



Department of Energy
Washington, DC 20585

June 8, 2022

Dr. Jean M. Bahr
Chair
Nuclear Waste Technical Review Board
2300 Clarendon Boulevard, Suite 1300
Arlington, Virginia 22201

Dear Dr. Bahr:

The U.S. Department of Energy (DOE) appreciates your April 2021 report to the Congress of the United States and the Secretary of Energy which provided the Board members' synthesis of their reviews of DOE's activities related to the management and disposal of spent nuclear fuel and high-level radioactive waste.

The report provides six overarching recommendations (and 27 associated action items) in several areas, including the design and effective operation of an integrated nuclear waste management program, guidance on creating a more effective and rigorous science and engineering program, and building public trust and international engagement to foster success. The Board stated that the "progress the nation is making in developing its waste management capability, as well as public and stakeholder acceptance, could be improved with regard to both timeliness and effectiveness by adopting these recommendations as core principles of the nuclear waste management program." DOE agrees with the Board that some of the action items identified require contributions from entities that are beyond DOE's control and require both authorization and appropriations by Congress.

Enclosed are DOE's responses to the six recommendations and associated action items. In general, there are existing activities in progress that address many of the Board's actions items. However, there are additional actions that could be taken and will be considered for future implementation. These are identified as "Relevant Existing Activities" and "Potential Future Actions" in the Enclosure.

DOE appreciates the Board's input to our program and looks forward to continued input and insight from the Board on DOE's activities related to the management and disposal of spent nuclear fuel and high-level radioactive waste. If you have any questions, please feel free to contact me or Kimberly Petry, Deputy Assistant Secretary for Spent Fuel and Waste Disposition, at (301) 903-5685.

Sincerely,

A handwritten signature in black ink that reads "Kathryn Huff".

Dr. Kathryn Huff
Assistant Secretary
for Nuclear Energy

Enclosure



**Department of Energy (DOE) Response to the
Nuclear Waste Technical Review Board (NWTRB) Report
to the U.S. Congress and the Secretary of Energy**

**“Six Overarching Recommendations for How to Move the Nation’s Nuclear
Waste Management Program Forward” (April 2021)**

The DOE’s responses to the six recommendations and associated action items are listed below. In general, there are many DOE activities that were already in progress that address the Board’s action items. However, there are additional actions that will be considered for future implementation that may more fully address the action items. These are identified as “Relevant Existing Activities” and “Potential Future Actions” in the response below.

1) NWTRB Recommendation #1: Ensure an Integrated Organizational Approach

a) *NWTRB Recommended Action Item 1a: Foster broader sharing of information among DOE offices, national laboratories, and contractors (e.g., university researchers supported by Nuclear Energy University Program grants).*

i) Relevant Existing Activities:

- Multiple laboratories work together to develop the Integrated Priorities List (IPL), as well as to coordinate program management and execution.
- Work packages that involve contributions from multiple laboratories have monthly status meetings with contributing labs to enable effective integration of activities across the laboratories.
- Technical Research & Development (R&D) projects are actively integrated across national laboratories and other DOE offices, with applicable developments and results presented at numerous domestic and international conferences each year.
- Weekly meetings are held to discuss management integration.
- Dozens of publicly available milestones/reports are published each year. Additionally, internal-use-only work is also shared as appropriate within controlled groups. Public reports are available from either the DOE website or the DOE Office of Scientific and Technical Information (OSTI) database. In addition, The DOE Office of Spent Fuel and Waste Disposition (SFWD) milestone reports are archived in Sharepoint databases (public and non-public reports) within the Sandia National Laboratories (SNL) External Collaboration Network (ECN) accessible to SFWD staff and external individuals with an account.

ii) Potential Future Actions

- Expand tools such as the Used Nuclear Fuel – Storage, Transportation & Disposal Analysis Resource and Data System (UNF-ST&DARDS) ¹, incorporating the latest GC-859 information in the Unified Database (UDB) and the Next Generation System

¹ UNF-ST&DARDS = Used Nuclear Fuel-Storage, Transportation & Disposal Analysis Resource and Data System

Analysis Model (NGSAM) to include other DOE-managed spent fuel and high-level waste.²

- Establish an outward-facing document archive in FY2022; the archive could be similar to CURIE³.
- Expand the SFWD seminar series to include broader audiences.

b) ***NWTRB Recommended Action Item 1b:*** *Further enhance integration of R&D programs executed by DOE's Office of Environmental Management (DOE-EM), Office of Nuclear Energy (DOE-NE), and other DOE offices to optimize collaboration, minimize duplication, and maximize the effectiveness of the effort.*

i) Relevant Existing Activities:

- Integration of scientific R&D occurs regularly within and across the National Laboratories through execution of collaborative projects. For example, Oak Ridge National Laboratory (ORNL), Argonne National Laboratory (ANL), Pacific Northwest National Laboratory (PNL) and Sandia National Laboratories (SNL) collaborated to provide input to ARPA-E⁴ for its workshop on advanced reactors in December 2020. ARPA-E has hosted additional coordination events (including workshops, industry days, meetings), where national labs, NE, EM, and the National Nuclear Security Administration (NNSA) have been invited to comment on program development and areas of technical and programmatic coordination.
- Staff from multiple laboratories support a range of programs for several DOE energy and science offices. The knowledge and experience gained in those programs can be leveraged to support SFWD objectives.
- The Disposal Research International Activities Program collaborates actively with science-based R&D disposal programs around the world.
- SFWD engages in direct communication with the other DOE-NE offices as well as with the DOE's Office of Environmental Management (DOE-EM), e.g., through DOE's Spent Nuclear Fuel Working Group, to discuss or collaborate on a variety of topics including:
 - Considerations for advanced fuels/reactors
 - Potential changes to High-Level Waste (HLW) glass compositions
 - Development and maintenance of DOE O 460.2B⁵
 - Operation of the National Transportation Stakeholders Forum (NTSF), primarily through conferences and webinars
 - Standard Canister design work

² These tools are currently used by NE to better understand the spent fuel component of the integrated waste management system.

³ CURIE = Centralized Used-Fuel Resource for Information Exchange. CURIE is an information-sharing website, accessible to federal and laboratory partners, as well as other stakeholders that provides usable, collaborative document and data access. CURIE helps users find resources, upload documents, and work more efficiently.

⁴ ARPA-E = Advanced Research Projects Agency - Energy

⁵ DOE O 460.2B = DOE Transportation Order for Departmental Materials Transportation & Packaging Management

- The Hanford Lead Canister Project⁶
 - The DOE Spent Nuclear Fuel (SNF) Packaging Demonstration
- Under the auspices of the DOE Spent Nuclear Fuel Working Group (SNFWG), DOE is integrating development of packaging and processing technologies not only to address aging SNF and SNF facilities but also to facilitate a seamless transition from DOE-regulated SNF management to an NRC-regulated nuclear waste management environment
 - SFWD is contributing to development of fully remote Cold Spray Coating (CSC), Friction Stir Processing (FSP), and Friction Stir Welding (FSW) for small diameter standardized canisters which could be used on DOE Standard Canisters, and which could also be slightly modified to include Multi-Canister Overpacks (MCOs). The specific use cases are being considered are part of the DOE SNF Packaging Demonstration.
 - SFWD collaborates with Energy Information Administration (EIA) on the Nuclear Fuel Data Survey Form GC-859 data collection process.
 - SFWD has been expanding the Next Generation Systems Analysis Model (NGSAM) to be able to explicitly model individual assemblies of non-commercial SNF.
- ii) Potential Future Actions
- In FY2022, SFWD will enhance collaboration with the DOE Office of Nuclear Fuel Cycle and Supply Chain (NE-4) and the DOE Office for Reactor Fleet and Advanced Reactor Deployment (NE-5) to address SNF and HLW waste management challenges from advanced reactors.
 - Opportunities exist for additional integration through collaborations on subsurface characterization and modeling efforts. Specific opportunities include projects that utilize underground research labs (URLs) across the world.
- c) ***NWTRB Recommended Action Item 1c: Find ways to work with utilities, cask vendors, fuel manufacturers, and others in the nuclear industry in an ongoing manner, to more effectively develop and implement the nuclear waste management program.***
- i) Relevant Existing Activities:
- The SFWD Program actively collaborates with nuclear industry organizations including utilities, cask manufacturers, fuel vendors, and others (e.g., Orano (formerly Transnuclear Inc.), Dominion Energy Virginia, Orano (formerly AREVA), Framatome (formerly AREVA), Westinghouse, NAC International, the Electric Power Research Institute (EPRI), and the Nuclear Energy Institute (NEI). The SFWD Program also coordinates with the U.S. Nuclear Regulatory Commission (NRC) and international nuclear agencies on a variety of research activities related to storage, transportation, or disposal of SNF. Examples include:

⁶ This collaborative project seeks to transfer Cs/Sr capsules from the Waste Encapsulation and Storage Facility (WESF) into dry storage.

- The Canister Deposition Field Demonstration to run a field-based controlled study to measure the deposition of corrosive species (chloride salts) from marine coastal ambient air onto prototypic spent nuclear fuel (SNF) canisters.
- The large scale, long term, dry storage cask research and development project for spent nuclear fuel. That is the High Burnup (HBU) demo cask, currently on the pad at Dominion's North Anna storage facility, and the associated post-irradiation testing/characterization of the HBU fuel rods (sibling pins).
- Studies of Dual-Purpose Canister (DPC) direct disposal evaluating various processes including potential future basket/neutron absorber modifications. Associated corrosion testing of advanced neutron absorbers to gain knowledge in "other" repository environments to inform absorber selection. External review of the DPC studies includes industry staff.
- Rail Car Optimization
- The Studsvik Cladding Integrity Project (SCIP-IV) on SNF characterization/testing, the 1/3-scale drop test at the German Federal Institute for Materials Research and Testing (Bundesanstalt für Materialforschung und-prüfung, or BAM) facility in Germany, and the multimodal transportation test with the Korea Atomic Energy Research Institute (KAERI) of the Republic of Korea and ENSA (Equipos Nucleares S.A) of Spain.
- SFWD partners with EPRI for development of the Used Nuclear Fuel (UNF) standards and technology transfers.
- The GC-859 web-based application development effort is being conducted to allow utilities to easily provide information on spent fuel, and plans to incorporate their feedback based on pilot testing the application.
- SFWD collaborates with utilities to perform on-site and near-site transportation infrastructure evaluations.
- SFWD collaborates with the cask vendors on cask/canister-related data collection.
- SFWD collaborates with the railroad industry on the Association of American Railroads (AAR) Standard 2043 for railcar design and testing.

ii) Potential Future Actions:

- Work with vendors to develop "universal" transportation casks.
- As planned, support the 2022 NEI Used Fuel Conference.
- Possibility of future collaboration between DOE and cask vendors (and NRC) on a full-scale rail-sized cask package performance study.
- Collaborate with NEI and cask vendors on their performance margin-related efforts.
- Collaborate with utilities and cask vendors on developing dry cask loading that will support direct disposal.
- Collaborate with cask vendors in the areas of additive manufacturing of basket/canister/cask.

d) ***NWTRB Recommended Action Item 1d: Find additional innovative ways of information sharing through DOE-led conferences or workshops that might encourage the different entities in the implementation matrix in Table 3-1 to improve communications and engagement.***

i) Relevant Existing Activities:

- Leading the development of the 2022 International High Level Waste Conference. Note that Sylvia Saltzstein (SNL) is the General Chair and both Rob Howard (PNNL) and Brady Hanson (PNNL) are technical program chairs.
 - Funded the National Academy of Sciences (NAS) Study on Waste Aspects of Advanced Reactors.
 - Annual SFWD meeting with industry/vendor/university/other agency collaborators.
 - Leading the international DECOVALEX (DEvelopment of COupled Models and their VALidation Against EXperiments in Nuclear Waste Isolation) model validation initiative, which holds regular workshops twice a year.
- ii) Potential Future Actions:
- Reconstitute and support the Ad Hoc Working Group on Transportation Communications.
 - Develop plenary presentations for the 2022 National Transportation Stakeholders Conference.

2) NWTRB Recommendation #2: Anticipate Required Infrastructure and Personnel Needs

a) ***NWTRB Recommended Action Item 2a: Develop and communicate an integrated plan regarding physical infrastructure, information technology, and personnel needs over the next decade.***

i) Relevant Existing Activities:

- SFWD Knowledge Management (KM) activities are directly related to preserving and making available to DOE-NE and associated Labs existing critical knowledge and information, including the tacit knowledge of individual staff members, for training, development, and succession planning of more junior staff.
- The SFWD cloud-based information technology (IT) platform is capable of supporting a full-scale generic nuclear waste management program with applications to support organizational and quality assurance (QA) requirements. This cloud-based solution could facilitate fully integrated program-wide collaboration with the ability to communicate and share easily between multiple remote locations and multiple participating parties. A sample of capabilities includes email, teleconferencing, document/records management, project management, data storage, legacy applications, and a project portal.
- A pilot program for development of geoscience expertise was initiated in fiscal year 2022 to educate, attract, develop and train early-career scientists to build a diverse next-generation workforce for disposal research in the U.S.

ii) Potential Future Actions

- Create a deliverable in FY2022 related to creation of a draft integrated plan.⁷

b) ***NWTRB Recommended Action Item 2b: Formulate and implement research programs and other supporting infrastructure consistently to anticipate the effects of aging of facilities***

i) Relevant Existing Activities:

⁷ DOE will likely need to develop a separate document for federal staffing needs.

- SFWD has several ongoing activities to address this sub-recommendation, for example:
 - Active R&D on aging of commercial SNF (CSNF) canisters at storage sites, including potential changes to the stored CSNF.
 - The high burnup (HBU) demo canister is a long-term test (fielded at North Anna facility) to study aging of stored HBU SNF.
 - The Canister Deposition Field Demonstration in the Spent Fuel and Waste Science and Technology (SFWST) R&D program has acquired and is instrumenting storage canisters for the Canister Deposition Field Demonstration.
 - SFWD has supported several DOE Nuclear Energy University Program (NEUP)-funded Science & Technology projects. Examples include the Hanford Lead Canister project, Cold Spray Coating (CSC) and Friction Stir Welding (FSW).
 - SFWD is developing railcars (Cask railcars, a buffer railcar, and a rail escort vehicle) all of which are designed for 50-year service lives from the time of manufacture.
 - SFWD has studied the transportation infrastructure at and near to utility sites that will be the origin points for the transportation system with an understanding that local infrastructure may change over time, so there is a focus on major thoroughfares which not likely to change (mainline railroads, interstates, and navigable waterways) in our transportation planning activities.
- c) ***NWTRB Recommended Action Item 2c: Develop and maintain the capability to utilize DOE's leading-edge, high-performance computing (HPC) resources for the analysis and simulation of processes and systems related to the back-end of the fuel cycle.***
- i) **Relevant Existing Activities:**
- The SFWST campaign utilizes HPC for the Geological Disposal Safety Assessment (GDSA) Framework⁸. The GDSA is used for system analyses as well as for subsystem work. Both the systems models and subsurface analyses (including uncertainty quantification and sensitivity analyses) rely on access to HPC resources, though they can be executed on less powerful platforms.
- ii) **Potential Future Actions:**
- High performance computing can be applied to the Used Nuclear Fuel-Storage, Transportation & Disposal Analysis Resource and Data System (UNF-ST&DARDS)⁹/COBRA-SFS¹⁰.
 - Collaborate with the National Laboratories to apply their HPC capabilities to data analytics, data visualization, machine learning, and artificial intelligence.

⁸ GDSA Framework (<https://pa.sandia.gov>) is an open-source software framework developed to leverage the US DOE's high-performance computing (HPC) resources. The availability of this unique computing capability enables appropriately detailed modeling of the coupled physical and chemical processes affecting repository evolution and radionuclide transport, implementation of model domains with geologic fidelity, forward simulation over the 10⁴- to 10⁶-year timescale typically required by regulation, and propagation of uncertainty over many realizations of the problem.

⁹ ST&DARDS is thermal hydraulics code developed for steady-state and transient analysis of multi-assembly spent-fuel storage and transportation systems

¹⁰ COBRA-SFS is a module within ST&DARDS that is devoted to spent fuel package thermal analysis. It is a thermal-hydraulics code developed for steady-state and transient analysis of multi-assembly spent-fuel storage and transportation system.

d) **NWTRB Recommended Action Item 2d:** *Develop infrastructure for and implement data management systems that can meet the needs for long-term and efficient retrieval of information from current and, to the extent possible, previous relevant R&D programs.*

i) Relevant Existing Activities:

- The SFWD Cloud Project has migrated all the key project applications and their functionality and document collections from previous active nuclear waste disposal programs to an integrated cloud platform. The migrated information includes all materials pertaining to the technical and regulatory aspects associated with licensing a facility. This action preserves and facilitates efficient utilization of information related to that program. In addition, the cloud project provides a platform that enables the same capabilities to operate under a future nuclear QA program.
- SFWD Knowledge Management (KM) activities are directly related to preserving and making available existing critical knowledge and information, including the tacit knowledge¹¹ of individual personnel, to train and develop more junior staff, as well as to conduct succession planning.¹² A taxonomy developed on the knowledge base of nuclear waste management has been implemented to tag this content with metadata facilitating enhanced search for the database user.

e) **NWTRB Recommended Action Item 2e:** *Address the challenges of an aging workforce by expanding mentorship of a new generation of staff through: technical training programs; more effectively targeting undergraduate scholarships, graduate fellowships, and post-doctoral fellowships in areas of need; establishing internships at underground research laboratories (URLs); and promoting careers in nuclear waste management as an opportunity to address this grand environmental challenge.*

i) Relevant Existing Activities:

- National Laboratories supporting SWFD have developed internal programs for succession planning.
- SFWD has a pilot program for more active recruitment of junior geoscience personnel into the disposal research (DR) field. This pilot program for workforce development leverages the International Activities and the Geologic Disposal System Analyses (GDSA) activities to encourage student and post-doc involvement to grow a more diverse workforce.¹³
- Senior- and mid-career staff commonly serve as Control Account Managers (CAMs) while early-career staff serve as work package managers (WPMs).
- When appropriate, senior- and mid-level staff are actively paired with junior-level staff on projects to facilitate knowledge transfer and promote staff development.
- Funding of dozens of NEUP projects annually includes technical points of contact assigned from SFWST junior- through senior-level technical staff.

¹¹ *Tacit knowledge* can be defined as skills, ideas and experiences that are possessed by people but are not codified and may not necessarily be easily expressed. With tacit knowledge, people are not often aware of the knowledge they possess or how it can be valuable to others.

¹² The KM Repository is designed to contain the multimedia datasets of many types and to make them easy to retrieve and use in multiple manners that are preferred by different users.

¹³ The Workforce Initiative would focus on underrepresented groups and collaborate with minority-serving institutions.

- SFWD has recently hired and begun mentoring new technical staff to cover anticipated near-term and longer-term needs, including management of research work in the area of integrated waste management systems involving advanced reactor types, and consent-based siting.
- ii) Potential Future Actions:
- SFWD will consider more active involvement with universities to prepare the next generation of researchers and engineers.
 - SFWD plans to continue hiring new federal staff in FY22 to support new program areas and cover program areas where retirements are anticipated.
- 3) **NWTRB Recommendation #3: Expand the Research Paradigm to Embrace Hypothesis Testing**
- a) ***NWTRB Recommended Action Item 3a: Anticipate surprises or unexpected results that may arise during the R&D program and assure all research programs include ample provisions to accommodate possible changes in direction and focus.***
- i) Relevant Existing Activities
- The SFWD research approach is aligned with this associated action item. Modeling and testing work includes hypothesis testing and provides for the possibility of unexpected results and changes in direction. For example:
 - The HBU demo cask testing work (and sibling pins characterization testing) was analyzed with thermal models prior to the setting up the demo cask at the North Anna facility. The thermal models were benchmarked against the thermal testing facility-controlled experiments. The data collection in the test resulted in key refinements to specific modeling constraints such as thermal boundary conditions and heat transfer characteristics that improved the accuracy of the models.¹⁴
 - The results from the above example as well as other storage and transportation (S&T) testing (e.g., the international multi-modal transportation test) have been used to revise the gap analyses and reprioritize the R&D programs.
 - Within Disposal Research (DR), models of bentonite buffer are corroborated and/or adjusted as needed based on results from field-scale tests and laboratory experiments.
- b) ***NWTRB Recommended Action Item 3b: Test alternative hypotheses using careful experimental design over multiple scales from laboratory to full-scale in-situ tests in a URL.***
- i) Relevant Existing Activities
- The SFWD research approach is aligned with this associated action item as is our fundamental approach to the coupling of modeling and testing. Tests are performed from laboratory- to field-scale throughout the R&D activities. Specific examples include:
 - Field-scale S&T work on the North Anna HBU demo (refer to 3a for additional information) with coupled testing of sibling pins and thermal modeling. All of

¹⁴ Ultimately this approach led to the understanding that prior models overestimated peak cladding temperatures of fuel rods within the canisters and provided an improved basis for assessing evolution of stored CSNF.

this work demonstrated conservatism of previous estimates and resulted in modification of thermal modeling approaches.

- The Brine Availability Test in Salt (BATS) (refer to 3d, 3e and 5ai for additional information) is the field-scale component of the Salt R&D program, which includes laboratory testing, coupled process modeling (e.g., TH, THM¹⁵), and refinement of constitutive models using all of the above to provide GDSA the bases and models for system-scale analyses.
- Testing on natural and engineered barriers, including different host rocks, bentonite buffers and cementitious materials, occurs from small-scale in the laboratories to field-scale measurements and long-term tests in international URLs. Processes are evaluated with models from the molecular-scale to the drift scale to evaluate model concepts and scaling issues.

c) **NWTRB Recommended Action Item 3c:** *Continue to make new measurements to build a database that tests the abilities of existing models to capture important processes and evaluate the possible need for new conceptual models to improve estimates of system properties and thus prediction accuracy.*

i) Relevant Existing Activities:

- The SFWD research approach is aligned with this associated action item as is our fundamental approach of the coupling of modeling and testing throughout the R&D activities.
- Each technical R&D area has various principal-investigator-created/managed databases utilized to test models and improve representations, for example:
 - Sandia and Lawrence Livermore National Laboratories manage thermochemical data obtained during geochemical studies and modeling.¹⁶
 - Argonne National Laboratory has constructed data sets for SNF characteristics to use for testing models and improving understanding.¹⁷

d) **NWTRB Recommended Action Item 3d:** *Use results of repeated testing of existing and evolving hypotheses to enhance the usefulness of models in performance assessment.*

i) Relevant Existing Actions:

- The SFWD research approach is aligned with this associated action item as is our fundamental approach of the coupling of modeling and testing throughout R&D activities. Examples discussed above include:
 - The HBU demo project on thermal conditions in storage and the evolution of CSNF fuel rods during storage and transportation.
 - The BATS research program conducted in bedded salt in the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico.
 - Research activities in underground research laboratories in our international collaborations as discussed under Recommendation #6 below.

¹⁵ THM = Thermal-Hydro-Mechanical

¹⁶ The geochemical studies and modeling referenced are conducted under the disposal research (DR) program.

¹⁷ The SNF data compilation referenced is conducted under the Science and Technology R&D program.

- The international DECOVALEX Project involves model comparison studies between research teams from multiple organizations for the purpose of hypothesis testing. DOE is a partner in the DECOVALEX Project and the project is chaired by a National Lab scientist.
- e) **NWTRB Recommended Action Item 3e:** *Establish one or more dedicated domestic underground research laboratories that will provide the necessary opportunities for researchers and students to conduct in-situ investigations into sub-surface processes at scale, test models, and further international collaboration.*

i) Relevant Existing Activities:

- SFWD is conducting generic salt R&D testing in the underground at WIPP. This work, known as the Brine Availability Test in Salt (BATS), is evaluating heated salt beds to understand mobilization of brine during thermal perturbations. SFWD staff are leaders in the Nuclear Energy Agency (NEA) Salt Club and the BATS is being used as a data set for international model validation activities. Additional testing expansion is underway in this area.
- Work is ongoing in SFWD to refurbish and utilize a tunnel in unsaturated tuff as a URL for studies on generic unsaturated disposal systems.¹⁸

ii) Potential Future Actions

DOE considers the current utilization of underground research facilities (including the Waste Isolation Pilot Project in bedded salt, and participation with international partnerships such as research in argillite (Mt. Terri in Switzerland) and crystalline media (Grimsel Test Site in Switzerland)) adequate for current research needs. Establishing a dedicated domestic URL is not appropriate at this time, however, as the research program and repository program advances, DOE will consider additional research opportunities as appropriate in the future, such as:

- Supporting the collaborative establishment of a state-of-the-art borehole to advance subsurface science and technology. The borehole laboratory design is a flexible, multi-purpose configuration that enables one or more borehole utilizations for singular or multiple simultaneous experiments to study phenomena at all scales.
- Consider use of the Sanford Underground Research Facility (SURF)¹⁹, URL located in Lead, South Dakota. There is potential to use this full-scale, crystalline rock URL to:
 - Develop and advance technologies for repository characterization that can improve the uncertainty quantification and sensitivity analyses for modeling efforts.
 - Develop and advance technologies for long-term and/or real-time monitoring of waste packages.
 - Design engineered processes and systems for applied energy and national security.

¹⁸ The site infrastructure developments have been delayed by COVID. Planning for tests include underground passive monitoring of site gas movement and Muon detection in the subsurface.

¹⁹ For more information on the SURF URL visit <https://www.sanfordlab.org/>

- Consider support of R&D activities associated with the Deep Vadose Zone (DVZ) Test Site.²⁰

4) NWTRB Recommendation 4: Apply an Iterative, Adaptive Approach in Developing and Managing the Nuclear Waste Management Program.

a) **NWTRB Recommended Action Item 4a:** *Iterate between testing individual components of the nuclear waste management program and testing integrated models of the entire waste management system, always being ready to adapt each approach based on what is learned from such testing.*

i) Relevant Existing Activities:

- This is a core, fundamental process of the coupling of modeling and testing throughout SFWD R&D activities. Please see above examples provided in Recommendation 3 for examples.
- The development of the Geological Disposal Safety Assessment (GDSA) capabilities is inherently an iterative process of continued evaluation, addition, testing, refinement, and reassessment, both for understanding of process representations and for prioritization of next stages of R&D for disposal system analyses.
- Systems analyses using the Next-Generation System Analysis Model (NGSAM), embraces this approach. System model representations of waste acceptance, transportation, storage, and disposal operations are developed iteratively.

ii) Potential Future Actions:

- The GDSA is currently focused on addressing generic repository systems in the SFWD program, but the capabilities are developed in a manner (both technical and documentation) that facilitates utilization in potential future application in other programs that may evolve to more site-specific focus.

b) **NWTRB Recommended Action Item 4b:** *Be open and structured to adapt to surprises during all aspects of the nuclear waste management program and always be willing to reevaluate and rethink previous decisions.*

i) Relevant Existing Activities:

- SWFD is committed to proceeding in a manner that is inclusive, transparent, participatory, and responsive to new information and the suggestions and recommendations of communities, stakeholders, and the public.
- This is a core, fundamental aspect of the coupling of modeling and testing throughout SFWD R&D activities, for example:
 - The HBU Demo cask studies used thermal measurements of a HBU SNF cask to update the understanding of model representations for boundary conditions and other conservative heat transfer process. Updated models led to improved,

²⁰ The DVZ Test Site is leveraged for development and demonstration of advanced monitoring technologies within consolidated and unconsolidated sediments and crystalline rock. The unique characteristics of this area allow for in-depth analysis and learning that can be applied to multiple sites and needs across the country.

more realistic representations and better understanding of the peak cladding temperatures in HBU casks.

In implementing its Strategic Framework for DOE-Managed Spent Nuclear Fuel (June 2021) DOE is reevaluating and validating or modifying, as appropriate, previously made decisions with respect to storage and disposition of DOE-managed SNF.

c) ***NWTRB Recommended Action Item 4c: Establish mechanisms as part of on-going evaluations to facilitate and incentivize solicitation of input and feedback from all affected stakeholders, including: independent scientists and engineers outside of the nuclear waste management program; local, state, and tribal governments; nuclear utilities; and the interested public.***

i) Existing Relevant Activities:

- Integration of inputs/constraints from all relevant sources is a fundamental activity in the coupling of modeling and testing throughout the R&D activities within SFWD.

ii) Potential Future Actions:

- Develop and implement a Strategic and Comprehensive Stakeholder Engagement and Communications Plan that includes mechanisms to facilitate and solicit input from affected stakeholder groups and tribal representatives.

5) NWTRB Recommendation #5: Expand Engagement with the International Community to Benefit from Lessons Learned.

There are four sub-recommendations under Recommendation #5, however because there is an actively integrated collaborative international program, a single response to all four sub-recommendations is provided. The four sub-recommendations for NWTRB Recommendation #5 are as follows:

a) ***NWTRB Recommended Action Item 5a: Build on current initiatives and continue to expand engagement with the international community, recognizing the need for global cooperation in science and technology in this world-wide grand environmental challenge.***

NWTRB Recommended Action Item 5b: Sustain active engagement in international programs given the tangible benefits derived from close involvement.

NWTRB Recommended Action Item 5c: Continue and expand participation in collaborative international underground research laboratory activities. If, as recommended, DOE develops one or more underground research laboratories, it should encourage international participation, which could benefit the DOE program by incorporating broader perspectives and expertise.

NWTRB Recommended Action Item 5d: Emphasize engagement with countries that have advanced to the demonstration and/or construction authorization stages of repository development to enhance knowledge of these stages.

Overall, SFWD believes that focus on international collaboration allows close integration with the international waste management R&D community in terms of best practices, new science advances, state of the art simulation tools, new monitoring and performance confirmation approaches, lessons learned, etc. SFWD has therefore established a broad range of international collaboration activities. The joint R&D with international researchers, the worldwide sharing of knowledge and experience, and the direct access to relevant

data/experiments from a variety of underground research laboratories and host rocks provides an improved understanding of the current technical basis for disposal in a range of potential host rock environments. Comparison with experimental data allows for testing and validating predictive computational models for evaluation of disposal system performance in a variety of generic disposal system concepts. Comparison of model results with other international modeling groups, using their own simulation tools and conceptual understanding, enhances confidence in the robustness of predictive models used for performance assessment. The possibility of linking model differences to particular choices in conceptual model setup provides guidance into “best” modeling choices and understanding the effect of model uncertainty. These outcomes, including improved predictive models and a deep understanding of conceptual model uncertainties, can be directly incorporated into GDSA activities.

i) Relevant Existing Activities:

- SFWD researchers actively participate in numerous international activities. See previous responses for some examples from the Storage and Transportation (S&T) R&D program as well as from the Disposal Research (DR) R&D programs.
- Disposal Research R&D includes projects in URLs from many countries as well as development of domestic URL programs. The SFWD BATS is a U.S.-based field test with international collaboration. Much of this collaborative international work is available in public reports, journal articles, and conference publications.
- SFWD has a balanced portfolio of international collaboration activities in DR and addresses relevant R&D challenges in near-field perturbation, engineered barrier integrity, radionuclide transport, and integrated system analysis. These activities form a central element of SFWD DR programs, and significant advances have been made across different host rock types and engineered barriers.
- SFWD recognizes that international collaboration enables (1) leveraging a deep knowledge base regarding alternative repository environments developed across the world, (2) utilizing international research facilities, especially operating underground research laboratories not available in the U.S., and (3) sharing the cost of major tasks such as full-scale *in situ* experiments or complex modeling efforts.
- SFWD currently has in place formal collaboration agreements with multiple international partners on several international initiatives, including the following:
 - The DECOVALEX Project²¹
 - The Mont Terri Project²²
 - SKB Task Forces²³

²¹ The DECOVALEX project is an international research and model comparison collaboration, initiated in 1992, for advancing the understanding and modeling of coupled thermo-hydro-mechanical-chemical (THMC) processes in geological systems. <https://decovallex.org/>

²² The Mont Terri Project is an international research project for the hydrogeological, geochemical, and geotechnical characterization of a clay formation (Opalinus Clay). Mont Terri is located in Switzerland. <https://www.mont-terri.ch/>

²³ SKB is the Swedish Nuclear Fuel and Waste Management Company that is tasked with finding solutions for the safe management of Sweden’s radioactive waste. The SKB Task Force is an international collaboration that focuses on selecting and

- HotBENT²⁴
- SFWD researchers are conducting several collaborative R&D activities that align with R&D priorities across most of the technical areas discussed in this section. In these collaborations, SFWD scientists contribute world class analyses, models, and data for both process understanding and system risk modeling and assessment (see e.g., Birkholzer and Faybishenko, 2021²⁵).
- Early efforts to develop a consent-based siting (CBS) approach to site a SNF repository and/or interim storage facility were built upon examples, experiences and lessons learned from countries such as Canada, Sweden, and Finland.

6) NWTRB Recommendation #6: Embrace Openness, Transparency, and Engagement

As noted in the 2017 *Draft Consent Based Process for Consolidated Storage and Disposal Facilities for Spent Nuclear Fuel and High-Level Radioactive Waste*, NE is committed to proceeding in a manner that is inclusive, transparent, participatory, and responsive to new information and the suggestions and recommendations of communities, stakeholders, and the public.

a) **NWTRB Recommended Action Item 6a:** *Inform and engage the public and other affected stakeholders early in the planning and review of all aspects of the nuclear waste management program.*

i) Relevant Existing Actions:

- A DOE-NE Request for Information (RFI) was issued in December 2021, that seeks public input on several SFWD programs, including consent-based siting (CBS).
- Much of the collaborative work generated within SFWD is available in public reports, journal articles, and conference publications.
- SFWD and its National Lab partners regularly engage in public conferences and meetings with external entities in industry, regulatory agencies, and academia.
- SFWD funds the Nuclear Energy University Program (NEUP), which has dozens of active projects.
- Stakeholder feedback from earlier consent-based siting (CBS) efforts was a central component of designing the 2017 *Draft Consent-Based Siting Process for Consolidated Storage and Disposal Facilities for Spent Nuclear Fuel and High-Level Waste*. Over 10,000 pieces of correspondence, received by DOE via a variety of mechanisms, were

overseeing specific experiments to be performed at the Äspö Hard Rock Laboratory for parallel modeling by more than one participating team. Currently, the SKB Task Force is focused on two tasks: Task 8 is investigating the interface of engineered and natural barriers, and Task 9 seeks to develop more realistic models of solute flow and transport through fractured rock. <https://www.skb.com/about-skb/our-task/>

²⁴ HotBENT is a collaborative international effort to evaluate the effects of high temperatures on bentonite-based barriers and their safety functions. Field work for HotBENT takes place in Switzerland at the Grimsel Test Site URL. <https://www.grimsel.com/gts-projects/hotbent-high-temperature-effects-on-bentonite-buffers/hotbent-introduction>

²⁵ Birkholzer, J., and Faybishenko, B. 2021. International Collaboration Activities in Geologic Disposal Research: FY20 Progress, Spent Fuel Waste Science and Technology (SFWS), Milestone Report, M2SF-20LB010307012, LBNL-2001433, Lawrence Berkeley National Laboratory, Berkeley, CA USA, 333 pp.

carefully tracked, processed, and summarized using a language processing tool known as the Comment Response Management System (CRMS).²⁶

- SFWD is engaged with Native Americans through the Nuclear Energy Tribal Working Group (NETWG) and the Tribal Radioactive Materials Transportation Committee (TRMTC), and with State governments through four State Regional Groups (SRGs) covering the continental US. SFWD funding to TRMTC and the SRGs supports the operation of their respective committees, as well as participation in DOE's National Transportation Stakeholders Forum (NTSF) and its associated topical ad hoc working groups.
- SFWD has operated multiple NTSF ad hoc working groups comprised of federal, State, and Tribal government representatives to address technical and policy topics related to spent nuclear fuel transport. The NTSF Rail/Routing ad hoc working group has worked with States, Tribes, the US Department of Transportation Federal Railroad Administration, and the railroad industry to understand railroad transport operations, regulatory structures, process for identifying transport routes for hazardous materials, and safety inspection practices. The group is currently collaborating on development of a railcar safety inspection protocol for future DOE shipments of spent nuclear fuel that could enable States and Tribes along a transportation route access to safety inspection information on spent nuclear fuel shipments, and enable an inspection reciprocity arrangement, similar to what is available for highway radioactive materials shipments through the Commercial Vehicle Safety Alliance's Level VI inspection.
- SFWD nuclear power plant infrastructure evaluations include participation from State and Tribal government representatives in the region of a plant to both seek local input and expertise on options and challenges for transporting spent nuclear fuel away from reactor sites as well as lend transparency to DOE's considerations for transport modal options, logistical operations, safety, and security.

ii) Potential Future Actions:

- One or more community Funding Opportunity Announcements (FOAs) may be issued in FY2022. The FOAs will allow communities that are potentially interested in hosting a consolidated interim storage facility (CISF) to apply for funding to learn more and develop outreach and engagement activities of their own.
- DOE plans to create opportunities to discuss the Draft Strategic Plan with stakeholders.
- In FY22, SFWD plans to resume operation of the NTSF Section 180(c) ad hoc working group to continue collaborations with State and Tribal governments and work toward a final Departmental policy for how DOE will provide funds to States and Tribes through whose jurisdictions DOE transports spent nuclear fuel and high-level radioactive waste, consistent with the intent of Section 180(c) of the NWSA.

b) ***NWTRB Recommended Action Item 6b: Be transparent in decision-making and provide support for meaningful stakeholder participation.***

²⁶ The CRMS is a proven and effective knowledge management tool to provide a rapid and effective way to efficiently synthesize public and stakeholder comments at both large scales and broad scopes. It has been used successfully to process tens of thousands of comments, shortening agency response time, while facilitating consistency and ensuring comments and concerns are captured and incorporated into the decision-making process and record.

- i) **Relevant Existing Activities:**
- Senior-level communications and environmental justice (EJ) personnel are being integrated into the design and implementation of a consent-based siting (CBS) process.
 - SFWD is investing in the development of FACET²⁷ and related tools to develop meaningful engagement and outreach opportunities. FACET is a science-based framework for transparently evaluating tradeoffs among complex environmental, economic, and social issues. It offers support for policy and business decisions, resulting in risk-informed, socially equitable, and defensible evaluations for all stakeholders.
- ii) **Future Potential Actions:**
- Restart bi-annual (every 6 months) Transportation Core Group Meetings.
 - Reconvene and support Ad Hoc Working Groups on Transportation Communications.
 - Strive to publicly release all fully developed reports and notify State, Tribal, and federal partners, as appropriate, when they are posted publicly.
 - Design and implement a Comprehensive and Strategic Stakeholder Engagement and Communications Plan (See NWTRB Recommendation #6 opening paragraph, above).
- c) ***NWTRB Recommended Action Item 6c: Take account of lessons learned in other countries about listening to and informing the public, in order to improve communications, better understand community perspectives, and avoid unnecessary delays of the program.***
- i) **Relevant Existing Activities:**
- This recommended action item is aligned with SFWDs path forward on developing an integrated nuclear waste management system that includes a consent-based approach to siting waste management facilities. SFWD has consultants with experience from other nuclear waste management programs such as the Canadian Nuclear Waste Management Organization (NWMO) and plans to seek additional advice and lessons learned from international waste management programs, whenever possible.
- d) ***NWTRB Recommended Action Item 6d: Though not a license requirement for any new site selected for a repository, DOE should develop and make available a clear characterization of the facility early in the process that describes the waste management concept and its multiple barriers and other attributes that contribute to safety. DOE must also clearly acknowledge and communicate its commitment that the safety concept will be revised to update it as new information and input are received.***
- i) **Relevant Existing Activities:**
- This recommended action item is aligned with SFWDs path forward on developing an integrated nuclear waste management system that includes a consent-based approach to siting waste management facilities. Multiple products need to be developed for a wide range of audiences to explain overall waste management system concepts and approaches, facilities, and safety features.

²⁷ FACET = The Framework for Assessment of Complex Environmental Tradeoffs
<https://www.pnnl.gov/projects/environmental-justice/facet>

- e) **NWTRB Recommended Action Item 6e:** *Develop site-suitability criteria prior to the start of site selection so as to minimize any ambiguity and latitude in their interpretation, thus helping to ensure the objectivity of the process and public confidence in its outcome. If, at any point during the siting process, the criteria need to be changed, a transparent and meaningfully participatory process to do so needs to be followed.*
- i) Relevant Existing Activities
- There is discussion of “Siting Considerations” for both repositories and a CISF in the 2017 *Draft Consent-Based Siting Process for Consolidated Storage and Disposal Facilities for Spent Nuclear Fuel and High-Level Radioactive Waste* document.
- f) **NWTRB Recommended Action Item 6f:** *If, as recommended, the United States develops one or more underground research laboratories, these laboratories, in addition to their research function, should be utilized for outreach and public engagement, in order to provide access to the subsurface (a vague concept with the public) and to build public confidence and trust and engineering behind the safety concept, as well as in the operational capabilities for remote handling of waste underground.*
- i) Relevant Existing Actions:
- URL work in the US is currently used for outreach, however the sites themselves have/may have restrictions regarding direct public access.
 - Operational testing for disposal concepts goes well beyond generic disposal system R&D and may not be warranted in the R&D program until further progression into a disposal program timeline. Currently, the international collaboration provides insight into this area for generic disposal system R&D.
- ii) Potential Future Actions:
- If DOE develops a specific underground research laboratory in the future to support repository development, DOE will consider the use of the URL for outreach, public engagement, and for testing operations as recommended.