UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
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May 22, 2025

Dr. Michael Goff
Acting Assistant Secretary for Nuclear Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

Dear Dr. Goff:

On behalf of the U.S. Nuclear Waste Technical Review Board (Board), I want to thank you and your staff, as well as the staff from the national laboratories, for supporting the Board's Spring 2024 Meeting, which was held on May 21–22, 2024, in Knoxville, TN. The purpose of the meeting was to review information on U.S. Department of Energy, Office of Nuclear Energy (DOE-NE) research and development (R&D) activities related to the geologic disposal of spent nuclear fuel (SNF) and high-level radioactive waste (HLW) in crystalline host rocks[1] and on corrosion of commercial spent nuclear fuel[2] (CSNF) after disposal. This letter[3] presents the Board's review resulting from the Spring 2024 Meeting and information obtained during a tour of Oak Ridge National Laboratory (ORNL) facilities on May 20, 2024. The agenda, presentation materials, meeting transcript, and an archived recording of the webcast for the meeting are posted on the Board's website.[4]

The Board also thanks the staff from DOE and the national laboratories for supporting technical fact-finding meetings on April 23 and 25, 2024. These fact-finding meetings enabled the Board to prepare for the Spring 2024 Meeting.

In 2024, DOE-NE had been continuing non-site-specific R&D on the potential disposal of SNF and HLW in several host rocks including crystalline rock formations. Crystalline rocks offer advantages such as low bulk permeability and high thermal conductivity, making them potentially suitable for waste disposal. However, they also require a robust engineered barrier system to reduce the potential for radionuclide release through fractures which can serve as fast pathways for the transport of radionuclides. DOE had been assessing the performance of a repository in crystalline host rock using the Geologic Disposal Safety Assessment (GDSA) Framework. Additionally, DOE was developing a Fuel Matrix Degradation Model (FMDM) to model the corrosion of CSNF under various repository conditions. The Board's review focused on these R&D activities.

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[1] Crystalline host rock is a term for igneous rocks and metamorphic rocks (e.g., granite and gneiss) in which a repository could be developed.

[2] The focus of the Board's review in this letter is limited to CSNF and does not include R&D activities related to corrosion of DOE-managed SNF and advanced reactor fuels.

[3] Current and past Members of the Board who have contributed to this letter include P. Swift (Chair), R. Ballinger, S. Becker, A. Croff, T. Illangasekare, K. L. Peddicord, N. Siu, S. Tyler, and B. Woods.

[4] https://www.nwtrb.gov/meetings/past-meetings/spring-2024-board-meeting---may-2024

At the meeting, the Board heard presentations from DOE staff and national laboratory researchers about their work for DOE. These presentations covered the recent reorganization forming the Office of Disposal R&D within DOE-NE and its research activities, as well as topics related to disposal in crystalline host rocks, including site characterization, physical and chemical processes, buffer behavior, conditions in the engineered barrier system, and the integration of process models into the GDSA Framework.

Presentations on the corrosion of CSNF after disposal included an overview that addressed models for the degradation rate of CSNF, process model coupling and implementation within the GDSA Framework, international collaborations, and a strategic approach to fill identified knowledge gaps for waste form degradation. Additional presentations addressed the FMDM, surrogate models, and electrochemical testing used to obtain data needed for model implementation.

The Board also heard presentations by Dr. Laura Pyrak-Nolte, from Purdue University; Mr. Andrew Parmenter from Nuclear Waste Management Organization, Canada; Dr. Erika Holt from the Finnish Technical Research Centre; and Dr. Barbara Pastina from Posiva Oy, Finland.

Based on the information presented at this Spring 2024 Meeting, in fact-finding meetings, and in related technical reports, the Board has developed observations regarding DOE's non-site-specific disposal R&D program, R&D activities related to disposal in crystalline host rock, and corrosion of CNSF after disposal. The Board commends the presenters for their informative and comprehensive presentations, which effectively addressed a number of key questions presented in the meeting agenda.

DOE R&D activities related to nuclear waste disposal

As the Board has noted earlier, DOE can gain valuable insights from international experience in nuclear waste disposal and leverage global expertise in program integration, siting, research strategy, and public engagement.[5, 6] International efforts highlight the importance of early public involvement and the decades-long nature of repository characterization and modeling. Regardless of the chosen disposal strategy, DOE's program can benefit significantly from these international experiences.

The Board commends DOE for its leadership and participation in international collaborative research projects on geological disposal of nuclear waste such as DECOVALEX[7] and modeling

[5] NWTRB. 2020. Filling the Gaps: The Critical Role of Underground Research Laboratories in the U.S. Department of Energy Geologic Disposal Research and Development Program. Arlington, Virginia: U.S. Nuclear Waste Technical Review Board. January. https://www.nwtrb.gov/docs/default-source/reports/nwtrb-url-report.pdf?sfvrsn=9.

[6] NWTRB. 2021. Six Overarching Recommendations for How to Move the Nation's Nuclear Waste Management Program Forward. Arlington, Virginia: U.S. Nuclear Waste Technical Review Board. April. https://www.nwtrb.gov/docs/default-source/reports/nwtrb-six-recommendations-report.pdf?sfvrsn=20.

[7] DEvelopment of COupled models and their VALidation against EXperiments - https://decovalex.org/

of experiments being conducted at underground research laboratories in different host rocks such as argillites (e.g., Mont Terri), granites (Grimsel Test Site) and salt (WIPP[8]). Furthermore, the Board commends DOE for participating in several international projects related to SNF degradation. These include EURAD[9] projects on the fraction of relatively mobile radionuclides that may be released from high burn-up SNF immediately following failure of waste packaging and cladding relevant to all host rock types,[10] and SNF dissolution and chemistry under failed container conditions;[11] as well as the International Atomic Energy Agency project focusing on spent fuel performance assessment and research.[12]

The Board notes that DOE is using state-of-the-art modeling approaches and methods of analysis for evaluating and predicting long-term repository performance in crystalline host rock. DOE efforts also include activities related to understanding the crystalline host rock and engineered barrier behavior at high temperatures and evaluating alternative buffer materials. The Board recognizes the technical challenges DOE faces related to field and laboratory studies needed to support and validate numerical models but is encouraged by ongoing DOE efforts to collaborate with and leverage experience from disposal programs in other countries.

The Board observes that DOE's focus on international collaborations has been effective in advancing DOE's state of knowledge related to nuclear waste disposal. The Board also notes that DOE has a technically valid approach to developing its modeling capability, the GDSA Framework, which will enable DOE to evaluate the post-closure performance of a potential repository in crystalline host rock. The Board encourages DOE to continue international collaborations and its engagement with countries who have made considerable progress in repository design, construction, and operation.

Leveraging advances in geophysical characterization tools and techniques from other industries

There is a rapidly growing knowledge base in geophysical techniques for fracture characterization, especially in deep formations used in geothermal, geologic carbon storage, and hydraulic fracturing industries. The DOE has supported collaborative programs like SubTER[13] in the past. These advances can be used for site characterization of host rock and excavation damaged zone in geologic repositories.[14]

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[8] Waste Isolation Pilot Plant

[9] European Joint Programme on Radioactive Waste Management

[10] http://www.firstnuclides.eu/Default.aspx

[11] Modern Spent Fuel Dissolution and Chemistry in Failed Container Conditions- https://www.disco-h2020.eu/

[12] Spent Fuel Performance Assessment and Research - Phase IV - https://www.iaea.org/projects/crp/t13016

[13] Subsurface Science, Technology, Engineering, and R&D Crosscut (SubTER). https://www.energy.gov/subsurface-science-technology-engineering-and-rd-crosscut-subter

[14] Dobson, P. "Geophysical Techniques for Site and Excavation Damage Zone Characterization," NWTRB Public meeting, May 21-22, 2024. https://www.nwtrb.gov/docs/default-source/meetings/2024/may/day1_dobson-geophysical_site-edz_char.pdf?sfvrsn=a658f005_8

The Board encourages DOE to build on past collaborations to leverage advances in geophysical characterization techniques and tools from petroleum engineering, carbon storage and geothermal energy industries. These efforts can add significantly to DOE's programs in representation of fluid flow, transport, and geomechanical responses in crystalline host rock repository modeling and characterization.

CSNF corrosion after disposal

DOE's FMDM comprehensively addresses electrochemical processes that may affect fuel matrix dissolution behavior in a deep geologic repository. Incorporating the FMDM into a numerical model, such as GDSA, faces multiple challenges and uncertainties, including developing data sufficient to support model implementation, verification, and validation. The DOE has acknowledged and documented these uncertainties in the FMDM as knowledge gaps, and it has been working to prioritize R&D to address these gaps.[15] The Board continues to follow the DOE's efforts with interest. Given the overall uncertainties in the system characteristics and performance, and in particular in the FMDM, it is essential that the program define "good enough" for the models in the FMDM to avoid unnecessary effort for limited benefit.[16] If the DOE continues pursuing the FMDM as a preferred degradation model, the Board looks forward to receiving more information about the FMDM gaps and the DOE's priorities for addressing these gaps.

Site tour at Oak Ridge National Laboratory

The day prior to the Spring 2024 Meeting, the Board toured the Molten Salt Reactor Experiment (MSRE) and High Flux Isotope Reactor facilities at ORNL. The Board expresses its gratitude to DOE and ORNL staff for facilitating this tour. This visit provided crucial insights supporting the Board's ongoing evaluation of DOE's activities related to the management and disposal of SNF and HLW. While acknowledging that MSRE was an experimental reactor, the Board notes that the MSRE experience highlights the importance of clearly and fully understanding the details of proposed reactor operations, and their implications for waste management in the design-build-operation-decommissioning phases, for first-of-a-kind advanced commercial nuclear reactors such as molten salt-fueled or salt-cooled reactors.

Sincerely,

Peter Swift
Chair

[15] Meszaros, J. et al. 2021. Draft Experimental Plan for Commercial SNF Degradation in Repository Environments with a Focus on Fuel Matrix Degradation. M3SF-21OR010309072. Oak Ridge, TN: Oak Ridge National Laboratory. May.

[16] For example, DOE could consider an approach that defines the functions of each barrier in the context of overall system performance and the degree to which each barrier must perform its functions and determine whether a simple model is sufficient to reflect the required performance before developing a more sophisticated or realistic model that would require additional R&D be conducted.