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

February 26, 2018

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

SUBJECT: BIENNIAL REVIEW AND EVALUATION OF THE NRC SAFETY RESEARCH PROGRAM

Dear Chairman:

During the 650th meeting of the Advisory Committee on Reactor Safeguards, February 8-9, 2018, 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 May 5, 2017, September 6, 2017, October 3, 2017, and October 31, 2017. In addition, we benefitted from the referenced documents.

CONCLUSION AND RECOMMENDATIONS

1. The NRC safety research program, which is largely directed through user need requests (UNRs), appears to be meeting near-term agency needs satisfactorily.

2. The current process to prioritize agency research could be improved by performing a systematic assessment that emphasizes ‘enterprise risk’ in research project selection, evaluation, and termination.

3. RES should develop long-term strategies to address emerging technical issues, support development and maintenance of needed analytical tools and data bases, emphasize activities that improve regulatory efficiency, and identify and preserve needed core competencies.

BACKGROUND

RES supports the mission of the NRC by providing technical advice, tools, and information to resolve safety and security issues, inform regulatory decisions, and promulgate regulations and guidance. In 1974, congress mandated the formation of RES to ensure "an independent capability for developing and analyzing technical information related to reactor safety, safeguards and environmental protection in support of the licensing and regulatory process.”

Currently, RES research activities are primarily limited to addressing UNRs. In recent years, the agency has implemented the feasibility study request process, which allows shorter-term scoping efforts to assess if future research on a topic should be initiated. These studies are also used to support possible new program areas, support development of technical bases for anticipated regulatory decisions, address emerging technologies that could have future regulatory applications, and assist in developing plans to implement needed research.

Formal ACRS reviews of NRC research began in 1977. In 1997, the Commission directed ACRS to examine the need, scope, and balance of the safety research program, to consider how well RES anticipates research needs, and how the RES program is positioned for the changing environment. The approach for conducting our reviews has evolved over the years. For this report, we have implemented a new approach to emphasize:

- The ability of the RES program to meet future and emerging, as well as current, agency needs
- Developing recommendations regarding prioritization and identification of new research needs
- Long-term planning on issues, such as maintenance of essential core competencies that the agency must preserve, modernization of processes, and development and maintenance of methods and tools
- Developing a more succinct report

Our review included an initial meeting with the Director of RES to obtain an overview of his program, plans, priorities, and areas of interest, and three working group information meetings to discuss research conducted by each RES division: Division of Risk Analysis (DRA), Division of System Analysis (DSA), and Division of Engineering (DE). As part of our normal activities, we review important ongoing research projects, as well as research conducted in support of specific regulatory activities. Additionally, we annually conduct in-depth quality reviews of selected research projects.

DISCUSSION

The following sections summarize our findings and recommendations.

Division of Risk Analysis

DRA develops, recommends, plans, and manages research programs relating to probabilistic risk assessments (PRAs), human factors, and human reliability analysis. The division also assesses U.S. power reactor operational safety data and reliability information to determine risk-significant insights and trends. DRA is organized into four branches: Probabilistic Risk Assessment, Fire and External Hazards, Performance and Reliability, and Human Factors and Reliability. Core competencies of the division include human factors and reliability analysis, reliability and risk analysis, operating experience, fire protection, and hydrology.

The PRA and Performance and Reliability Branches conduct research to support the Reactor Oversight Process, facilitate implementation of risk-informed regulation, expand PRA infrastructure to address emerging technical areas and reactor designs, and support continuous advancement in PRA state-of-practice. Ongoing efforts include development of a Level 3 PRA for the Vogtle site, and updates to standardized probabilistic analysis of risk (SPAR) models to consider FLEX and new reactor designs such as the AP1000. The Level 3 PRA project is a good example of research that will preserve advanced PRA analysis skills and tools.

Ongoing activities by the Fire and External Hazards Branch include tests to enable better understanding of fire hazard characterization and to validate fire analysis, development of PRA and human reliability analysis (HRA) methodologies and approaches suitable for use in fire PRAs, a knowledge management initiative in fire protection and fire safety with associated training, and flooding and other external event analysis approaches to support licensing reviews and oversight activities. We concur with the DRA decision to understand and take appropriate actions to address results from most recent high energy arc flash event tests involving aluminum bus components. This assessment should be completed before additional testing is initiated.

The Human Factors and Reliability Branch supports advanced control room development, data collection, and methods development. We continue to monitor evolution of the Integrated Human Event Analysis System (IDHEAS) methodology for evaluation of human performance. An initial application of this methodology provides guidance for evaluating human performance after initiating events that occur during power operation at nuclear plants. We look forward to a coherent articulation of the general methodology (IDHEAS-G) that provides a unifying concept for HRA and meets the needs of the November 8, 2006 Staff Requirements Memorandum, resulting from the October 20, 2006 meeting with ACRS.

Ongoing DRA research activities are meeting current agency needs. It is not clear how research priorities within DRA and other RES divisions account for an integrated consideration of ‘enterprise risk’, which addresses factors such as safety and security, emerging issues, innovative technologies and associated uncertainties, preservation of core competencies, and development and maintenance of analysis methods and tools. For example, we are unaware of any DRA research addressing the need for models to assess the risks involved with implementation of digital instrument and control solutions or the need to quantify uncertainties affecting the reliability of passive heat removal and passive injection systems.

Division of Systems Analysis

The agency must have the capability to independently evaluate reactor safety analyses. To address this need, DSA maintains analytical capabilities for assessing a wide spectrum of conditions, i.e., during normal operation, accidents, and severe accidents for current, new, and advanced reactor designs. DSA consists of four branches: Accident Analysis, Code and Reactor Analysis, Fuel and Source Term Code Development, and Radiation Protection. It maintains core competencies in neutronics and reactor physics, fuels, thermal-hydraulics, severe accident analysis, and radiation protection. Systems analysis computer codes developed and maintained by DSA are state-of-the-practice or near state-of-the-art in support of regulatory use and licensing support needs. These include:

- TRACE/PATHS/PARCS – codes for modeling light-water reactor (LWR) systems during design basis events with coupling to fuels and neutronics

- SCALE – a suite of neutronics codes for cross section generation

- FRAPCON/FRAPTRAN/FAST – steady state, transient, and accident analysis fuels codes

- MELCOR – systems code with integrated models for fuel behavior, fission product release, and containment response for source term analysis, beyond-design-basis events, and severe accident progression

- MACCS – models for radioactive nuclide dispersion from a nuclear power plant, health, economic, and consequence analysis

- RASCAL and other dose assessment codes – models for radioactive nuclide dispersion, dose assessment, and radiation protection

NRC users and their supporting contractors rely on DSA codes to provide essential input for regulatory decisions. There is a wide user-support base for these codes, with extensive international participation. Interactions between code users facilitate a common understanding on technical issues and provide funding to offset code development and maintenance costs. In addition, DSA codes, such as MACCS, MELCOR, and RASCAL, are used by other government agencies, including the Department of Energy and the Defense Nuclear Facilities Safety Board.

In prior research reviews, we have emphasized the need for the staff to have access to high-performance computing capabilities. During this review, we were pleased to learn that the staff now has access to a high-performance computer cluster at a national laboratory and the agency is in the process of acquiring additional high-performance cloud computing capabilities from a commercial vendor.

DSA is assessing the applicability of TRACE for analyzing new reactor designs. A recently-completed assessment validated the use of TRACE for performing confirmatory analyses of safety-significant thermal-hydraulic phenomena in the APR1400 design certification process. Work is also ongoing to develop TRACE for applicability to the NuScale small modular reactor design. In light of declining resources and the large number of non-LWR concepts being proposed, it is critical that the staff communicate to applicants what data will be required for the agency to render regulatory decisions. The staff should review and update their non-LWR Implementation Action Plan to ensure that it emphasizes the data that design developers must obtain for the staff to evaluate various concepts.

Work to combine FRAPCON/FRAPTRAN into the new FAST fuel performance framework should continue. This effort will allow the staff to have a single code for evaluating steady-state and transient fuel performance with improved capabilities. In addition, having a single modern code structure should reduce subsequent code maintenance efforts.

Severe reactor accident research was an essential element in the agency response to the events at Fukushima Daiichi. The NRC has developed the MELCOR systems-level accident analysis code as the 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, code modernization and maintenance, as well as associated development of staff expertise. In order to review new plant designs, new models are required to simulate novel features not encountered in the current fleet of boiling-water reactors and pressurized-water reactors. In addition, information obtained from the affected units at Fukushima Daiichi should continue to be evaluated to discern required model updates. Furthermore, recent State-of-the-Art Consequence Analysis or SOARCA evaluations have emphasized the benefit of including uncertainty and sensitivity analyses in MELCOR applications.

Gains are being achieved in the consequence analysis area by considering state-of-the-art models developed by other agencies for MACCS improvements. For example, MACCS has been updated with 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, we find that consequence analysis should also be identified and supported as a core competency.

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, which are primarily applied in analyses of radionuclide transport and dispersion and of radiation protection. These are 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 to address user needs. 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.

In summary, DSA has done an exemplary job in maintaining the analytical capabilities required to meet current agency needs. However, current and projected budget scenarios suggest that difficult strategic choices will be necessitated if DSA is to maintain its current suite of computational capabilities, anticipate and adapt to future regulatory needs, and simultaneously maintain critical core competencies in the staff. Possible solutions to address these issues include:

- Continuing to exploit 'centers of excellence' that the agency has established at universities with known expertise as a pipeline for maintaining core competencies needed to replace its aging workforce

- Emphasizing validation of physics-based approaches to modeling improvements, solutions, and enhancements to address evolving current, as well as advanced reactor design issues

- Developing and keeping abreast of improved numerical techniques to increase robustness of codes, capture efficiencies made possible by the rapid advances in computational platform capabilities, and improve user interfaces through advanced graphical interfaces and displays

- Continuing collaborations with the Department of Energy, other agencies, industry, and international partners to leverage research (and, as appropriate in cases where NRC codes are benefitting other agencies, obtain increased cost-sharing), particularly in state-of-the-art physical model development and filling the many needs for experimental data

- Increased collaboration between DSA development teams and agency organizations who deploy and utilize their technologies to facilitate increases in regulatory efficiencies and offset staffing limitations across the NRC.

Division of Engineering

DE develops and directs safety research programs and contributes to standards that support current and advanced nuclear power plants and other facilities regulated by the NRC. The Division is organized into five branches: Component Integrity; Corrosion and Metallurgy; Instrumentation, Controls, and Electrical Engineering; Structural, Geotechnical, and Seismic Engineering; Regulatory Guidance and Generic Issues. DE maintains core competencies in materials, non-destructive examinations, instrumentation and controls, and seismic and structural analyses.

Current DE research on reactor pressure vessel integrity and embrittlement/pressurized thermal shock is in its final stages. Activities are limited to completing Regulatory Guide 1.99, "Radiation Embrittlement of Reactor Vessel Materials," evaluating the adequacy of models for subsequent license renewal, research to support advanced reactor submittal reviews, and codes and standards support.

Codes and standards support, which includes review and approval of proposed code revisions and code cases, has often lagged significantly the publication of revised codes, leading to additional effort by industry and the Office of Nuclear Reactor Regulation staff. We encourage the DE staff to make a concerted effort to review their processes and undertake a more assertive role in promoting more timely promulgation of coordinated code revisions, code cases, and regulatory text.

To support its mission, DE has developed computer codes, such as xLPR and FAVOR, for evaluating materials degradation (e.g., corrosion, aging, irradiation performance, etc.). These codes provide important insights related to pipe rupture probability and weld residual stress. Efforts to release xLPR should be completed expeditiously.

We identified several efforts where DE should reevaluate if the agency needs to continue to obtain independent data. For example, the staff should identify the tests required to support regulatory decisions regarding use of Alloy 690 and associated inspection intervals. Likewise, the staff should require applicants and licensees to provide steam generator tube integrity test data to demonstrate the adequacy of proposed new inspection techniques. Any new data to support subsequent license renewal should also be provided by industry. It is important for the staff to remain cognizant of ongoing industry research. In designs with unique components, such as the NuScale steam generator, the staff should work with the applicant to identify the data that the agency will need to render regulatory determinations. NRC research should focus upon obtaining data for evaluating new methods, such as XFEM for analysis of primary water stress corrosion cracking.

Evaluations of proposed new research on aging management of spent fuel dry storage should first perform an analysis of the consequences from canister failure due to stress corrosion cracking. Risk of cask failure from other mechanisms is extremely low because the frequencies and associated consequences of such cask leaks are low. There does not appear to be risk-based justification for additional research on this topic.

Staff efforts to identify and become informed on emerging issues, such as additive manufacturing (e.g., 3-D printing) of reactor components and research into advanced non-LWR materials, are valuable. However, staff efforts should be limited to identifying required data and tests that the licensee or applicant should provide and then independently interpreting such data.

The staff should provide a schedule for obtaining ACRS input on the Digital Instrumentation and Control Integrated Action Plan that the staff is developing. It is important the research identified in this plan be included and prioritized based on enterprise risk.

We support ongoing collaborative efforts by the staff with external organizations in areas of seismic, flooding, and other external hazards and concur with staff plans to update guidance as necessary. Remaining staff efforts on concrete degradation should be limited to evaluating data obtained by others.

During our discussions, we learned that a website is being developed to solicit ideas from the staff for feasibility study requests. This appears to be an innovative method to anticipate and develop research in response to emerging issues. We suggest that ‘process improvement’ topics, which could help the agency perform its efforts more efficiently, be emphasized in this solicitation. We also recommend that external input be considered as part of this evaluation process.

In summary, DE research is adequately meeting near-term user needs. Recognizing current and future budget constraints and the agency need to address licensee submittals and a diversity of new reactor technologies, DE should reduce its own efforts to develop data independently and focus on identifying data that licensees or applicants must provide. Furthermore, DE should develop an effective process, applicable to all programs in RES, for terminating ongoing research that ceases to be high priority.

INTEGRATION OF RES PRIORITIES

The current research program appears to be satisfactorily meeting near-term agency needs. There are several examples where research efforts and capabilities have provided essential input to agency decisions, such as the heavy reliance on severe accident methodologies developed and maintained by RES to inform agency actions regarding the Fukushima Near-Term Task Force recommendations. Each division within 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.

It isn’t clear that the process used by RES to prioritize research projects is optimized for meeting longer term agency needs. Within this letter report, we identify several efforts having the potential to be risk significant that are not currently being addressed by RES projects. We also note several ongoing projects that would likely be discontinued or redirected if subjected to more rigorous evaluations.

To address our concerns, we suggest that RES perform a systematic assessment that emphasizes enterprise risk in selecting and evaluating research projects. The assessment should support development and maintenance of needed analytical tools and data bases, emphasize activities that improve regulatory efficiency, identify and preserve needed core competencies, and proactively determine when programs should be terminated. To promote coordination within the agency, this assessment should consider all NRC safety research allowing RES to become the conscience of all agency research activities. The requisite skills to develop the analysis approach and organize implementation of the systematic approach may well reside in DRA.

Sincerely,

/RA/

Michael L. Corradini
Chairman

REFERENCES

1. U.S. Nuclear Regulatory Commission, NUREG-1614, Volume 6, “Strategic Plan Fiscal Years 2014-2018”, August 2014 (ML14246A439).

2. U.S. Nuclear Regulatory Commission, NUREG-1925, “Research Activities FY2015-FY2017, Revision 3, February 2016 (ML16060A414).

3. U.S. Nuclear Regulatory Commission, NUREG-1802, Volumes 1 and 2, “Role and Direction of NRC Research”, September 2001 (ML012760230, ML012760301).

4. Staff Requirements Memorandum M061020, November 8, 2006 (ML063120582).

coordination within the agency, this assessment should consider all NRC safety research allowing RES to become the conscience of all agency research activities. The requisite skills to develop the analysis approach and organize implementation of the systematic approach may well reside in DRA.

Sincerely,

/RA/

Michael L. Corradini
Chairman

REFERENCES

1. U.S. Nuclear Regulatory Commission, NUREG-1614, Volume 6, "Strategic Plan Fiscal Years 2014-2018", August 2014 (ML14246A439).

2. U.S. Nuclear Regulatory Commission, NUREG-1925, "Research Activities FY2015-FY2017, Revision 3, February 2016 (ML16060A414).

3. U.S. Nuclear Regulatory Commission, NUREG-1802, Volumes 1 and 2, "Role and Direction of NRC Research", September 2001 (ML012760230, ML012760301).

4. Staff Requirements Memorandum M061020, November 8, 2006 (ML063120582).

Accession No: ML18057B139 **Publicly Available Y** **Sensitive N**
Viewing Rights: ☒ NRC Users or ☐ ACRS Only or ☐ See Restricted distribution

OFFICE	**ACRS/TSB**	**SUNSI Review**	**ACRS/TSB**	**ACRS**	**ACRS**
NAME	HNourbakhsh	HNourbakhsh	MBanks *(KWeaver for)*	AVeil	MCorradini *(AVeil for)*
DATE	2/26/2018	2/26/2018	2/26/2018	2/26/2018	2/26/2018

OFFICIAL RECORD COPY