UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
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Dr. Kathryn Huff
Assistant Secretary for Nuclear Energy
U.S. Department of Energy
1000 Independence Ave., SW
Washington, DC 20585

Dear Dr. Huff:

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 2022 Winter Meeting, which was held virtually on March 1–2, 2022. The purpose of the meeting was to review information on the U.S. Department of Energy, Office of Nuclear Energy (DOE-NE) activities related to spent nuclear fuel (SNF) and high-level radioactive waste (HLW). DOE described research and development (R&D) on SNF and HLW in the areas of storage, transportation, non-site-specific disposal, and integrated waste management, and its consent-based siting process with regard to federal interim storage facilities. This letter presents the Board's observations, findings, and recommendations resulting from the meeting. The agenda, presentation materials, and an archived recording of the webcast for the meeting are posted on the Board's website at https://www.nwtrb.gov/meetings/past-meetings/winter-2022-board-virtual-meeting---march-1-2-2022. A meeting transcript is also available there.

Background

Over the past several years, DOE has been conducting R&D to enable storage, transportation, and disposal of SNF and HLW from existing and future nuclear fuel cycles and planning for an integrated waste management system to transport, store, and dispose of those wastes. In addition, DOE recently re-initiated an effort to use a consent-based siting process with regard to federal interim storage facilities for SNF. The Board recognizes these DOE efforts as positive steps towards having the capability to address several recommendations the Board made in its Six Recommendations Report,[1] issued in April 2021, namely, to:

- Ensure an integrated organizational approach.
- Anticipate the required high-performance computing and data management infrastructure required for a multi-decade waste management program.

[1] 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.

- Facilitate application of iterative and adaptive approaches to development of a geologic repository.
- Embrace openness, transparency, and engagement.

The Board's meeting examined DOE's R&D activities related to storage, transportation, and disposal of dual-purpose (storage and transportation) canisters (DPCs). DOE presentations in previous Board meetings have touched upon some aspects of these efforts and the Board has commented on those in Board reports or letters to DOE.[2,3,4] At the meeting, DOE also updated the Board on some of its integrated waste management system R&D activities and its consent-based siting process. The Board has commented on some aspects of DOE's earlier efforts in these areas in Board reports or letters to DOE.[5,6,7]

At the meeting, the Board received an update from Timothy Gunter (DOE-NE) and from a national laboratory researcher on DOE's DPC direct disposal R&D activities. Then national laboratory researchers gave two presentations, one on a repository-scale performance assessment[8] that takes account of post-closure criticality and another on cladding degradation model development. Ned Larson (DOE-NE) provided a summary and status of storage and transportation R&D, including efforts related to DPCs. National laboratory researchers described canister surface environment investigations and the potential for corrosion of commercial SNF storage canisters and aerosol transmission through stress corrosion crack-like geometries.

The Board then heard several presentations on DOE's integrated waste management system R&D activities. A national laboratory staff member and a representative from a contractor at the Hanford, Washington, site described the Hanford Lead Canister (HLC) project, which is jointly supported by DOE-NE and the DOE Office of Environmental Management (DOE-EM). A national laboratory staff member brought the Board up to date on the Next Generation System Analysis Model (NGSAM) and described updated NGSAM requirements and

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[2] Bahr, J.M. 2021. Board letter to Dr. Rita Baranwal with comments from July 2020 Board meeting (January 11, 2021). https://www.nwtrb.gov/docs/default-source/correspondence/jmb026.pdf?sfvrsn=8. (Accessed June 2, 2022)

[3] NWTRB. 2019. *Preparing for Nuclear Waste Transportation–Technical Issues that Need to be Addressed in Preparing for a Nationwide Effort to Transport Spent Nuclear Fuel and High-Level Radioactive Waste*. Arlington, Virginia: U.S. Nuclear Waste Technical Review Board. September.

[4] Ewing, R. 2015. Board letter to Mr. John Kotek with comments from June 2015 Board meeting (August 31, 2015). https://www.nwtrb.gov/docs/default-source/correspondence/rce083115.pdf?sfvrsn=12. (Accessed June 2, 2022)

[5] Ewing, R. 2015. Board letter to Mr. John Kotek with comments from June 2015 Board meeting (August 31, 2015). https://www.nwtrb.gov/docs/default-source/correspondence/rce083115.pdf?sfvrsn=12. (Accessed June 2, 2022)

[6] NWTRB. 2019. *Preparing for Nuclear Waste Transportation–Technical Issues that Need to be Addressed in Preparing for a Nationwide Effort to Transport Spent Nuclear Fuel and High-Level Radioactive Waste*. Arlington, Virginia: U.S. Nuclear Waste Technical Review Board. September.

[7] Bahr, J.M. 2022. Board letter to Dr. Kathryn Huff with comments from November 2021 Board meeting (January 7, 2022). https://www.nwtrb.gov/docs/default-source/correspondence/jmb039.pdf?sfvrsn=4. (Accessed June 2, 2022)

[8] The Board notes that what was presented was not a formal performance assessment meant to address all the regulatory requirements described in the Code of Federal Regulations (CFR) at 10 CFR Part 63. As such the Board will refer to it as an assessment of post-closure criticality.

enhancements. Erica Bickford (DOE-NE) updated the Board on DOE's Stakeholder Tool for Assessing Radioactive Transportation (START) and described the current functions and capabilities of START. In the final meeting presentation, Alisa Trunzo (DOE-NE) updated the Board on DOE's current efforts on a consent-based approach to siting federal interim storage facilities. These efforts include a DOE request for information (RFI), for which DOE was still accepting comments, and plans for issuing a funding opportunity for interested groups and communities later this year.

Board Observations, Findings, and Recommendations

After discussing and examining the information presented at the public meeting along with related technical reports, the Board has several observations, findings, and recommendations on DOE's R&D activities and consent-based siting program, which are provided below. The Board notes that the meeting presentations were informative and addressed many of the questions the Board posed in the meeting agenda.

DOE's DPC Direct Disposal R&D Activities

Alternatives for disposal of commercial SNF

Since 2013, DOE has funded a DPC direct disposal R&D program that has focused on determining the technical feasibility of the safe, cost-effective, licensed, direct disposal (without removing and repackaging the SNF assemblies but including placing the DPC in a disposal overpack) of commercial SNF packages used by electric utilities operating nuclear power plants. A fundamental decision that will need to be made is whether to accept loaded DPCs into an integrated waste management system instead of accepting SNF assemblies.[9] The Board has noted that decisions in the near term on the disposability of SNF in DPCs and on the direction of the nation's geologic disposal program are needed because their interdependence will shape waste management and disposal activities over many years.[10]

The Board observes that a decision on disposability of SNF in DPCs would substantially impact how SNF is stored, transported, and disposed of, and may require interim storage of SNF for many decades to hundreds of years, depending on the availability of a repository that can accept DPCs. The Board has described how the complex structure of responsibilities and stakeholders presents challenges to DOE in executing a nuclear waste management program.[11] The Board notes that, as DOE pursues federal interim storage facilities using a consent-based approach, newly identified conditions of consent could make DOE's efforts to execute its program more complex. However, we believe a consent-based siting process that is well-conceived and well-executed has the potential to greatly increase public trust and confidence in siting efforts.

[9] " … For example, under the provisions of the Standard Contract, spent nuclear fuel in multi-assembly canisters is not an acceptable waste form, absent a mutually agreed to contract amendment. … ." (Gunter and Freeze, 2022). https://www.nwtrb.gov/docs/default-source/meetings/2022/march/gunter_freeze.pdf?sfvrsn=6. (Accessed June 2, 2022)

[10] Bahr, J.M. 2021. Board letter to Dr. Rita Baranwal with comments from July 2020 Board meeting (January 11, 2021). https://www.nwtrb.gov/docs/default-source/correspondence/jmb026.pdf?sfvrsn=8. (Accessed June 2, 2022)

[11] 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.

Following its July 2020 public meeting, the Board recommended that DOE provide information to decision-makers related to repository design concepts for various host rock types, the timing and rate of DPC disposal, and total system life cycle costs to inform their decisions on the use of DPCs.[12] DOE has completed a comparative cost analysis of SNF management alternatives[13] and has noted that a possible benefit of the direct disposal of DPC option is a lower cumulative worker dose.

- *The Board finds that additional analyses and quantitative information regarding the potential pros and cons of the DPC direct disposal option will be useful to decision-makers.*

  To provide decision-makers with information about the pros and cons of direct disposal of DPCs versus repackaging of SNF assemblies currently in DPCs, the Board recommends that DOE complete quantitative assessments for both concepts spanning the waste management lifecycle. These assessments should include estimates of costs and radiation doses related to packaging (or repackaging) of SNF, transportation, interim storage, and repository operations, including the ramifications of disposal in alternative geological media.

Independent technical review of the DOE DPC R&D program

As part of its R&D oversight, in 2021, DOE-NE funded an independent technical review (ITR) of its DPC direct disposal R&D program to help guide the future direction of the program. The Board commends DOE for sponsoring the ITR and soliciting feedback on its R&D program. The Board understands that the ITR was an internal (non-public) effort, and the Board appreciates being allowed access to the results of the ITR.[14] The ITR assessed some of the same R&D topics that were discussed in the Board's Winter Meeting, including cladding degradation modeling and post-closure criticality consequence assessments. The Board recognizes that the scope of these R&D efforts could change as DOE evaluates the results of the ITR and previous Board recommendations.[15]

In keeping with its mandate to conduct on an ongoing review before decisions are made, the Board held an initial fact-finding meeting with DOE on May 19, 2022 and is planning another fact-finding meeting with DOE to obtain more information on DOE's ITR. In the May 19, 2022, fact-finding meeting the discussion focused on neutronics calculations that affect the assessment of post-closure criticality. The Board plans to discuss further the scope of the ITR, including the criteria used to define "DPC disposability" and "feasibility of disposal." The Board would like to discuss the ITR results and how DOE will use the results to guide its DPC disposability

[12] Bahr, J.M. 2021. Board letter to Dr. Rita Baranwal with comments from July 2020 Board meeting (January 11, 2021). https://www.nwtrb.gov/docs/default-source/correspondence/jmb026.pdf?sfvrsn=8. (Accessed June 2, 2022)

[13] Freeze, G., E. Bonano, E. Kalinina, J. Meacham, L. Price, P. Swift, A. Alsaed, D. Beckman, and P. Meacham. 2019. *Comparative Cost Analysis of Spent Nuclear Fuel Cost Alternatives*. SAND2019-6999, Revision 1. Albuquerque, New Mexico: Sandia National Laboratories. June.

[14] Under the Nuclear Waste Policy Act, as amended, the NWTRB has the authority to request and review DOE draft reports.

[15] Bahr, J.M. 2021. Board letter to Dr. Rita Baranwal with comments from July 2020 Board meeting (January 11, 2021). https://www.nwtrb.gov/docs/default-source/correspondence/jmb026.pdf?sfvrsn=8. (Accessed June 2, 2022)

studies and its determination of whether direct disposal of DPCs is feasible (or not). The Board appreciates DOE's willingness to discuss these issues in the upcoming fact-finding meeting.

Assessment of post-closure criticality

DOE is conducting studies on post- closure criticality consequences to assist in assessing the technical feasibility of direct disposal of DPCs loaded with commercial SNF (both currently loaded DPCs and those still to be loaded). Other factors in DOE's assessment of the feasibility of direct disposal of DPCs include challenges associated with thermal management and engineering (weight and size) posed by large DPCs.

The criticality consequence studies involve post-closure repository calculations using the PFLOTRAN model-based Geologic Disposal Safety Assessment Framework coupled with neutronics calculations. Some of the recent criticality studies are still in draft form.[16] The studies do not yet consider the probability for criticality to occur which will be needed to assess risk. To date, all evaluations have been done for pressurized water reactor (PWR) SNF and have not evaluated boiling water reactor (BWR) SNF. DOE continues to make good progress in developing a capability to model the consequences of post-closure criticality. DOE has made improvements in PFLOTRAN, including capabilities to (i) change the radionuclide inventory and thermal output during the simulation, (ii) begin to take account of coupling between neutronics, in-canister thermohydraulic processes, and rates of heat transfer out of the canister, and (iii) take account of thermally induced mineralogic changes in permeability of the bentonite buffer. The Board observes that DOE appears to be building a case that radionuclide releases resulting from a postulated post-closure criticality event (consequences, not weighted by probability to yield risk) will not lead to significant changes in predicted doses (compared to cases with no criticality) for the unsaturated and shale scenarios that were simulated.

The Board notes that, in a comprehensive post-closure criticality assessment, several parameters will have a significant influence on the results. Among those parameters are the properties of the construction material of the outer layer of the waste package (i.e., the disposal overpack) and rate of degradation through the material. These factors will, in turn, determine when canister degradation could occur allowing water infiltration, and then, potentially, criticality. However, DOE has not yet included consideration of these parameters in its post-closure criticality assessments. The Board observes that other countries, such as Finland and Sweden, are employing waste packages that include a copper-based outer layer for waste disposal in crystalline rock repositories that are claimed to be long-lived. The Board notes that if DOE takes account of likely waste package materials and degradation rates for crystalline, argillite, and salt disposal concepts in its assessment of post-closure criticality, its assessment of the technical feasibility of the direct disposal of DPCs would be better informed and future R&D efforts better focused.

If DOE decides to continue criticality consequence studies without simultaneously considering the probability for criticality to occur, then the Board notes that DOE will need to consider the following questions and issues. First, how does criticality affect the performance of engineered

[16] The Board reviewed a draft report that formed the basis of the March meeting presentation on the repository-scale assessment incorporating post-closure criticality.

barriers and host rock, particularly in environments such as a crystalline repository under saturated conditions, which has yet to be evaluated? Second, does the range of infiltration rates DOE used for the unsaturated scenario, while reasonable for a site such as Yucca Mountain, capture the full range of plausible infiltration rates for other settings where there also could be a thick unsaturated zone? The Board encourages DOE to focus more on the effects of criticality events (transient and steady-state) on engineered material (e.g., waste package, bentonite buffer) properties, and on the processes that could lead to permanent termination of a criticality event, as well as the items the Board has previously identified.[17] As part of that effort, DOE will need to consider several neutronics-related issues including use of and validation of RAZERBACK and S3K, assessment of higher enrichments associated with HALEU,[18] and the impacts of BWR fuel on the potential consequences of criticality events. The planned evaluations for BWR SNF are important given the difference in water to uranium volume ratios and presence of water rods, water crosses, and part length fuel rods as compared to PWR SNF. Note that an alternative approach to assessing the risks from post-closure criticality may be to determine that the probability for criticality to occur is sufficiently small so that a detailed consequence assessment is not needed.[19]

SNF cladding degradation modeling

The Board appreciates the thorough presentation that summarized the consideration of SNF cladding in domestic and foreign repository programs. The Board commends DOE for completing the comprehensive, non-site-specific repository review and update of the features, events, and processes that could affect SNF cladding degradation. Degradation of cladding, SNF assembly hardware (e.g., grid spacers), and baskets within a DPC will affect the potential for criticality. Results from short-term testing[20] suggest that the grid spacers would degrade faster than cladding. DOE recognizes that partial grid collapse may occur for horizontally emplaced DPCs, which could permanently terminate criticality. The Board observes that this partial grid collapse scenario deserves attention because it could reduce the probability of criticality, but additional knowledge of grid material properties and stresses may be needed. To be noted is that BWR SNF is normally stored with the channel box in place, so the consequences of basket and grid spacer degradations may differ from that of PWR SNF. DOE is planning long-term cladding corrosion testing to validate extrapolations from short-term tests. The Board notes that efforts to refine cladding degradation modeling as part of the DPC direct disposal R&D effort will be influenced by DOE's decision on its overall approach for disposal criticality. These issues, as well as many of the topics mentioned above, will be influenced by DOE's

[17] Bahr, J.M. 2021. Board letter to Dr. Rita Baranwal with comments from July 2020 Board meeting (January 11, 2021). https://www.nwtrb.gov/docs/default-source/correspondence/jmb026.pdf?sfvrsn=8. (Accessed June 2, 2022)

[18] HALEU is high-assay, low-enriched uranium, which is uranium that has been enriched so that the concentration of the fissile isotope U-235 is between 5 and 20 percent of the mass of the fuel. This is higher than the 3 to 5 percent U-235 concentration, or "assay," of low-enriched uranium that fuels the existing fleet of light water reactors.

[19] Expected average doses for a scenario, such as post-closure criticality, in a probabilistic performance assessment are calculated by multiplying the conditional consequence by the probability (some value less than one) for the scenario to occur.

[20] Hillner, E., D. Franklin and J. Smee. 1998. *The Corrosion of Zircaloy-Clad Fuel Assemblies in a Geologic Repository Environment*. Bettis Atomic Power Laboratory Report WAPD-T-3173.

consideration and implementation of recommendations made by a DOE-sponsored ITR team that addressed a broad range of issues associated with the DPC direct disposal R&D program.

DOE's Storage and Transportation R&D Activities

DOE's summary presentation on its storage and transportation R&D activities covered the breadth of its R&D program. The Board commends DOE-NE for obtaining commercial DPCs for use in storage and disposal R&D efforts and for planning two full-scale field demonstration studies within its storage and transportation R&D program and its integrated waste management system R&D program.

The Board notes that obtaining and testing high burnup BWR SNF cladding is identified in DOE's storage and transportation R&D 5-year plan and in DOE's gap analysis as an action that is needed to fully "close multiple gaps," including potential cladding degradation due to hydride reorientation.[21,22] DOE still believes that pressurized water reactor PWR data for high-burnup fuels bound BWR behavior.

- *The Board finds that DOE has not yet provided evidence for making this conclusion.*

For example, the Board recommended "that DOE indicate how its tests [with PWR fuel] and models do or do not apply to the broad range of high burnup fuel types and storage and transportation system designs for which information is still needed and take steps to meet those remaining technical information needs."[23] The Board is encouraged that DOE is continuing to seek opportunities to do the necessary BWR SNF cladding testing. The Board notes that similar questions of test result applicability are pertinent to newer accident tolerant fuels (ATF) and fuel assemblies containing integral fuel burnable absorbers (IFBA).

- *The Board recommends that DOE either demonstrate that existing data and modeling regarding the behavior of high burnup PWR SNF bound the behavior of BWR and ATF SNF and SNF containing IFBAs or complete the necessary testing and modeling for these fuel types.*

DOE's focus in its transportation R&D activities is on normal conditions of transport. DOE is considering the possibility of conducting a package performance study of an SNF transportation cask to address non-normal conditions of transport (e.g., accidents) and is in the early stages of

[21] Saltzstein, S., B. Hanson, G. Freeze and K. Sorenson. 2020. *Spent Fuel and Waste Science and Technology Storage and Transportation 5-Year R&D Plan*. SAND2020-9310 R. Albuquerque: Sandia National Laboratories. August. This document describes activities whose completion is subject to future funding and DOE does not intend to update the plan.

[22] Teague, M., S. Saltzstein, B. Hanson, K. Sorenson, and G. Freeze. 2019. *Gap Analysis to Guide DOE R&D in Supporting Extended Storage and Transportation of Spent Nuclear Fuel: An FY2019 Assessment*. SAND2019-15479R. Albuquerque: Sandia National Laboratories. December. This document serves as the technical guidance for planned work and is updated.

[23] NWTRB. 2021. *Evaluation of the Department of Energy's Research Program to Examine the Performance of Commercial High Burnup Spent Nuclear Fuel During Extended Storage and Transportation*. Arlington, Virginia: U.S. Nuclear Waste Technical Review Board. July.

developing a test plan. Like its successful multi-modal transportation test that addressed normal conditions of transport, DOE anticipates that surrogate fuel assemblies would be instrumented and placed inside a cask during testing. This would allow for the evaluation of both the cask and its internal contents under non-normal conditions of transport. The Board notes that DOE reviewed earlier full-scale accident testing efforts including the U.S. Nuclear Regulatory Commission (NRC)-sponsored package performance study. The NRC study included an opportunity for public comment on the draft protocols.[24] The Board commends DOE for considering anew the need and scope of a package performance study that assesses the performance of both the cask and cask contents, particularly considering extended aging affects, and encourages DOE to engage early with stakeholders in developing the plan.

DOE is conducting a comprehensive array of R&D activities that are addressing the technical issues related to the timing and conditions of occurrence of, and the risk of canister penetration from, chloride-induced stress corrosion cracking (CISCC) of welded stainless-steel dry-storage canisters during extended storage of SNF. The focused research on CISCC conducted under the storage and transportation R&D program includes:

- Defining the canister surface environment through thermodynamic modeling, independent spent fuel storage installation site sampling, a field demonstration study of horizontally stored canisters, and laboratory experiments.
- Determining canister degradation rates through corrosion experiments and modeling, pit-to-crack transition studies, and crack growth rate measurements.

These studies are complemented by development and evaluation of methods to mitigate and repair canister degradation. The Board commends DOE for the R&D work it is conducting on CISCC and encourages DOE to continue its R&D efforts on this technical issue. The Board notes one additional area that deserves focus.

- *The Board finds that DOE has not fully considered whether a different localized corrosion mechanism such as crevice corrosion could be a precursor process for initiation of CISCC in addition to pitting corrosion.*

  As DOE continues to develop the two full-scale canister demonstrations, the Board recommends that DOE consider whether localized corrosion such as crevice corrosion could be a precursor to CISCC and determine how that precursor mechanism could be assessed in the field demonstrations.

DOE-NE is also supporting, under its integrated waste management R&D program, the Hanford Lead Canister (HLC) project and is collaborating with DOE-EM and industry on that test. The Board commends DOE for supporting the HLC project. The project is a positive demonstration of the value of integration efforts across DOE programs, offices, and sites, which the Board previously has recommended to DOE.[25] The HLC project, which is focused on vertically stored

[24] Durbin, S., E. Lindgren, R. Rechard and K. Sorenson. 2014. *Full-Scale Accident Testing in Support of Used Nuclear Fuel Transportation*. SAND2014-17831 R. Albuquerque: Sandia National Laboratories. September.

[25] 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.

canisters, shares common objectives with DOE R&D activities on CISCC of commercial SNF dry-storage canisters. The speakers stated there is broad collaboration between DOE-NE, DOE-EM, and industry, and appear very open to input from researchers on how the HLC project can provide information that is useful to the dry-storage canister community. The Board encourages the HLC project investigators to further their collaboration with other researchers. The HLC project is still at an early stage, with ample opportunity to get input on how it can support research on corrosion mechanisms and sampling and characterizing atmospheric dusts that may deposit on canister surfaces.

The Board observes that there may be opportunities to incorporate monitoring and inspection results to inform HLC efforts. The Board encourages DOE to use monitoring and inspection results from other aging management efforts such as those at the Hanford 200 Area Interim Storage Area and at the Columbia Generating Station to inform development of the HLC test plan.

DOE is conducting R&D on aerosol transmission through machined microchannels that are early surrogates for stress corrosion cracks. The speaker indicated that in the next steps in the testing, they want to introduce more features that are prototypic of stress corrosion cracks. The Board agrees that refinements are needed. For example, if more prototypic stress corrosion crack geometries are used, the rates of depressurization and clogging (plugging) of a crack due to deposition of aerosol particles are likely to differ from what is now being measured. In particular, the crack geometry at the time of initial thru-wall crack penetration may lead to depressurization with effective filtering of aerosol size particles, thereby minimizing subsequent particle release due to prior depressurization as the crack enlarges. Also, the Board notes that, in the current experiments, multiple parameters that affect flow and transport are varied at the same time, which complicates modeling and interpretation. DOE recognizes these limitations and is preparing for testing of lab-grown corrosion cracks and clean (non-particulate) testing first for independent flow characterization before testing for particulate transmission. Eventually, the experimental data and modeling outputs on aerosol transmission will be used as input to consequence (dose) calculations for a postulated SNF canister breach.

The Board is encouraged by DOE's initial efforts and notes that DOE has described several potential refinements to the testing in its storage and transportation 5-year R&D plan.[26] In the storage and transportation 5-year R&D plan DOE listed the following improvements:

- "Via the sibling pin [high burnup PWR SNF] testing program, obtain the particle size distribution of fuel and aerosols released in different scenarios (e.g., burst vs. impact) and apply this distribution to the testing and modeling."
- "Measure aerosol release and depletion in environments characteristic of dry storage."

The Board agrees with these potential refinements. The Board notes that the overall risk of SNF canister degradation is best informed by combining the results of a realistic assessment of the

[26] Saltzstein, S., B. Hanson, G. Freeze and K. Sorenson. 2020. *Spent Fuel and Waste Science and Technology Storage and Transportation 5-Year R&D Plan*. SAND2020-9310 R. Albuquerque: Sandia National Laboratories. August.

consequences of canister penetration from degradation with the results of a more thorough assessment of the probability of breaching an SNF dry cask storage system. Prior scoping probabilistic risk assessments of dry casks[27,28] that describe the logic used and events that lead to radiologic release during storage can guide DOE to better define the processes and event sequences that are needed for a realistic assessment of the consequences of canister degradation.

- *As DOE conducts R&D to support its consequence assessment of canister failure, the Board recommends that DOE complete refinements that it has described for its aerosol transmission experiments, including conducting some experiments using a single effect approach to facilitate easier model development, validation, and interpretation of results. In the near-term, DOE should clearly define the events and processes that affect aerosol generation within a sealed cask that can lead to potential aerosol transmission when a crack forms to subsequently guide the R&D needed to realistically assess the consequence of a canister failure.*

DOE's Integrated Waste Management R&D Activities – System Tools

DOE-NE has developed several decision-support tools, including NGSAM and START, to assist in developing and managing an integrated waste management system. NGSAM is an agent-based discrete event simulation tool designed for modeling the evolution and fate of SNF from its site of origin at a nuclear power plant to a disposal site. START is a web-based application that utilizes geographic information systems technology to represent transportation network operations as well as proximate features, such as tribal lands, emergency response capability, schools and environmentally sensitive areas.

The NGSAM tool allows analysts to add, remove, and modify model logic and analyze a wide range of integrated waste management system configurations, approaches, and scenarios. NGSAM reference data are obtained from the Used Nuclear Fuel–Storage, Transportation & Disposal Analysis Resource and Data System (UNF-ST&DARDS), another DOE-NE funded system tool, and the DOE Spent Fuel Database, which is funded by DOE-EM and is the definitive database for DOE SNF quantities and characteristics.

The Board commends DOE for advancing development of NGSAM and adding the capability to model DOE SNF at an individual fuel element level, and HLW. NGSAM analyses of packaging scenarios of the numerous types of DOE SNF at Idaho National Laboratory, which will require four different waste packages and eight internal basket configurations,[29] could provide additional insights about packaging DOE SNF in multi-purpose canisters to meet a 2035 deadline to remove SNF from Idaho. Expanded NGSAM capabilities for analyzing repository operations could provide insights to help DOE-NE better understand how repository operations, including

[27] U.S. Nuclear Regulatory Commission. 2007. *A Pilot Probabilistic Risk Assessment of a Dry Cask Storage System at a Nuclear Power Plant*. NUREG-1864. Washington D.C. March.

[28] EPRI. 2004. *Probabilistic Risk Assessment (PRA) of Bolted Storage Casks Updated Quantification and Analysis Report*. Technical Report 1009691. Palo Alto: Electric Power Research Institute. December.

[29] NWTRB. 2017. *Management and Disposal of US Department of Energy Spent Nuclear Fuel*. Arlington, Virginia: U.S. Nuclear Waste Technical Review Board. December.

the rates of waste handling and emplacement, could impact overall waste management system operations and costs. DOE has focused on developing NGSAM capabilities, such as the capability to model individual elements of DOE SNF, but less so on NGSAM analyses and evaluations of various packaging/repackaging options, such as direct disposal of DPCs. While DOE has examined some cases which compared repackaging all DPCs to scenarios where standardized transportation, aging and disposal canisters are introduced in the future, DOE has not directly compared direct disposal of DPCs to repackaging options using NGSAM.

DOE has used outputs from NGSAM in multi-objective evaluation framework (MOEF) analyses. MOEF is a set of capabilities, methods, processes, and tools that provide a means to evaluate alternative scenarios and system architectures for an integrated waste management system where there are multiple conflicting objectives and differing stakeholder perspectives on a proposed waste management system.[30] DOE has supported MOEF analyses in the past and DOE may restart MOEF research depending on funding and program direction. The Board notes that by utilizing appropriate social science/behavioral science/public health expertise, DOE could develop a program that would include input from stakeholders on NGSAM capabilities and waste management scenarios to be analyzed that could inform their participation in a consent-based siting process.

- *The Board finds that there is value in expanding NGSAM capabilities and analyses to more completely address possible integrated waste management systems options and in renewing the development of MOEF as a part of understanding and addressing stakeholder objectives in support of consent-based-siting activities.*

  The Board recommends that DOE expand NGSAM capabilities and analyses to better address disposal of DPCs, including waste packaging operations and cost requirements, and that it include stakeholders involved in the consent-based siting process to inform NGSAM development and use.

DOE has made significant advances with the START tool, and DOE's continuous improvement and verification and validation efforts are positive. START includes a considerable amount of information that could be useful in familiarizing and training emergency response personnel for nuclear waste transport (e.g., where Transportation Emergency Preparedness Program trained personnel are located, where fire departments and healthcare facilities are based, sites of potential temporary evacuation or mass care, critical infrastructure locations, etc.). The Board commends DOE for beginning to communicate with and arrange training for local, state, and Tribal groups regarding START. The Board observes that other federal agencies use other transportation planning tools and have information that may allow DOE to gain insights for additional START development. DOE could learn how other agencies incorporate hazards, for example the effects of extreme/seasonal weather and climate change, and whether use of the other transportation tools with relevant stakeholders could inform DOE's outreach efforts with START.

[30] NWTRB. 2019. *Preparing for Nuclear Waste Transportation–Technical Issues that Need to be Addressed in Preparing for a Nationwide Effort to Transport Spent Nuclear Fuel and High-Level Radioactive Waste*. Arlington, Virginia: U.S. Nuclear Waste Technical Review Board. September.

- *The Board finds that there are additional opportunities for developing and using START as a training tool and to improve outreach using the knowledge bases of other agencies.*

  The Board recommends that DOE consider how START might be utilized as a resource to familiarize and train emergency response personnel for nuclear waste transport and as a component in tabletop exercises aimed at exploring emergency scenarios. Likewise, the Board recommends that DOE engage with other agencies involved in similar transportation efforts to leverage their experiences and approaches to stakeholder interactions and addressing hazards.

DOE's Consent-Based Siting Process for Federal Interim Storage Facilities

The Board again commends DOE for starting a new effort on consent-based siting and for recognizing the crucial importance of effective risk communication, full public engagement, and inclusiveness in the siting process. The Board appreciates the stated commitment to transparency, openness, and effectively engaging stakeholders, including historically underrepresented communities, in any consent-based siting process. At the same time, based upon what the Board heard in the March meeting, the Board notes that DOE already appears to be facing some significant difficulties early in the process. DOE does not appear to have effectively broadened its outreach to engage a larger number and broader range of participants. Although several Tribal organizations are engaged, DOE does not appear to have met its stated aim of tapping perspectives from diverse populations, and from organizations representing minority communities and underserved populations. More efforts to understand past initiatives (e.g., DOE's deep borehole demonstration project that was terminated in 2017) and the details and distinctions of consent-based siting in the international programs, particularly the differences between what is happening on consent-based siting in Sweden and Finland vis-à-vis France and Switzerland[31] could inform DOE's development of its consent-based siting process.

- *The Board finds that there are additional actions that DOE could take to meet its stated commitments, learn from domestic siting experiences and from siting processes in other nations, and strengthen its overall consent-based siting effort.*

  Although the Board applauds DOE for undertaking significant consent-based siting activities, the Board recommends that DOE significantly strengthen and improve its efforts. A larger and broader range of participants should be engaged, and expanded efforts to include historically underrepresented communities should be undertaken. DOE should also make systematic use of the large body of scientific and technical literature in such fields as the social/behavioral sciences and the public health sciences. By informing all consent-based siting efforts with relevant outside scientific/technical knowledge and expertise on risk communication, risk perception, effective outreach, inclusiveness, and public engagement, DOE can identify ways to engage a broader range of participants, better understand public views and concerns, and improve the overall effectiveness and face validity of its consent-based siting work. The Board also recommends that DOE produce a candid "lessons

[31] In Finland and Sweden, interim storage and final repositories are in communities where they have nuclear power already. In France and Switzerland, potential repository sites are in locations where there is not anything nuclear in the community.

learned" document on its deep borehole demonstration siting effort and review key lessons that have been learned from siting processes in other nations.

The Board held a fact-finding meeting with DOE on April 22, 2022, to obtain more information on DOE's consent-based siting efforts. The Board and DOE discussed the results from the RFI and how DOE may apply the results to inform and shape its planned funding opportunity announcement. The discussion also included DOE's efforts to develop the necessary in-house expertise to support the consent-based siting effort and extend its outreach to a larger public audience. The Board appreciates DOE's flexibility and support for a fact-finding meeting so soon after the public meeting.

Thank you again, on behalf of the Board, for the participation of DOE-NE staff and technical experts from the national laboratories at our March meeting and in the subsequent fact-finding meetings. We look forward to continuing our ongoing review of DOE's technical activities related to managing and disposing of SNF and HLW.

Sincerely,

{Signed by}

Jean M. Bahr
Chair

cc: Mr. William (Ike) White, DOE-EM
Dr. Kimberly Petry, DOE-NE
Dr. William Boyle, DOE-NE
Dr. Erica Bickford, DOE-NE