have further extended the evaluations of spent fuel risk to include full-scope analyses that account for plant conditions and activities that occur throughout the year.

The NRRC research program for fiscal year 2020 includes activities for testing of spent fuel cladding performance and use of the MAAP code to evaluate the thermal-hydraulic progression of an accident that involves complete loss of spent fuel cooling, including the effectiveness of alternative fuel pool sprays. However, the research plan does not currently include any activities that address development of integrated PRA models, methods, or guidance for evaluating the risk from events that affect the movement or storage of spent fuel. We have not been briefed on details of the Ikata Unit 3 and Kashiwazaki-Kariwa Unit 7 PRA models for plant shutdown modes. Therefore, we do not know whether, or how, those models may account for the risk from events that affect spent fuel. As noted in our preceding comments, the scope of any research activities in this area should be tailored to the technical needs of the current Japanese analysis practices.

As an adjunct to the activity that is discussed in Item (1) above, we recommend that the research program for fiscal year 2020 should also include an activity to interview the PRA analysts and examine the expert reviews of the Ikata Unit 3 and Kashiwazaki-Kariwa Unit 7 LPSD PRAs to identify research or guidance that may be needed to support the development of analytical methods and modeling techniques for the evaluation of risk from events that affect the movement and storage of spent fuel. Those research needs should focus first on integration of the analyses of spent fuel risk with the PRA models for plant shutdown modes, and then extend those methods and models to cover all plant operating modes, consistent with the international state-of-practice. Identified research activities should be integrated into the NRRC research program beginning in fiscal year 2021.

(3) Demonstration of PRA Methods and Models for Evaluating the Risk from Combined Effects of Earthquakes and Tsunamis

One of the Seismic PRA research activities for fiscal year 2020 involves the development of analysis techniques and methods to evaluate multiple dependent hazards. In particular, we were informed that this activity is focused primarily on an evaluation of the combined hazard from seismically-caused tsunamis. This research is very important for Japan, and it will significantly extend the international state-of-practice.

The development of an integrated PRA model for evaluating the risk from seismically-caused tsunamis presents unique challenges that are not easily adapted from analyses that evaluate only earthquakes or only tsunamis. For example, special techniques are needed to account for correlated dependencies in the frequency and severity of the composite hazard, and in the corresponding PRA models for coincident seismic damage and tsunami damage to plant structures and equipment.

We recommend that this 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 combined risk from seismically-caused tsunamis.

(4) Scope of Multi-Unit PRA Research

The scope of the multi-unit PRA (MUPRA) research activities is currently limited to only an evaluation of Level 1 risk.

The current scope may result in unforeseen technical challenges, iteration, and research inefficiency, compared to an approach that initially examines the needed methods, models, and guidance to evaluate Level 2 risk from all internal events, internal hazards, and external events. For example, as risk assessment technology and PRA models have evolved over the last 40 years, we have learned that the early guidance for developing only Level 1 PRA models would have benefited substantially from a better appreciation of the models and analyses that are needed to perform an integrated Level 2 PRA. In many cases, a limited focus on only core damage has resulted in the need for analytical iteration and inefficient changes to PRA models that would not have been necessary if the guidance and models had initially accounted for the broader perspective.

We have also learned that the most important contributions to core damage are not always the most important contributions to offsite releases. Therefore, if a proposed MUPRA methodology uses only core damage frequency as the primary metric for decisions to consolidate or truncate complex models, those decisions may inappropriately overlook or suppress important contributions to multi-unit accident scenarios that affect offsite releases.

We recommend that the MUPRA research scope should include an integrated evaluation of Level 1 and Level 2 risk, beginning in fiscal year 2020.

Research Applications

The following items summarize our recommendations for initial applications of specific research activities.

(5) Planned Use of the Fire PRA Guide

The current research plan indicates that a revised version of the NRRC Fire PRA Guide will be completed in fiscal year 2019. It contains contemporary state-of-practice methods, models, and guidance for evaluation of the risk from internal fires, which can be an important contribution to the overall plant-specific risk profile. This version of the Guide will benefit from input that has been provided by Japanese utilities and international fire PRA practitioners.

There are two schools of thought regarding use of this version of the Guide. One school is based on the U.S. experience from issuance and use of the guidance in NUREG/CR-6850. The lessons learned from that experience indicate that it is very important to first use the guidance to perform an integrated plant-specific fire analysis, identify needs for improvement based on that experience, and then issue the final guidance for general use. The second school of thought is that the Guide should now be issued for general use by the Japanese industry, without an intermediate iteration.

Of course, in practice, it is likely that the first users of the Guide will identify areas for possible improvement in both the technical methods and application guidance. However, unlike the U.S. experience, the NRRC Fire PRA Guide has already incorporated the lessons learned from use of NUREG/CR-6850 in the U.S. and other countries, including advances in fire analysis methods, models, and data that have evolved during the intervening years. Thus, there is a low risk of any significant technical deficiencies or programmatic problems in this version of the Guide, and that risk is outweighed by the greater benefits from timely use of the guidance by a broader cross-section of Japanese fire analysts.

We support issuance of the Fire PRA Guide for general use, without an intermediate trial application and iterative revision. We will comment separately on technical details of the guidance after this version of the Guide is issued.

(6) Seismic PRA Demonstration Project

One of the Seismic PRA research activities that is planned to begin in late fiscal year 2019 or early fiscal year 2020 involves the development of a plant-specific model to demonstrate how to integrate the analyses of seismic events with the Level 1 PRA models for internal initiating events. During this meeting, the research team discussed their selection of a model plant site and its supporting PRA models for this demonstration project.

We recommend that this demonstration project should instead use the pilot plant PRA models for Ikata Unit 3 or Kashiwazaki-Kariwa Unit 7. Some of the reasons for our position are based on proprietary information that was discussed during our meeting. However, in addition to those considerations, the pilot plant applications will provide the most effective demonstration of how state-of-the-practice methods and models for evaluating seismic events are used to develop good quality fully-integrated plant-specific PRAs. Consistent integration of the models for various internal events, internal plant hazards, and external events to develop a comprehensive risk profile is a fundamental element of the risk assessment process that cannot be demonstrated effectively by the use of separate models for different plants.

Despite the fact that good quality PRA models for internal initiating events are being developed at Ikata Unit 3 and Kashiwazaki-Kariwa Unit 7, we favor use of the Ikata

Unit 3 models for this demonstration project. The seismic hazard for the Ikata site has been developed through an advanced Level 3 application of the SSHAC methodology. Thus, use of the Ikata models to demonstrate how the risk from seismic damage is integrated into the full-scope PRA has the additional advantage to show how the best available seismic hazard information is used to develop the site-specific initiating event frequencies and the input to the fragility analyses for plant structures and equipment.

(7) Level 2 PRA Demonstration Project

One of the Level 2 PRA research activities that is planned to begin in approximately fiscal year 2021 or fiscal year 2022 involves the development of a plant-specific model and analyses to demonstrate how to integrate the Level 2 models for severe accident progression and containment performance with the Level 1 models for core damage. We recommend that this demonstration project should use the pilot plant PRA models for both Ikata Unit 3 and Kashiwazaki-Kariwa Unit 7. Use of both plants will provide valuable experience and insights for the evaluation of severe accident phenomena, application of analytical methods, and development of models that are quite different for PWRs and BWRs.

Research Assessments

The following items summarize our recommendations for re-examinations of individual research activities.

(8) High Wind Prediction Tool

One of the High Wind PRA research activities for fiscal year 2020 involves the development of a "high wind risk detection and prediction tool". Based on our discussions with the research team, we understand that this tool is intended to provide a capability to predict the severity and arrival time of high winds at a nuclear power plant site, with a particular emphasis on tornadoes. The team noted that some plants may need a warning time before the arrival of high winds to confirm that portable mitigation equipment is secure and to move potential wind-borne missiles away from plant buildings.

We do not have sufficient information to fully understand the technical needs for this research and why the NRRC is the most appropriate organization to develop this tool. We recommend that the NRRC should re-examine this research activity and confirm that it effectively supports the technical objectives and goals of the overall research program and the needs of the Japanese utilities.

(9) Phenomenological Relationship Diagram (PRD) Methodology

During this meeting, we were briefed on the basic concepts of the proposed Phenomenological Relationship Diagram (PRD) methodology, including two simplified numerical applications. According to the research team, the methodology is intended to streamline the computational process for analyses of severe accident progression, physical and thermal-hydraulic phenomena, and containment performance, and it facilitates more efficient quantification of the associated uncertainties. Based on the information provided during the meeting, it is not apparent that the simplified models and assumptions that are inherent in the example applications will provide the analytical capabilities that are needed to support a state-of-the-practice best-estimate evaluation of risk, including the treatment of complex phenomenological and timing dependencies.

Although analytical tools such as MELCOR and MAAP are resource-intensive and computationally complex, they are accepted internationally as providing a firm technical foundation for integrated analyses of accident progression and containment performance. Research projects have also demonstrated how uncertainties in the Level 2 and Level 3 PRA analyses can be quantified through integrated applications of the MELCOR and MACCS codes, albeit with substantial computational burden.

In summary, without better examples and benchmark comparisons with contemporary best-estimate analytical results, it is difficult for us to understand why the proposed PRD methodology will provide an appropriate alternative to the established modeling tools. We recommend that the NRRC should re-examine this research activity and confirm that it effectively supports the technical objectives and goals of the overall research program and the needs of the Japanese utilities.

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

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