



U.S. Nuclear Waste Technical Review Board

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# **Management and Disposal of U.S. Department of Energy Spent Nuclear Fuel**

Presented to:  
**Idaho Cleanup Project Citizens Advisory Board**

Presented By:  
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**April 19, 2018  
Fort Hall, ID**

# Independent Federal Agency

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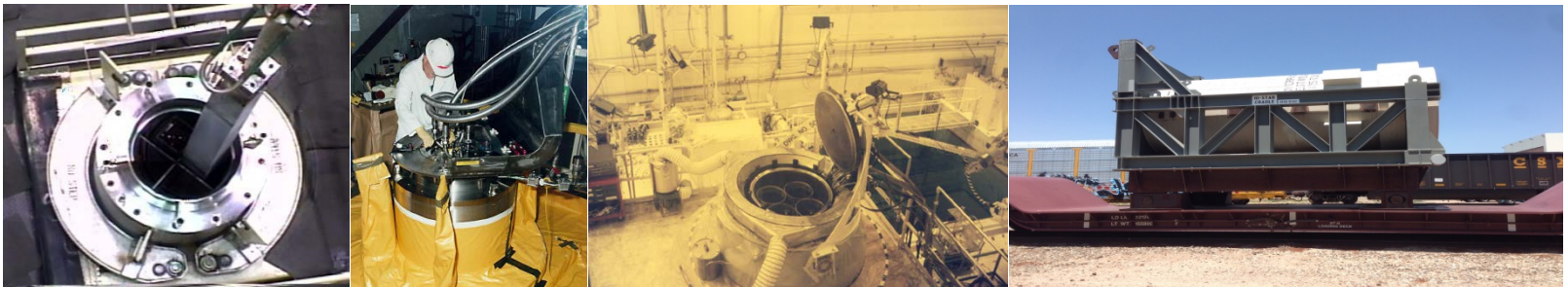
The U.S. Nuclear Waste Technical Review Board (Board) was established by Congress as an independent federal agency in the 1987 amendments to the Nuclear Waste Policy Act (NWPA).



# Board Mission

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- The Board evaluates the “technical and scientific validity” of U.S. Department of Energy (DOE) activities undertaken under the NWPA, including
  - Activities related to the packaging or transportation of high-level radioactive waste or spent nuclear fuel
  - Site characterization, design, and development of a disposal facility for spent nuclear fuel and high-level radioactive waste



# Board Members



NATIONAL ACADEMY  
OF SCIENCES



## The Eleven Board members:

- Are nominated by the National Academy of Sciences based solely on eminence and expertise
- Are appointed by the President
- Serve part time for four-year, staggered terms



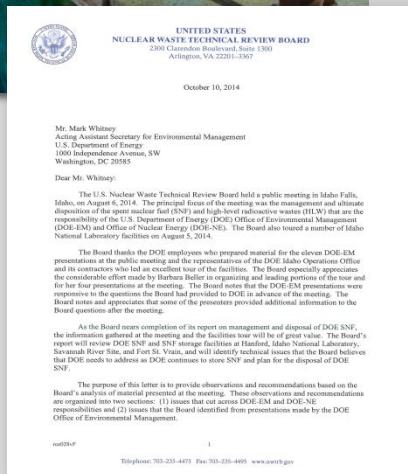
**U.S. Nuclear Waste Technical Review Board**

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# Board Review of DOE SNF

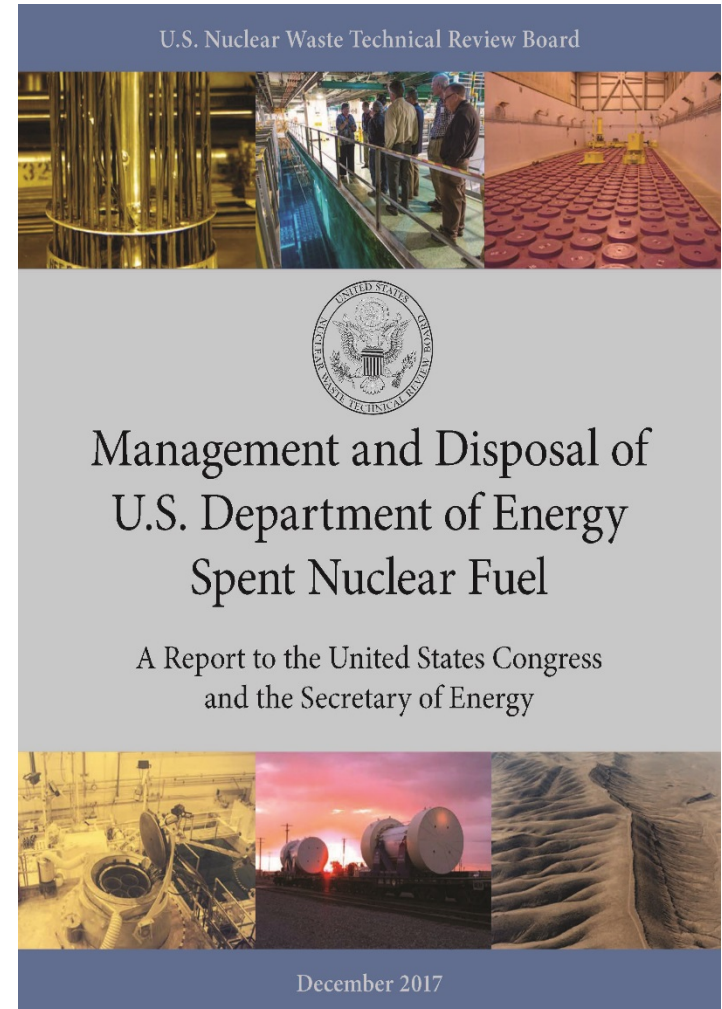


- Multi-year review focused on continued storage of DOE spent nuclear fuel at the surface followed by geologic disposal in a repository
- Public meetings held with DOE and toured DOE spent nuclear fuel (SNF) storage facilities at
  - Hanford
  - Idaho National Laboratory
  - Savannah River Site
- Provided technical and scientific comments in letters to DOE following public meetings



# Board Report

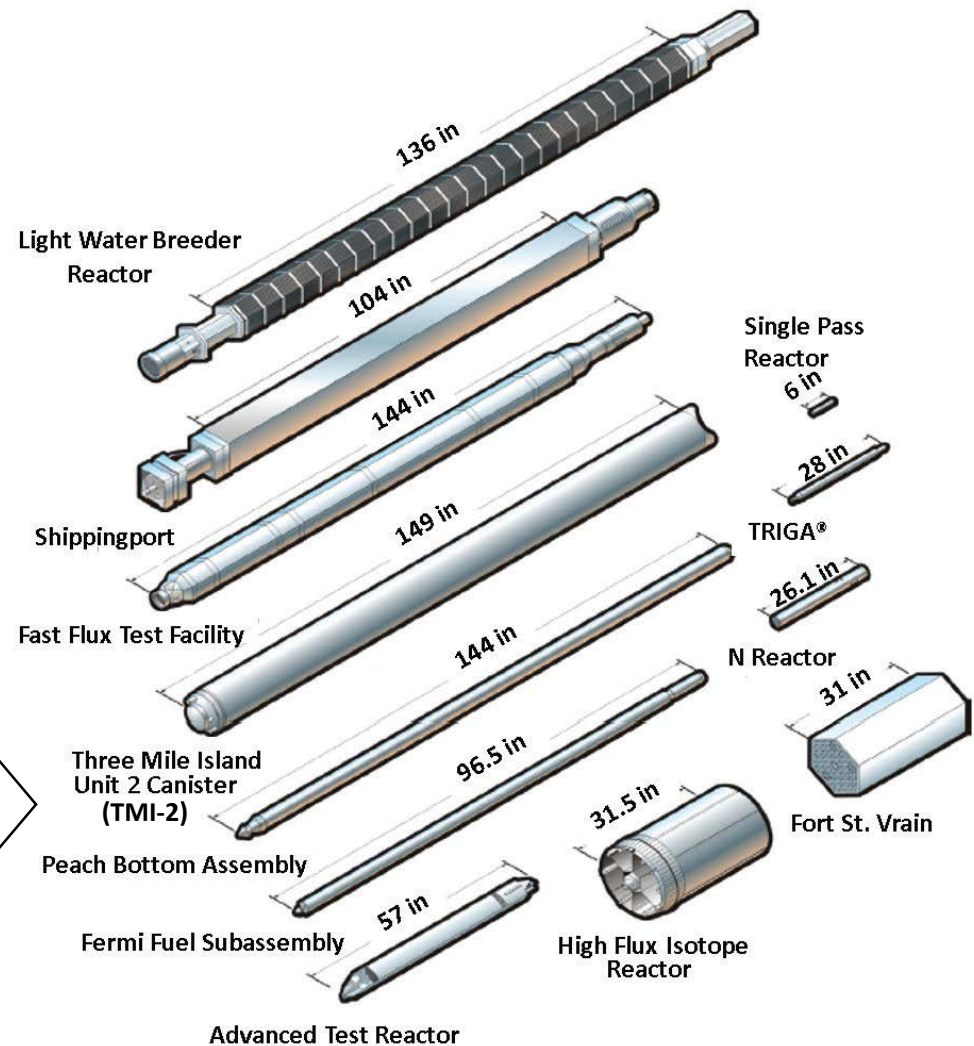
- Examines technical issues related to DOE SNF packaging and storage that might affect continued storage, transportation, and disposal
- Records quantities and characteristics of DOE SNF
  - Hanford, Idaho National Laboratory (INL), Savannah River Site (SRS), and Fort St. Vrain
  - 250 types of fuel
- Analyzes DOE's packaging and storage activities and DOE's plans for management and disposal



# DOE SNF

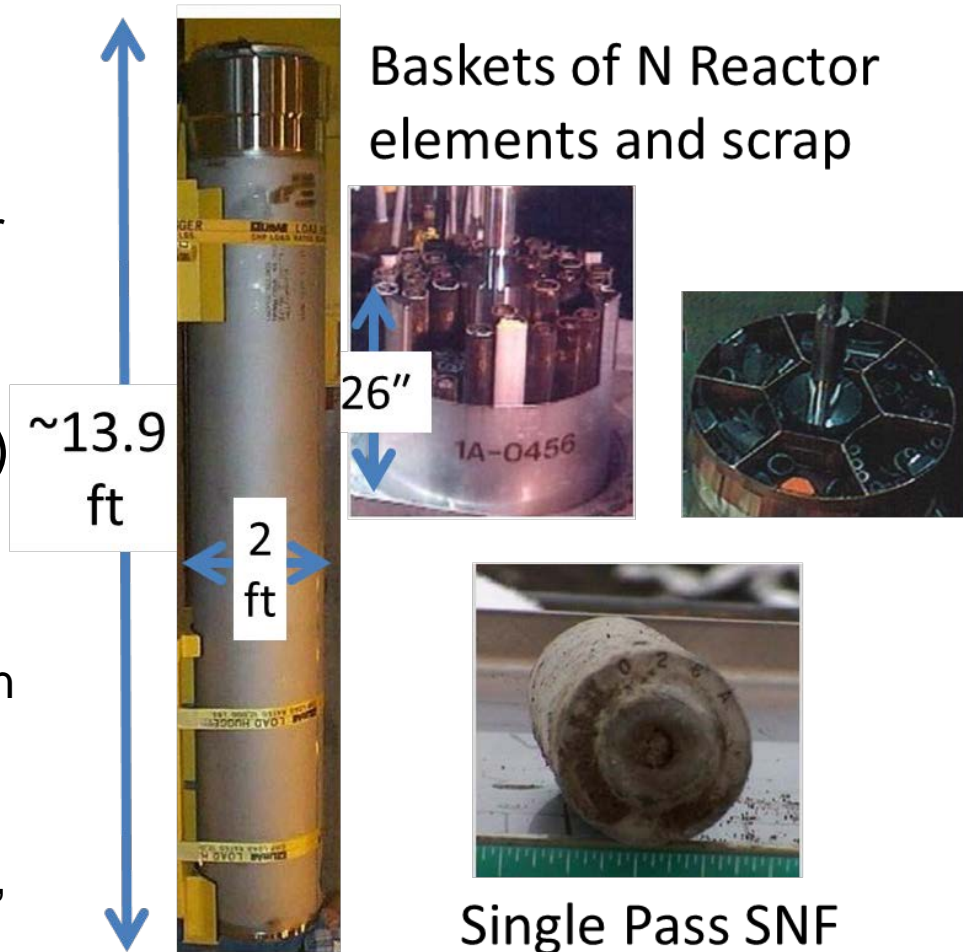
- Approximate mass in metric tons of heavy metal (MTHM) at four sites
  - Hanford – 2,130 MTHM
  - INL – 325 MTHM
  - SRS – 30 MTHM
  - Fort St. Vrain – 15 MTHM

Comparison of size of 12 of the approximately 250 spent nuclear fuel types and their sources



# DOE Packaging Approach

- Multi-purpose canisters (dry storage, transportation, and disposal)
  - 3 different systems developed for different DOE SNF
- Multi-canister overpack (MCO)
  - Used only at Hanford
  - Contains SNF from plutonium-production reactors that had been stored wet for decades
  - Drying and packaging completed
  - 15 of 394 monitored for pressure, temperature, and gaseous constituents





# DOE Packaging (continued)

- Naval canister

- Used at INL for naval SNF
- Packaging ongoing (>100 of 400 completed)
- 2 sizes

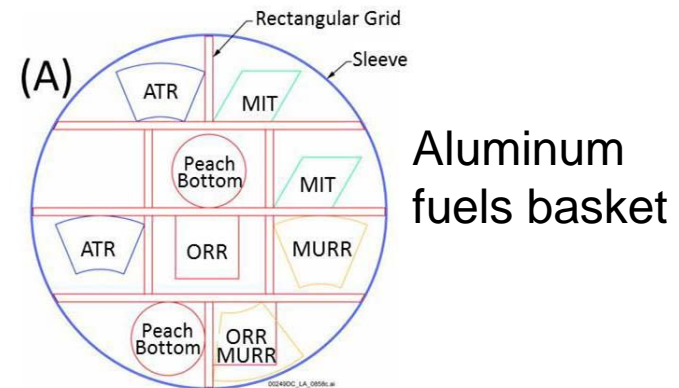
Naval Long SNF Canister  
Height (Nominal): 210.5 in

Naval Short SNF Canister  
Height (Nominal): 185.5 in

Naval SNF Canisters Outer  
Diameter (Nominal): 66.5 in

- DOE standardized canister

- Development stopped before deployment
- For all remaining non-naval DOE SNF (~3,500 packages)
- 2 heights (10 and 15 feet)
- 2 diameters (18 and 24 inches)
- Advanced neutron absorbers
- 8 basket arrangements



# Key Observations on INL

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- DOE is required by the 1995 Settlement Agreement with the state of Idaho to remove SNF from wet storage by 2023, use multi-purpose canisters to prepare SNF for shipment and ultimate disposal outside Idaho, and remove SNF from Idaho by 2035.



# Key Observations on INL

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- DOE will need to build a new facility or reuse an existing one to repackage non-naval SNF into NRC-approved multi-purpose canisters to meet the 2035 deadline for removing INL SNF from Idaho. The throughput capability of the packaging facility is dependent on the ability to retrieve fuel from existing on-site storage locations; the drying time required for the wide range of fuel types, which increases as degradation of the SNF increases; the opening date for a repository or consolidated interim storage facility; and the acceptance rate of the receiving facility.



# Key Observations on INL

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- Managing aging SNF and SNF storage facilities is a common challenge. Both DOE-EM and the Navy identified a need for new facilities, either because existing facilities are at the end of their service lives or because existing capabilities are not sufficient to receive SNF and prepare it for off-site transport. The NRC-licensed dry storage facility at INL, which stores TMI-2 SNF, is subject to a formal program to manage age-related degradation. Other aging management programs focus mainly on storage facility aging and, in general, do not address the effects of aging SNF or the implications of SNF aging for future packaging, storage, transportation, and disposal systems.





# Key Observations on INL

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- DOE is not implementing a multi-purpose canister approach for non-naval SNF and needs to complete development of the DOE standardized canister. The Navy continues to remove naval SNF from wet storage, and dry and package it into the naval canisters that were designed for disposal in the Yucca Mountain repository. In contrast, DOE has stopped developing the DOE standardized canister to store, transport, and dispose of SNF at Yucca Mountain. DOE planned to use this multi-purpose canister at the Hanford Site, INL, and SRS to package all remaining non-naval disposable SNF. DOE will need to finish developing a number of standardized canister components and fabrication methods.



# Key Observations on INL

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- DOE-NE treats sodium-bonded driver SNF by dissolving it in a molten salt medium. This process creates two waste streams (metallic and salt) that are both considered HLW. Because DOE-NE is not a “waste custodian” and, hence, is not subject to the waste acceptance system requirements that apply to all SNF and HLW that will be disposed in a repository, the fate of these waste streams is uncertain.



# Issues Identified

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- Managing the aging of DOE SNF and the facilities in which it is stored
- Packaging of stored non-naval DOE SNF into DOE standardized canisters, a type of multi-purpose (storage, transportation, and disposal) canister system
- The need for disposal-related research on DOE SNF degradation processes **IF** DOE's generic repository research continues



# Aging Management

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- DOE SNF will be stored decades longer than expected
  - Some DOE SNF is already in multi-purpose canisters
  - Plans are to package remaining SNF in multi-purpose canisters
  - DOE SNF is more degraded than commercial SNF
- Wide diversity of fuel types and storage conditions affects aging management efforts
  - Fuel compound (e.g., U metal, U dioxide, Th-U dioxide, Th-U carbide, mixed oxide, and U-aluminum)
  - Cladding composition (e.g., none, stainless steel, zirconium alloy, and aluminum) and condition (good-fair-poor-none)
  - Enrichment of U-235 varies widely (0.2-93%)
  - Storage (wet and a variety of dry storage configurations)
  - Storage materials (e.g., aluminum, carbon steel, and stainless steel)



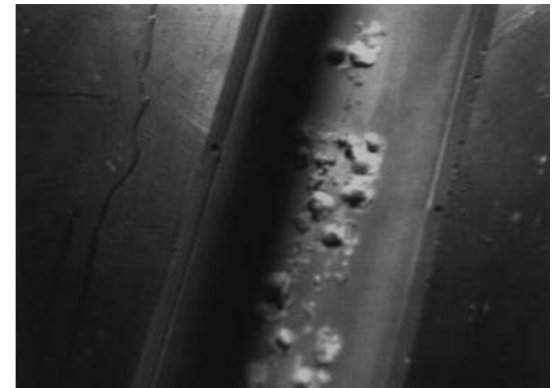


# Aging Management (continued)

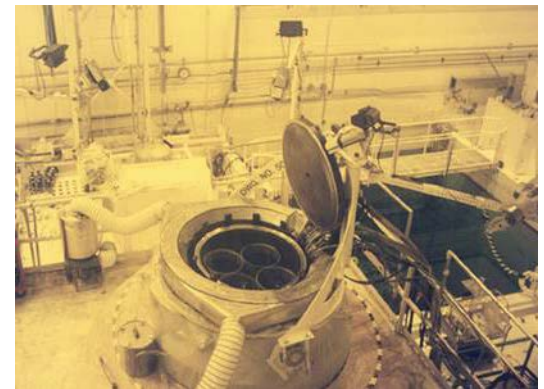
- It is essential to manage SNF in a manner that will not impede its eventual disposal
- It is important to improve understanding of processes related to packaging and storing DOE SNF that could affect future transportation and disposal activities

Corrosion of  
Materials Testing  
Reactor–type  
assembly  
(aluminum-based)

with pit corrosion damage on fuel plate cladding over fuel material region.



Equipment used for  
drying Three-Mile  
Island Unit 2 SNF  
core debris at INL.  
The heated vacuum  
drying procedure  
used to dry the SNF during packaging for storage  
was determined experimentally.



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# Board Findings and Recommendations



# Aging Management

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- **Board Finding:** DOE's aging management programs are not fully implemented.
  - Assessments missing for some facilities and incomplete implementation at other facilities
- **Recommendation:** The Board recommends that DOE develop and fully implement programs to manage degradation of SNF, the materials that contain SNF, and SNF facilities for additional multiple decades of storage operations at all storage facilities.

[ More of the recommendation is in the backup slides]



# Measuring and Monitoring

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- **Board Finding:** Measuring and monitoring conditions of the SNF during dry storage is important.
  - The ability to measure and monitor conditions of the SNF in the storage facility during future dry storage (e.g., monitoring gas composition in a multi-purpose canister like that being done for the MCOs) is important to the design, development, and deployment of new DOE storage systems.
- **Recommendation:** The Board recommends that DOE include the capability for measuring and monitoring the conditions of the SNF in new DOE storage systems, such as the DOE standardized canister, and in new packaging and storage facilities to aid in establishing the condition of the SNF during subsequent operations and its acceptability for those operations.





# Drying

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- **Board Finding:** An improved technical basis is needed for proposed drying procedures for DOE SNF before packaging it in multi-purpose canisters.
- **Recommendation:** The Board recommends that DOE conduct research and development activities to confirm that reactions between DOE SNF and any water remaining in any multi-purpose canister do not cause cumulative conditions inside the canister (e.g., combustibility, pressurization, or corrosion) to exceed either the design specifications or applicable regulatory operational requirements. The period of interest extends over the duration of canister use, including the time spent in storage, in transportation, and at a repository, until DOE closes the repository.

[ More of the recommendation is in the backup slides]



# Packaging Facilities

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- **Board Finding:** Technical and regulatory uncertainties complicate planning for packaging facilities.
- **Recommendation:** To minimize complications in developing and operating a packaging facility for DOE SNF at Idaho National Laboratory, the Board recommends that DOE complete research, development, and licensing-related activities for the DOE standardized canister—and any other canisters that may be used—prior to completing the facility's preliminary design.

[ More of the recommendation is in the backup slides]



# Waste Acceptance

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- **Board Finding:** Waste acceptance system requirements affect the disposition of DOE SNF and DOE's Office of Nuclear Energy (DOE-NE) is not subject to the requirements.
- **Recommendation:** The Board recommends that DOE-NE implement the existing Office of Civilian Radioactive Waste Management waste acceptance system requirements to increase the likelihood that SNF managed by DOE-NE and that waste forms resulting from electrochemical processing of sodium-bonded SNF will be acceptable for geologic disposal in a repository.



# Disposal Research

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- **Board Finding:** The diversity of DOE SNF combined with differences in physical and chemical characteristics of potential repository environments complicates the potential disposal of DOE SNF.
- **Recommendation:** **If** DOE continues to conduct generic investigations of a range of potential repository environments, the Board recommends that DOE identify and prioritize its research efforts concerning DOE SNF degradation related to disposing of DOE SNF in each of the potential host-rock environments.

[ More of the recommendation is in the backup slides]



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# Backup Slides



# Aging Management Recommendation (continued)

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- These aging management programs should take into account the following important considerations:
  - the diversity of degraded DOE SNF, storage facility construction materials, and storage systems that differ from those used commercially;
  - the potential for additional multiple decades of storage operations;
  - the requirements that may have to be met to manage degradation of multi-purpose canisters—and any other canisters that may be used—after multiple decades of storage until final disposal occurs;
  - the impact of potential future missions in existing storage facilities; and
  - lessons learned from similar programs developed for commercial nuclear reactors and commercial SNF dry storage facilities.





# Drying Recommendation (continued)

- These research and development efforts should include the following activities:
  - collecting and analyzing data applicable to drying DOE SNF—particularly aluminum-based fuels—that focus on the quantity of chemisorbed water;
  - determining whether the results and associated models from a DOE Office of Nuclear Energy (DOE-NE) study of a vacuum drying chamber can be used to inform efforts to understand and implement DOE SNF drying;
  - collecting data on potential hydrogen generated from SNF corrosion products that is focused on characterizing the mass and chemical composition of water-bearing aluminum minerals present after drying;



# Drying Recommendation (continued)

- collecting data on the rates of hydrogen produced from dissociation of water molecules by materials composing and within storage canisters (e.g., supplemental neutron absorbers or fuel corrosion products) by ionizing radiation;
- using validated models for physical and chemical processes that could occur inside sealed canisters to predict internal gas composition and pressure over the expected length of time the canisters will be in use and comparing model predictions to monitoring data collected during storage; and
- re-evaluating the adequacy of proposed drying protocols that reflect all the sources of water to assess the extent of potential corrosion damage and gas pressurization of the canister during its use.



# Packaging Facilities Recommendation (continued)

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- In particular, DOE should complete the following tasks related to the DOE standardized canister:
  - conduct remote welding and real-time, non-destructive, weld-testing research and development activities;
  - research and develop materials that will be packaged with the SNF (e.g., structural inserts using an advanced neutron absorber);
  - decide on and develop SNF treatment processes needed for specific SNF types (e.g., epoxied fuel may need organic components removed, and Fermi blanket fuel may be electrochemically processed or may have sodium removed and be placed in high integrity cans that are made with advanced corrosion-resistant metals such as Alloy 22);



# Packaging Facilities Recommendation (continued)

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- confirm, through research and development, that reactions between SNF and any water remaining in a canister do not cause conditions inside the canister to exceed either the design specifications or any applicable regulatory requirements during dry storage, transportation, and repository pre-closure operations;
- obtain NRC approval that the DOE standardized canister meets the transportation moderator exclusion requirements or receive an exemption to these requirements;
- analyze an existing NRC-certified rail transport cask or develop a new one, and obtain NRC approval to transport DOE standardized canisters to ensure that any canister packaging design features needed inside the rail cask (e.g., a supplemental impact limiter) to meet regulatory requirements are considered in the design of the packaging facility; and
- define the technical requirements for the packaging facility, including the regulatory standards (e.g., NRC regulations) that it will need to meet.



# Disposal Research Recommendation (continued)

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- As part of this effort DOE should complete the following tasks:
  - A) Improve its current understanding of post-closure DOE SNF degradation processes for DOE SNF types that constitute a large portion of the mass or radionuclide content or that could be in a large fraction of the disposal packages in a repository.
    - i. For each disposal environment, identify the processes that will occur, their rates, and their impact on repository performance, including assessing the potential generation of corrosion products that could affect the release of radionuclides from a waste package and the potential generation of hydrogen and other gases.



# Disposal Research Recommendation (continued)

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- B) Prioritize its research based on analyzing the features, events, and processes associated with those aspects of DOE SNF that differ significantly from commercial SNF and on types of DOE SNF that could constitute a significant fraction of the estimated post-closure risk to the public.

