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

April 13, 2020

The Honorable Kristine L. Svinicki
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: BIENNIAL REVIEW AND EVALUATION OF NRC SAFETY RESEARCH PROGRAM

Dear Chairman:

During the 671st meeting of the Advisory Committee on Reactor Safeguards, March 5-6, 2020, we completed our biennial review and evaluation of safety research sponsored by the NRC. We also reviewed this matter during several information meetings with the NRC Office of Nuclear Regulatory Research (RES) staff on April 4, 2019, July 9, 2019, September 4, 2019, and November 6, 2019. In addition, we benefitted from the referenced documents.

CONCLUSIONS AND RECOMMENDATIONS

1. The current user need process has allowed RES to satisfactorily meet agency near-term needs for regulatory decisions. Efforts to initiate "future-focused" research projects with longer-term horizons will help prepare the agency for upcoming challenges, including the regulation of advanced technologies and the transformation of the agency into a modern, risk-informed regulator.
2. We support the systematic approach implemented by RES to prioritize research emphasizing enterprise risk in project selection, evaluation, and termination. Ongoing RES efforts to engage other offices are critical for this approach to be successful.
3. As RES continues to leverage resources using international and inter-agency collaborations, it is important that agency priorities be clearly defined and addressed.
4. RES contributions are preparing the agency for anticipated non-light water reactor (LWR) submittals. Reference plant evaluations should provide confidence about the adequacy of selected computational tools and identify any remaining data gaps.
5. We plan to have additional briefings on several RES activities, such as efforts to address the gap created by the unexpected loss of the Halden test reactor, and the selection and progress of future-focused research projects.

BACKGROUND

ACRS reviews of NRC research consider 1997 Commission guidance to examine the need, scope, and balance of the safety research program, and how well RES anticipates research needs and positions itself for the changing environment. This letter report, which was

developed using the revised approach we adopted in 2018, emphasizes our recommendations to enhance the ability of the RES program to meet current and future agency needs, the prioritization and identification of new research projects, and long-term planning.

DISCUSSION

The following sections summarize our findings and recommendations. We include a discussion of our integrated assessment, followed by more detailed findings regarding research conducted by each RES division. These findings and recommendations were informed by meetings with representatives from RES, our episodic reviews of selected ongoing research projects, research conducted in support of specific regulatory activities, and our annual in-depth quality reviews of selected research projects.

INTEGRATED RES PRIORITIES

Prioritization

The current NRC research program is primarily directed through the user need process. Shorter-term scoping efforts or "feasibility studies" provide the agency opportunities to assess if a user need should be developed to support further research on a topic. In addition, the agency has started to provide a limited amount of resources for future-focused research with longer-term horizons to prepare for upcoming challenges, including the regulation of advanced nuclear technologies and the transformation of the agency into a modern, risk-informed regulator.

Our 2018 letter report identified the need for prioritization of research projects that emphasized enterprise risk, addressing factors such as safety and security, emerging issues, innovative technologies and associated uncertainties, preservation of core competencies, and the development and maintenance of analysis methods and tools. During our discussions we learned that RES has implemented a process that includes a numeric scale for prioritizing ongoing research projects. As part of this process, RES engages leads from other agency offices to provide input on this prioritization and review the progress of ongoing research. This is a positive step that should ensure that RES activities are strategically aligned to meet current and future agency needs. The success of this process, however, is dependent upon the engagement and support of other agency offices.

Our 2018 letter report observed that a healthy research program should be able to discern when specific research projects have achieved their objectives and continuing efforts provide little additional benefit. As part of its prioritization process, RES must have an effective process for terminating ongoing research that ceases to be of high priority. We continue to emphasize this point in our reviews. In this 2020 letter report, we identify several projects that should be terminated.

Preparing for Innovative Technologies

RES contributions have enabled the agency to be prepared for anticipated non-LWR submittals. We support RES activities to engage industry, the Department of Energy (DOE), and international collaborators to identify gaps in knowledge about materials and systems, structures, and components (SSCs) proposed for advanced non-LWRs as well as data that will be required by applicants to support their submittals. Planned reference plant evaluations should provide confidence about the adequacy of selected computational tools and identify data gaps for the spectrum of issues posed by non-LWRs. In addition, we recommend that RES review and update, as needed, the agency's "Non-LWR Implementation Action Plans" to ensure

they emphasize experimental data that design developers must obtain to validate codes used in licensing applications for various new concepts. As divisions within RES prepare for the reference plant evaluations, we recommend that plants be selected only when sufficient design details are available, and that all the RES divisions select the same plants for their reference plant evaluations.

As emphasized in our October 7, 2019, letter report on siting of advanced reactor designs, forward thinking is required to identify the scenarios to use for safety analyses of and the source of releases from non-LWR designs. For example, some microreactor modules may have fuel installed and removed offsite. Hence, reference plant evaluations should not only consider operational activities, but also risk-significant activities related to manufacture, transport, installation, and eventually removal of a fueled module.

Future-focused research will further prepare the agency for innovative technologies. It is important, however, that such activities also be prioritized and selected using a systematic process that considers enterprise risk. We request that RES brief us on the selection and progress of future-focused research projects.

Collaborations with Other Agencies and Organizations
RES is effectively leveraging its resources by collaborating with other U.S. and international organizations to exchange information, respond to emerging technical issues, promote best practices and consensus standards, and improve regulatory efficiency. Recognizing current and future resource constraints and the agency need to address submittals for subsequent license renewal and new technologies, we continue to emphasize that RES should reduce its efforts to develop data independently and focus on identifying data that licensees or applicants must provide so that the agency can make regulatory determinations.

RES leads many collaborations, such as the Rod Bundle Heat Transfer Program and the proposed Reduction Of Severe Accident Uncertainties (ROSAU) initiative to reduce uncertainties in severe accident phenomena (as emphasized by post-Fukushima examinations indicating that fuel materials have relocated ex-vessel into the containment). We also observe that the new collaboration with the Canadian Nuclear Safety Commission could provide RES with important data and models for evaluating non-LWR technologies. We emphasize that it is important for RES to be involved in planning and developing methods and tests in these collaborations to assure that agency priorities are addressed. One example that merits special attention is the need to address the gap in capabilities due to the premature closure of the Halden boiling water reactor (BWR).

DIVISION OF RISK ANALYSIS (DRA)

Transformation and Preparedness
The DRA is performing several activities to support agency transformation. For example, DRA has developed a strategy for selecting future-focused research to support the agency vision of becoming a modern, risk-informed regulator. The DRA strategy considers challenges such as resource limitations, the landscape of potential new projects (e.g., the number of diverse new reactor concepts and technologies) and the limited pool of expertise available for replacing staff that leave. This DRA prioritization also considers factors such as the potential to leverage resources and available timing before research projects will be deployed. We encourage RES to consider applying this systematic approach for selecting all future-focused research projects.

Furthermore, we suggest that DRA consider future-focused research to provide the basis for another “innovative” step to cement the Commission's commitment to risk-informed regulation through the expanded use of decades of probabilistic risk assessment (PRA) experience. This step would streamline new application reviews by building a unified risk-informed regulatory base. We encourage DRA to continue exploring the use of its extensive PRA experience as a basis for focusing regulatory oversight and transforming regulatory requirements, such as the selection of Chapter 15, “Transient and Accident Analysis,” events and mitigating SSCs.

Ongoing Projects
Ongoing efforts to complete the Level 3 PRA and to update the standardized probabilistic analysis of risk (SPAR) models continue. Our 2018 letter report emphasized the importance of this research, which is scheduled for completion in 2023, as an example of research to preserve and advance PRA analysis skills. We encourage staff to complete this important effort as scheduled. The staff continues to view both the Level 3 and SPAR projects as training opportunities, and much of these efforts are being done in-house. Staff access to high speed computing capabilities will assist their SPAR efforts.

We learned that the staff is engaged in a risk evaluation of dry storage casks. We look forward to a briefing by the staff about the results of this evaluation and its impact.

We continue to follow DRA efforts to understand and take appropriate actions to address results from two High Energy Arc Fault (HEAF) event tests involving aluminum bus components. To ensure that potential safety concerns posed by aluminum components in or near electrical equipment, as well as the potential for unanalyzed equipment failure mechanisms, are addressed, the staff is evaluating HEAF as a potential Generic Issue. We have requested briefings to keep abreast of this effort. In particular, we are interested in how knowledge gained from prior testing, including naval experience, is incorporated.

We continue to monitor evolution of the Integrated Human Event Analysis System (IDHEAS) methodology for evaluation of human performance. Recently, several members viewed a preliminary version of the software being developed for one application of this method. We encourage the staff to increase their interactions with potential users and focus any additional software development efforts to address comments received from such interactions. We also encourage staff to complete their current development and documentation efforts and start applying the results of their human factors research to evaluate actions in digital control rooms, in locations external to the control room, during low power and shutdown operation, and in deploying FLEX equipment.

DIVISION OF SYSTEMS ANALYSIS (DSA)

Transformation and Preparedness
A current focus of DSA is to implement the agency vision and strategy for computer codes for analyzing non-LWRs. The staff has assembled a suite of primarily NRC and DOE codes, “BlueCRAB,” to provide a comprehensive reactor analysis capability. DOE codes are included in BlueCRAB to ensure the capability to model some non-LWR phenomena that cannot be simulated with NRC methods. Although it is important for staff to become familiar with codes used by DOE and industry to simulate new designs, it is premature to focus efforts on linking these codes to NRC codes. It appears that detailed DOE-developed multi-physics methods will require significant validation efforts and high-performance computational capabilities. It is unclear whether regulatory decisions will require such detailed tools, especially if enhanced safety margins exist for these advanced reactor designs.

As noted in our November 4, 2019, letter on review of advanced reactor computer code evaluations, we recommend that DSA adopt an evaluation and review approach that tailors the selection and application of codes, beginning with "working the problem backwards" by developing source terms for maximum hypothetical accidents, acknowledging the risk, and seeking simplified solutions when adequate for the problem at hand. As part of this approach, we recommend that DSA focus on developing and maintaining in-house codes, capabilities, and expertise.

To support their efforts to be ready for emerging technologies, staff emphasized their plans to participate in future-focused research and development (R&D) for capabilities that may be needed beyond a three-year horizon (in a 5 to10 year timespan). We encourage staff to take a broad look at emerging technologies, without committing too much to "design-specific" applications. As a good example, we point to the recently completed RES-sponsored Pacific Northwest National Laboratory (PNNL) report, "Degradation and Failure Phenomena of Accident Tolerant Fuel Concepts." This report provides current state-of-the-industry information on material properties and fuel performance considerations for chromium (Cr)-coated cladding concepts, both for reactor operating conditions and design basis accident conditions.

Ongoing Projects

DSA continues to maintain and develop new features in their codes for analyzing new concepts such as accident tolerant fuels (ATFs), including extended burnup and higher enrichments, and for non-LWR and small modular LWR designs. The independent capabilities obtained with DSA tools, such as the TRACE code, provided confidence in vendor analyses submitted to support the NuScale design certification application.

A recent quality review of work related to nuclear data and cross-section uncertainties in the SCALE code (NUREG/CR-7249) suggests that the effect of delayed neutron precursors uncertainties on the calculated effective delayed neutron fraction may be of concern and significance for advanced reactor concepts, particularly for designs that are strongly dependent on reactivity feedback for safe operation and shutdown. DSA should follow up on those findings.

Work to combine FRAPCON/FRAPTRAN into the new FAST fuel performance framework continues. Initial release of FAST is planned for 2020. This effort will allow the staff to have a single code for evaluating steady-state and transient fuel performance with improved capabilities for applications such as ATF. In addition, having a single modern code structure should reduce subsequent code maintenance efforts. Work is underway to create generic fuel models in anticipation of advanced non-LWR designs, with emphasis on TRISO and metallic fuels, including material properties, fuel phenomenology such as fission product release, and failure modes, and also non-cylindrical coordinates models. This effort should provide requisite fuel failure information for analyses of design basis and beyond design basis events.

Severe reactor accident research was an essential element of the agency response to the events at Fukushima Daiichi. The MELCOR systems-level accident analysis code is the agency's vehicle for systematically preserving and applying severe accident knowledge. Continued application of MELCOR to evaluate severe accident phenomena necessitates that DSA expend resources for new models (e.g., for ATF and non-UO_2 fuels), code modernization and maintenance, as well as associated development of staff expertise. To review new plant designs, new models are required to simulate novel features not encountered in the current fleet of LWRs. In addition, information obtained from the affected units at Fukushima Daiichi should

continue to be evaluated to discern required model updates. Recent State-of-the-Art Consequence Analysis (SOARCA) evaluations have emphasized the benefit of including uncertainty and sensitivity analyses in MELCOR applications.

Gains have been achieved in the consequence analysis area by considering state-of-the-art models developed by other agencies for MACCS improvements. A major upgrade to MACCS (Version 4.0) has been completed with the incorporation of the HYSPLIT atmospheric model, developed by the National Oceanic and Atmospheric Administration, and REAcct economic models, developed by the Department of Homeland Security. In light of the agency's heavy reliance on severe accident methodologies to close Fukushima Near-Term Task Force recommendations, consequence analysis has been identified and is now supported as a core competency. Continuing application of both MELCOR and MACCS to Fukushima forensics will also aid in benchmarking the codes against real data.

MELCOR and MACCS modernization efforts are focusing on separating the development of the physical models from development of computational methods for improved numerical solvers and for data handling and processing. An evolutionary approach is being implemented so that analysis capabilities are not lost, thereby avoiding negative impact on current NRC work. We support the approach being used by the staff to update and improve the efficiency of code models.

In addition, the staff relies on a number of legacy codes, such as RASCAL, RADTRAD, and GALE, which are primarily applied for analyses of radionuclide transport and dispersion and for radiation protection. These continue to be espoused by line organizations because of convention and simplicity of use but suffer when compared to more recent "best-estimate" models.

DSA should work with user organizations to facilitate crossover to integrated best-practice calculational tools and sunset efforts to support legacy codes. This requires DSA to: 1) deploy modularity in code design (primarily in MACCS) to be responsive to separate user needs previously met with legacy code solutions; and 2) avail itself of the modern computational capabilities of desktop/handheld solutions for utility use and staff field deployment.

As the Radiation Protection Branch continues to modernize and consolidate its code infrastructure, we urge that DSA take an integrated, longer-term view to combining its 12+ RAMP codes and addressing non-LWR licensing, siting, and radiation protection needs. For example, we suggest that staff explore the potential for a simplified option of MACCS to replace NRCDose3.

DIVISION OF ENGINEERING (DE)

Transformation and Preparedness

There are several emerging technology areas where DE could benefit from larger research efforts that are being conducted outside the nuclear industry. In the areas of "big data" and artificial intelligence, DE is a collaborative partner in a National Institute of Standards and Technology (NIST)-led effort. DE is developing an advanced manufacturing technologies (AMT) plan that will provide guidance on quality assurance requirements based on the risk significance of the manufactured components. This is an area that could benefit from additional collaboration with non-nuclear entities and professional standards groups. We look forward to working with staff as they develop approaches to be ready for these emerging technologies.

We were updated on the progress of identifying alternatives to the "capability gap" for obtaining research data following the closure of the Halden facility, which was announced on June 27, 2018. Over the last several decades, the well-instrumented test rigs at the Halden BWR provided critical data for evaluating the performance of fuels and materials used in nuclear reactors. DE staff indicated that the agency is exploring several paths to address the Halden capability gap. We look forward to a briefing on these activities.

Ongoing Projects
During our discussions, DE informed us that research in several programs that we suggested be sunset in our 2018 letter report, such as primary water stress corrosion cracking, alkali silica reactions, and aging management of spent fuel storage casks, are expected to sunset within the next two years because these projects have reached their objectives.

RES should continue to support the efforts in the digital instrumentation and control (DI&C) Integrated Action Plan (IAP) regarding Common Cause Failure (CCF), assessing the state of the art to address CCF hazards in DI&C, and other IAP efforts where needs are identified. We will review staff work in this area as it progresses.

DE is working to address several other recommendations from our 2018 letter report.

- Extremely Low Probability of Rupture (xLPR) Method: DE is continuing their efforts to release this tool for evaluating material degradation of piping. The xLPR method can be used for evaluating leak before break applications for subsequent license renewal and new reactors. In addition to emphasizing the importance of releasing this method, we stressed the need for developing user guidance for xLPR.

- Codes and Standards Support: DE has established a steering committee to prioritize activities for reviewing and approving selected codes issued by standards development organizations. In addition, DE has implemented several process improvements, such as earlier engagement with standard development organizations, to facilitate more timely promulgation of coordinated code revisions, code cases, and regulatory text. As evidence of the increased efficiencies associated with these improvements, several codes and standards have or will soon be approved. We look forward to seeing results from these process improvements.

SUMMARY

The current user need process has allowed RES to satisfactorily meet agency near-term needs for regulatory decisions. Efforts to initiate "future-focused" research projects with longer-term horizons will help prepare the agency for upcoming challenges, including the regulation of advanced technologies and the transformation of the agency into a modern, risk-informed regulator.

RES is addressing many recommendations provided in our 2018 Biennial Review. We support the systematic approach RES has implemented to prioritize research emphasizing enterprise risk in project selection, evaluation, and termination. Ongoing RES efforts to engage other offices are critical for this approach to be successful.

As RES continues to leverage resources using international and inter-agency collaborations, it is important that agency priorities be clearly defined and addressed.

RES contributions are preparing the agency for anticipated non-LWR submittals. Reference plant evaluations should provide confidence about the adequacy of selected computational tools and identify data gaps.

We plan to have additional briefings on several RES activities, such as efforts to address the gap created by the unexpected loss of the Halden test reactor, and the selection and progress of future-focused research projects.

Member Rempe did not participate in the portion of this meeting related to RES continuing to evaluate information from the affected units at Fukushima Daiichi.

Sincerely,

Scott W. Moore

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Matthew W. Sunseri
Chairman

REFERENCES

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