U.S. Department of Energy Spent Nuclear Fuel at the Hanford Site: Management and Disposal

Presented to:
Oregon Hanford Cleanup Board

Presented By:
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July 16, 2018
Pendleton, OR

Independent Federal Agency

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

- 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

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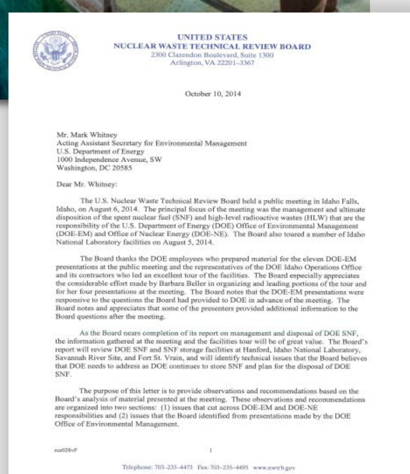
The Eleven Board members:

- 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

Board Review of DOE SNF



UNITED STATES
NUCLEAR WASTE TECHNICAL REVIEW BOARD
2300 Clarendon Boulevard, Suite 1300
Arlington, VA 22201-3367

October 10, 2014

Mr. Mark Whitney
Acting Assistant Secretary for Environmental Management
U.S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585

Dear Mr. Whitney:

The U.S. Nuclear Waste Technical Review Board held a public meeting in Idaho Falls, Idaho, on August 6, 2014. The principal focus of the meeting was the management and ultimate disposition of the spent nuclear fuel (SNF) and high-level radioactive wastes (HLW) that are the responsibility of the U.S. Department of Energy (DOE) Office of Environmental Management (DOE-EM) and Office of Nuclear Energy (DOE-NE). The Board also toured a number of Idaho National Laboratory facilities on August 5, 2014.

The Board thanks the DOE employees who prepared material for the eleven DOE-EM presentations at the public meeting and the representatives of the DOE Idaho Operations Office and its contractors who led an excellent tour of the facilities. The Board especially appreciates the considerable effort made by Barbara Beller in organizing and leading portions of the tour and for her four presentations at the meeting. The Board notes that the DOE-EM presentations were responsive to the questions the Board had provided to DOE in advance of the meeting. The Board notes and appreciates that some of the presenters provided additional information to the Board questions after the meeting.

As the Board nears completion of its report on management and disposal of DOE SNF, the information gathered at the meeting and the facilities tour will be of great value. The Board's report will review DOE SNF and SNF storage facilities at Hanford, Idaho National Laboratory, Savannah River Site, and Fort St. Vrain, and will identify technical issues that the Board believes that DOE needs to address as DOE continues to store SNF and plan for the disposal of DOE SNF.

The purpose of this letter is to provide observations and recommendations based on the Board's analysis of material presented at the meeting. These observations and recommendations are organized into two sections: (1) issues that cut across DOE-EM and DOE-NE responsibilities and (2) issues that the Board identified from presentations made by the DOE Office of Environmental Management.

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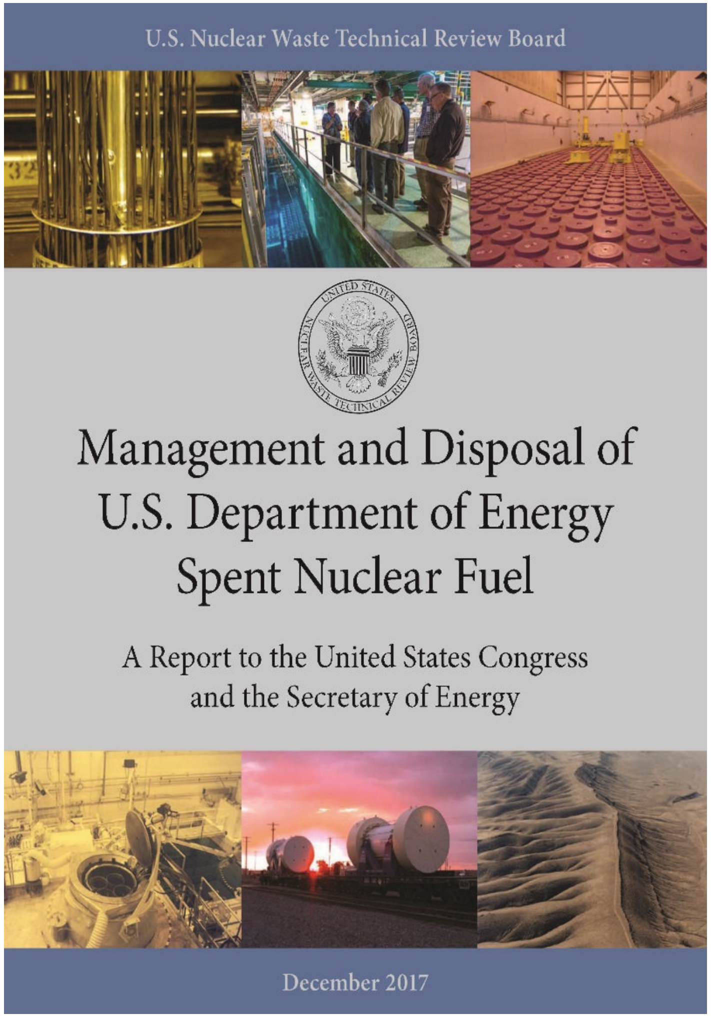
- Multi-year review focused on continued storage of DOE spent nuclear fuel (SNF) at the surface followed by geologic disposal in a repository
- Public meetings held with DOE
- The Board toured DOE SNF storage facilities at
  - Hanford
  - Idaho National Laboratory (INL)
  - Savannah River Site (SRS)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

Board Report

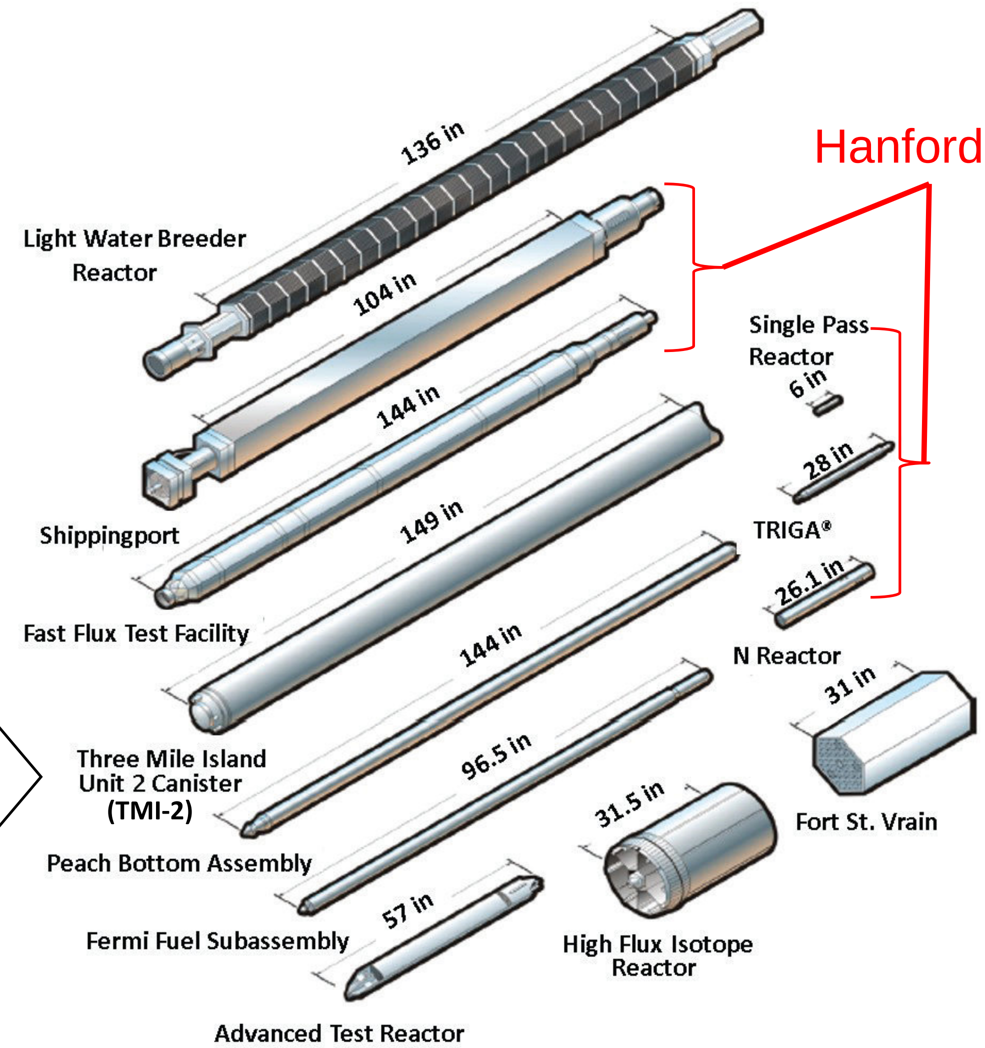
- Examines technical issues related to DOE SNF packaging and storage that might affect continued storage, transportation, and disposal
- Records quantities and characteristics of DOE SNF and storage capacities
  - Hanford, INL, SRS, and Fort St. Vrain
  - 250 types of fuel
- Analyzes DOE's packaging 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

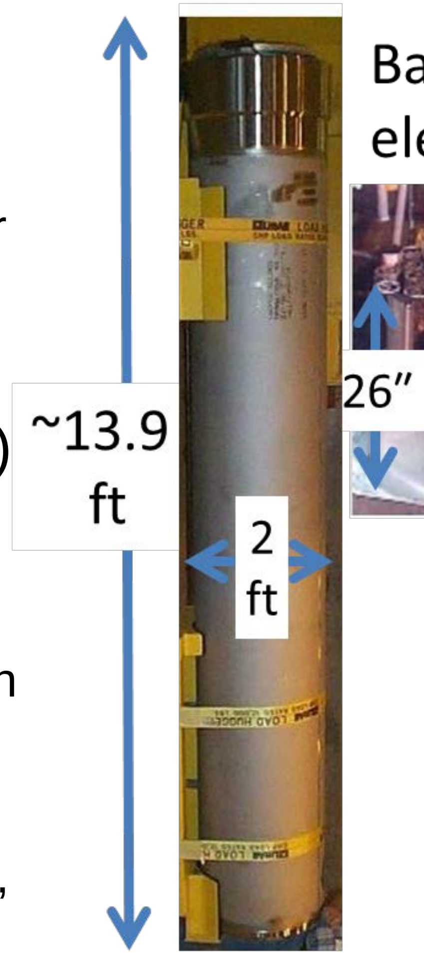


- DOE categorizes its fuel into 34 groups

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



Baskets of N Reactor elements and scrap

Single Pass SNF

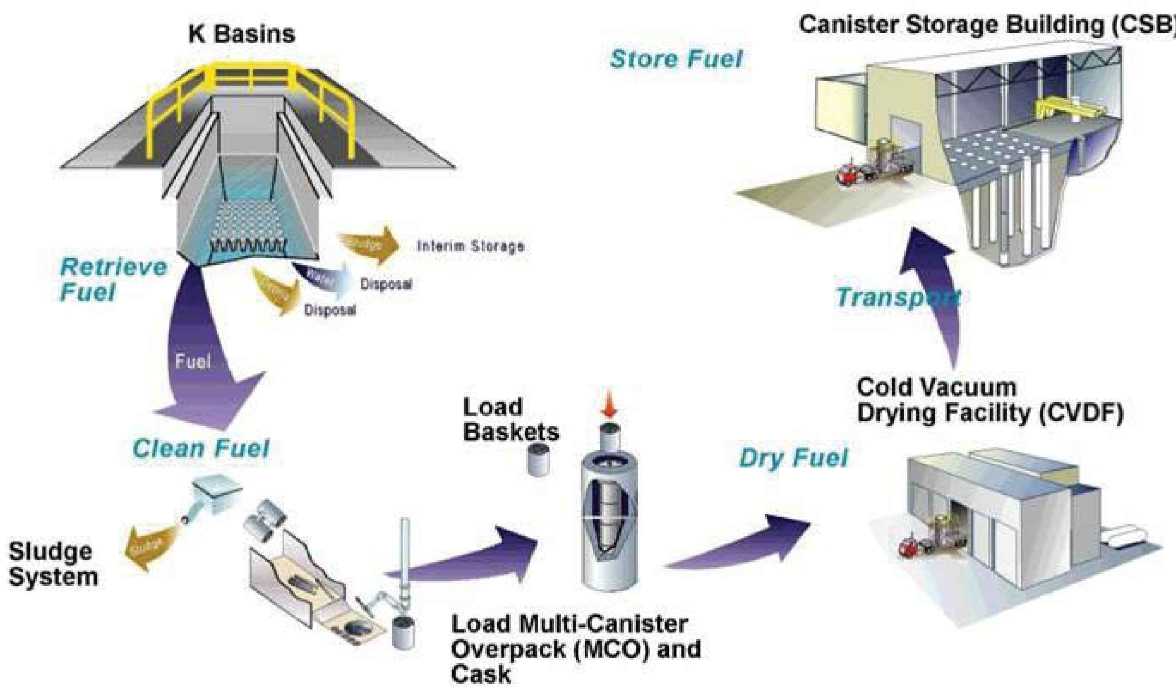
Packaging of MCOs

MCO

(A)

DOE's process to retrieve, clean, load, and dry SNF in an MCO with subsequent transport and storage of the MCO

(B)

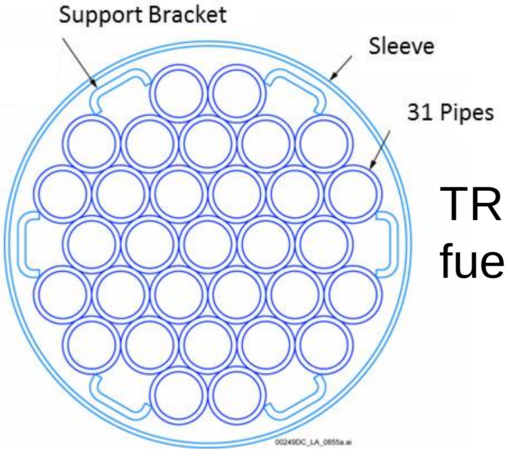


DOE Packaging Approach

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

Naval Long SNF Canister Length (Nominal): 210.5 in
Naval Short SNF Canister Length (Nominal): 185.5 in
Naval SNF Canisters Outer Diameter (Nominal): 66.5 in

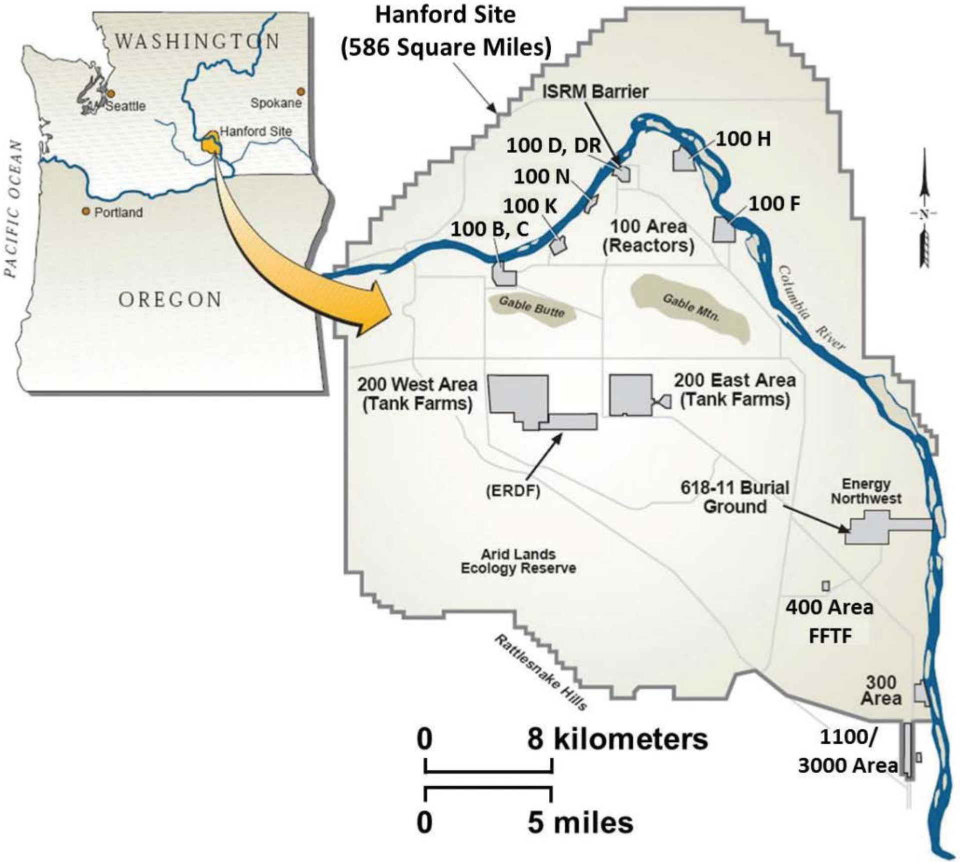
- DOE standardized canister
  - ➢ Development stopped before deployment
  - ➢ For all remaining non-naval DOE SNF (~3,500 packages)
  - ➢ 2 lengths (10 and 15 feet)
  - ➢ 2 diameters (18 and 24 inches)
  - ➢ Advanced neutron absorbers
  - ➢ 8 basket arrangements



TRIGA® fuel basket

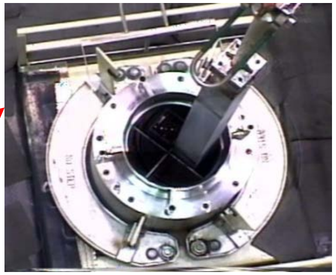
Storage of DOE SNF at Hanford

- Storage occurs in 200 East Area
- Storage at two facilities
  - Canister Storage Building
  - 200 Area Interim Storage Area
- Both facilities began operations in early 2000s
- Design life of facilities and SNF packages is 40 years (see Table 4-1 of the Board's report for more details)

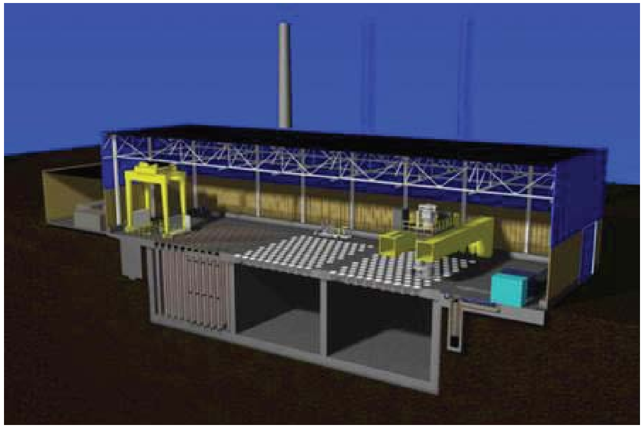


Canister Storage Building

- Vault storage
- 220 storage tubes below operations floor of facility
- Each tube can hold 2 packages of SNF (MCO-sized containers)
- 412 SNF packages stored
  - 394 MCOs
  - 18 Shippingport Spent Fuel Containers



- Additional six overpack tubes, which can hold a single abnormal or suspect storage canister, are designed to monitor and confine leaks



Cutaway of facility

Vault under construction

Canister Storage Building (continued)

- Facility designed to allow monitoring of MCOs
  - Gas pressure, temperature, and gaseous constituents
- Sampling terminated 9/2017
- Mechanical seals on 15 MCOs will need to be welded

Circles in facility floor are locations of storage tubes
(CH2M 2016)

MCO sampling for gaseous constituents, gas pressure, and temperature
(Covert 2017)

200 Area Interim Storage Area

- Dry cask storage
- Variety of storage arrangements
- Packaging required for off-site transportation and disposal

One of 49 Interim Storage Casks, 45 of which contain Fast Flux Test Facility SNF, being placed on a concrete pad

Six NAC-1 casks, which contain commercial SNF, are inside six International Standards Organization containers (cubes on the left). A Rad-Vault is the cylinder on the right.

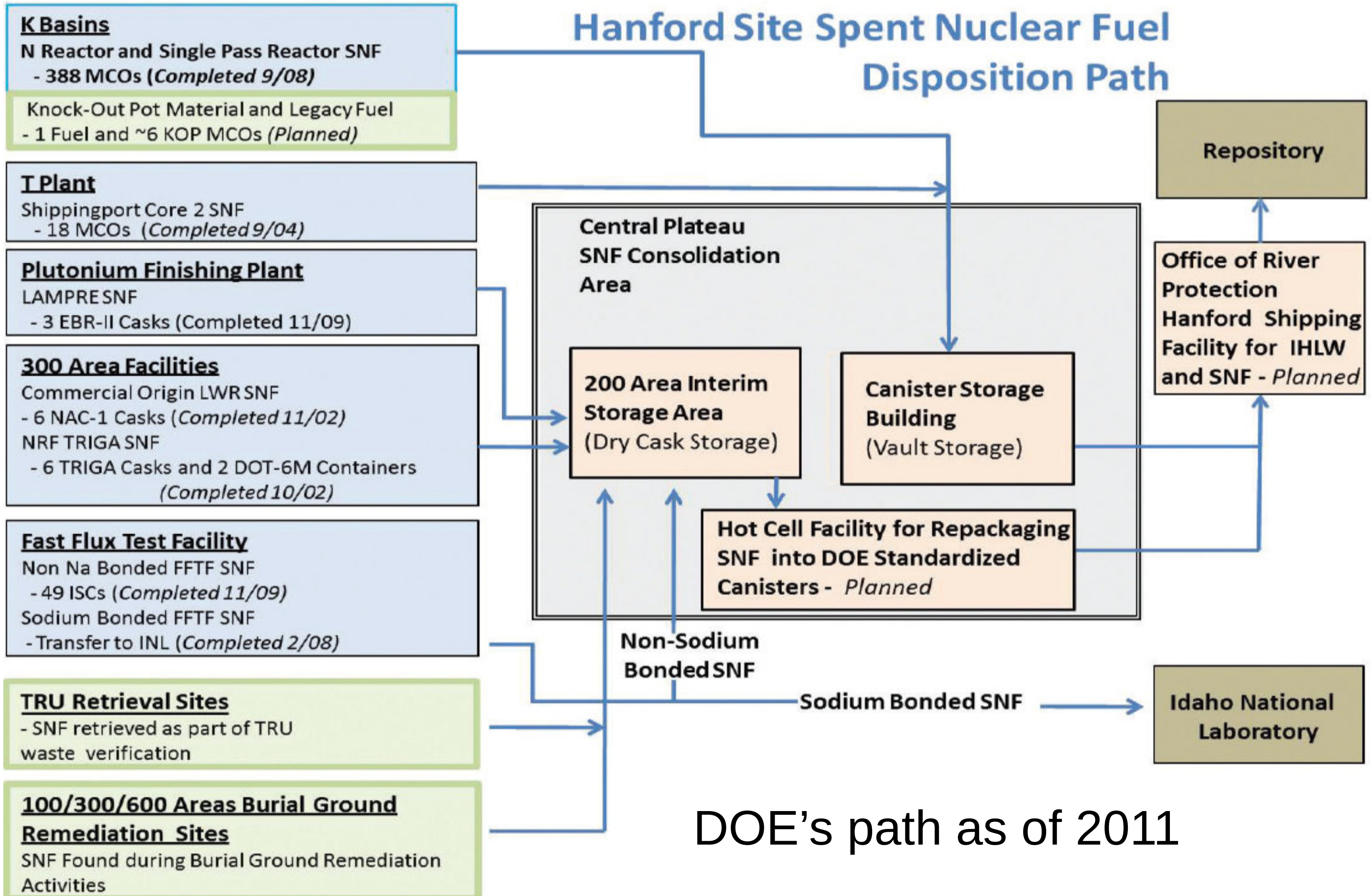
Rad-Vaults at Interim Storage Area

One of six TRIGA® casks, which contain Neutron Radiography Facility SNF, is placed into a Rad-Vault

Installation of the Rad-Vault lid on one of the two Rad-Vaults stored at the 200 Area Interim Storage Area

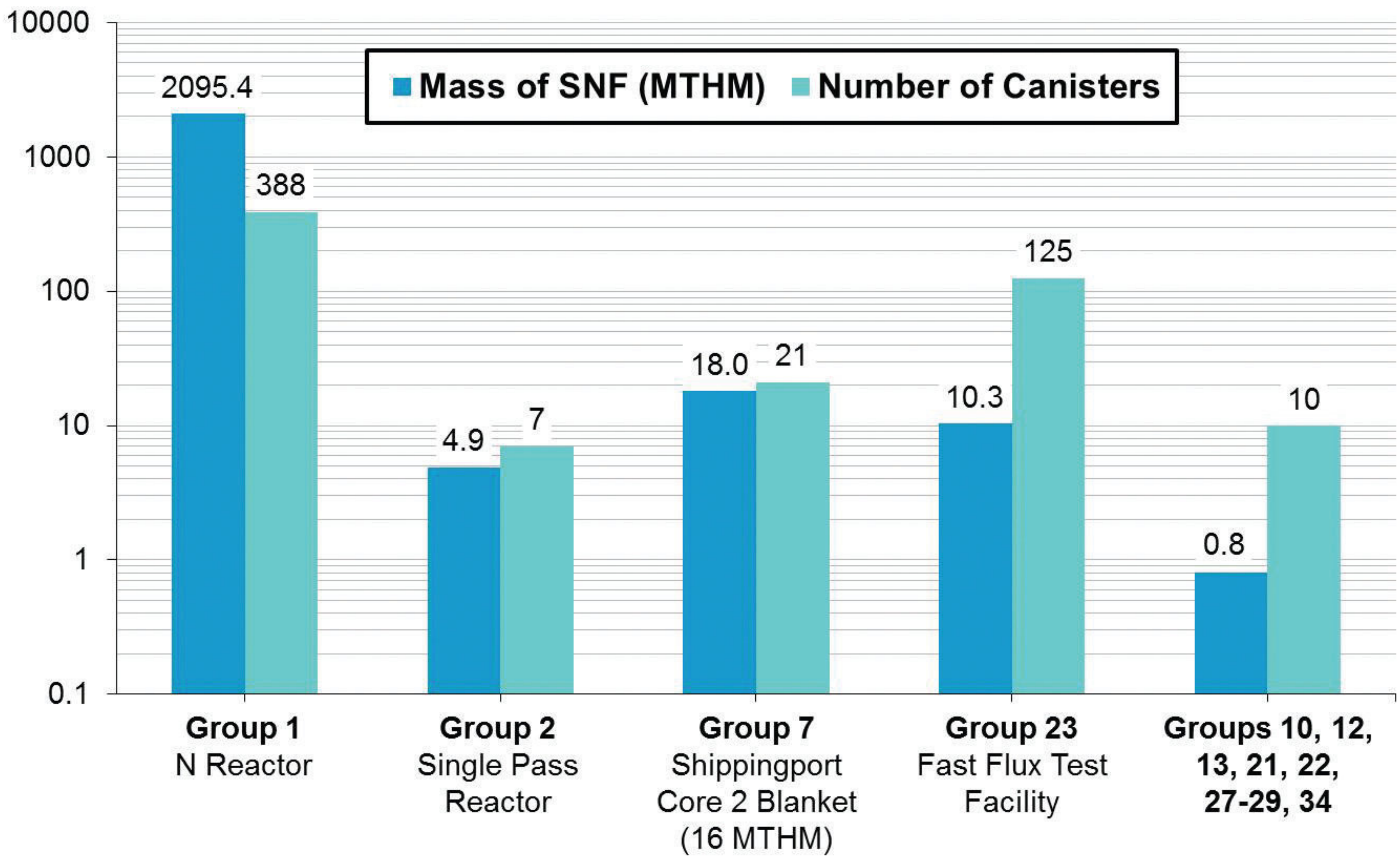
(McCormack 2014)

Hanford SNF Disposition Path



DOE's path as of 2011

Mass of SNF by DOE SNF Group and Estimated Number of Multi-purpose Canisters to be Transported to a Repository



Key Observations on Hanford

- DOE removed approximately 2,105 MTHM of corroding, low-enriched (less than 1.25% uranium-235), chemically-reactive, metallic uranium SNF from storage in water-filled basins, dried the SNF, packaged it in MCOs, and transferred it to a dry storage facility.
- DOE determined drying process requirements by modeling the SNF and various sources of bound water (*e.g.*, aluminum hydroxide cladding film that formed during storage of some of the SNF in aluminum canisters) rather than relying on drying experiments.
- DOE's model projects that, after 40 years of storage, the concentration of hydrogen could be two times below to more than six times above the NRC transport package acceptance criterion concentration limit of 4%. DOE completed packaging MCOs in 2012.

Key Observations on Hanford

- DOE monitors temperature, pressure, and gas composition in 15 of the 394 MCOs during storage.
- Monitoring results are crucial to demonstrate that the concentration of hydrogen is not higher than the NRC acceptance criterion and to support DOE's projections that challenges to MCO integrity from internal reactions are limited during storage.
- Monitoring results indicate hydrogen concentrations are lower than predicted and seem to be decreasing with time.
- The results are consistent with hydrogen uptake by reactions with SNF, a process that DOE, conservatively, did not include in its model.

[DOE stopped monitoring the MCOs during publication of the Board's report]

Key Observations on Hanford

- DOE designed the MCOs for on-site storage at the Hanford Site, and transportation to and disposal at Yucca Mountain.

- The MCOs have a design life of 40 years and serve as the radionuclide confinement barrier during storage, transportation, and pre-closure operations at a repository.

- Given DOE's current strategy for SNF management and disposal, the MCOs likely will be in service, prior to disposal, for more than a decade beyond their design life.

Key Observations on Hanford

- Additional MCO system design is required to provide transportation features such as impact limiters within the transportation cask.

- NRC approval for MCOs will be required before DOE can use them to transport Hanford SNF off site to an interim storage facility or geologic repository.

- DOE needs to complete additional analyses to confirm that the MCOs can be safely received and handled at a repository during pre-closure operations.

Key Observations on Hanford

- DOE plans to build a new facility to repackage approximately 12 MTHM of SNF that is stored at 200 Area Interim Storage Area before it is transported to a repository. The material includes higher-enriched (3% to < 20% uranium-235) SNF and mixed plutonium-uranium oxide SNF with 20%–30% plutonium.
- DOE plans to repackage the SNF into approximately 140 DOE standardized canisters that were designed for storage, transportation, and disposal at Yucca Mountain.
- DOE will need to use supplemental neutron absorber materials in some of the standardized canisters for criticality safety.

Key Observations on Hanford

- Because decades will pass before SNF currently in dry storage at Hanford will be repackaged or transported and disposed of, retaining records and preserving knowledge from past waste management activities will be a key consideration for future waste management and disposal activities.

Issues Identified by the Board

- 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

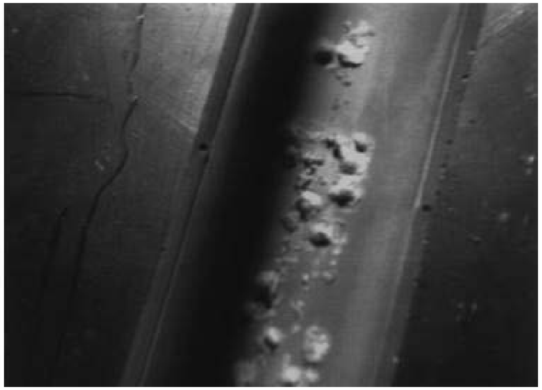
- DOE SNF will be stored decades longer than expected
  - Some DOE SNF is already in multi-purpose canisters
  - Plans are to package remaining SNF in multi-purpose canisters
  - DOE SNF is more degraded than commercial SNF
- Wide diversity of fuel types and storage conditions affects aging management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

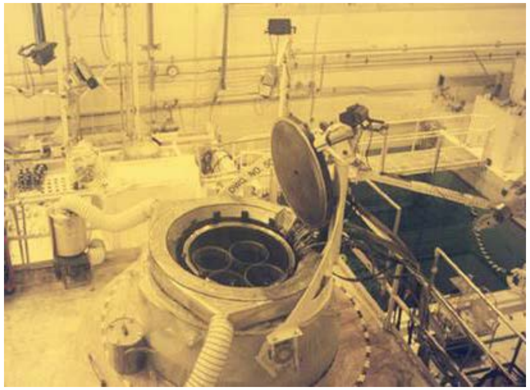
- It is important to improve understanding of processes related to packaging and storing DOE SNF that could affect future transportation and disposal activities

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.

Board Findings and Recommendations

Aging Management

- **Board Finding:** DOE's aging management programs are not fully implemented.
  - ➢ Assessments not completed 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

- **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

- **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

- **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

- **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

- **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]

Backup Slides

Aging Management Recommendation (continued)

- 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)

- 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)

- 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)

- 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)

- 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.

References for Images

- Except for those listed below, all images of Hanford facilities and DOE SNF, with full citations, are in the Board's report "Management and Disposal of U.S. Department of Energy Spent Nuclear Fuel"
- Ch2m. 2016. *Canister Storage Building Project Factsheet*. https://chprc.hanford.gov/files.cfm/CSB_Factsheet.pdf .
- Covert, Ryan. 2017. *MCO Sampling Program: Multi-Canister Overpack (MCO) Gas Sampling Program Evaluation*. Presentation to the DOE Richland Operations Office at its April 5, 2017, meeting.
- McCormack, Roger. 2014. *Hanford Spent Nuclear Fuel Facility Aging*. Presentation to the Nuclear Waste Technical Review Board at its August 6, 2014, meeting.