SAND2016-2592PE

Used Fuel Disposition R&D Campaign

Used Fuel Disposition R&D Campaign Overview

David C. Sassani

Sandia National Laboratories
Used Fuel Disposition R&D Campaign

MRWFD Campaign Working Group Meeting
March 22-23, 2016
PNNL, Richland, WA

Sandia National Laboratories is a multiprogram laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND2015-XXXXXX

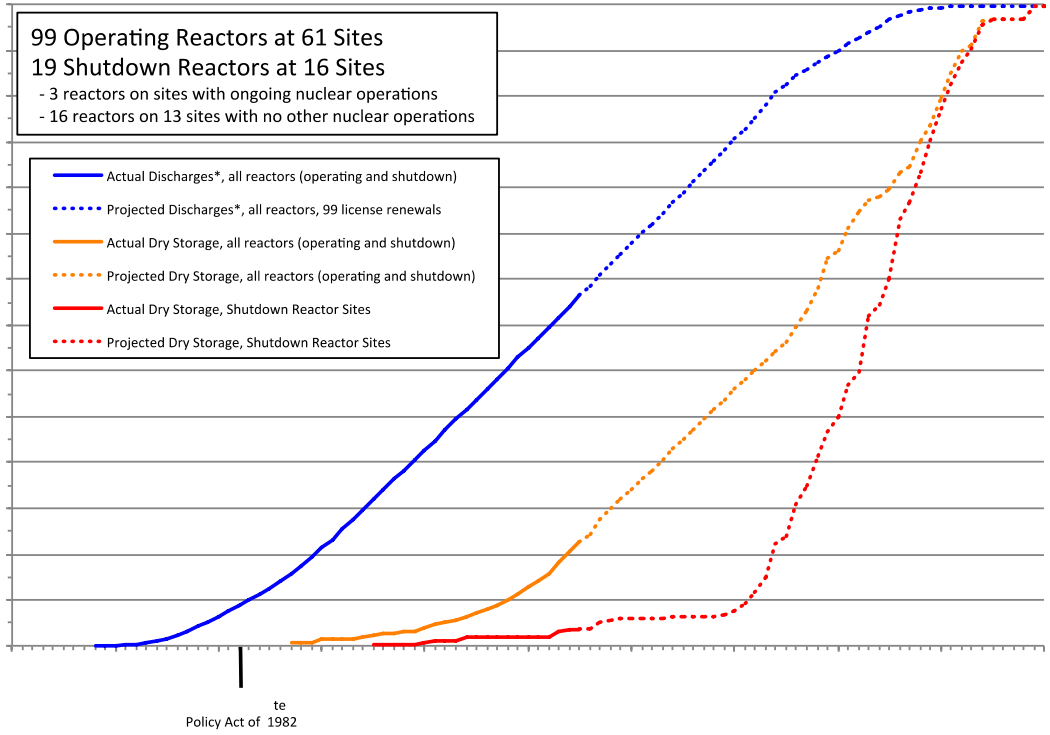
Used Fuel Disposition

Outline

- **The Campaign Overview**
  - Background and Mission
  - UFD R&D Campaign Focus Areas and Structure
  - Selected Accomplishments for FY15
  - Overview of FY2016 Activities
    - *Selected Updates*
  - Outlook and Conclusions

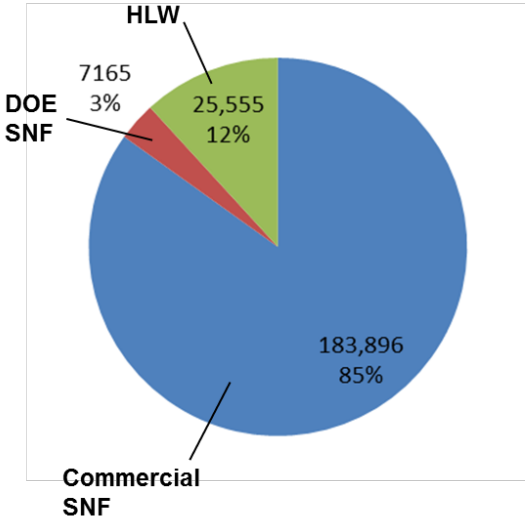
Used Fuel Disposition

Historical and Projected Spent Nuclear Fuel (SNF) and High-Level Radioactive Waste (HLW) in the United States



Historical and Projected Commercial SNF Discharges

Projected Volumes of SNF and HLW in 2048



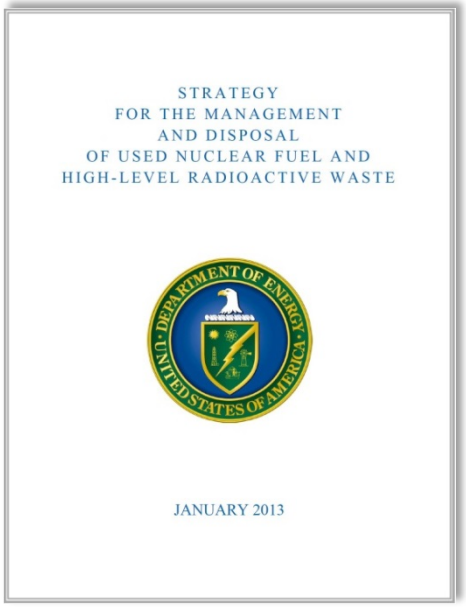
Volumes shown in m^3, assuming constant rate of nuclear power generation and packaging of future commercial SNF in existing designs of dual-purpose canisters

Summary of the Administration's UNF and HLW Strategy

Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste **issued January 2013**

The Strategy is:

- **A statement of Administration policy regarding the importance of addressing the disposition of used nuclear fuel and high-level radioactive waste**
- **The response to the final report and recommendations made by the *Blue Ribbon Commission on America's Nuclear Future***
- **The initial basis for discussions among the Administration, Congress and other stakeholders**



The Strategy outlines a 10-year program of work that:

- Sites, designs, licenses, constructs and begins operations of a pilot interim storage facility (operating 2021)
- Advances toward the siting and licensing of a larger interim storage facility (operating 2025)
- Makes demonstrable progress on the siting and characterization of repository sites (repository sited 2026, licensed 2042, operating 2048)

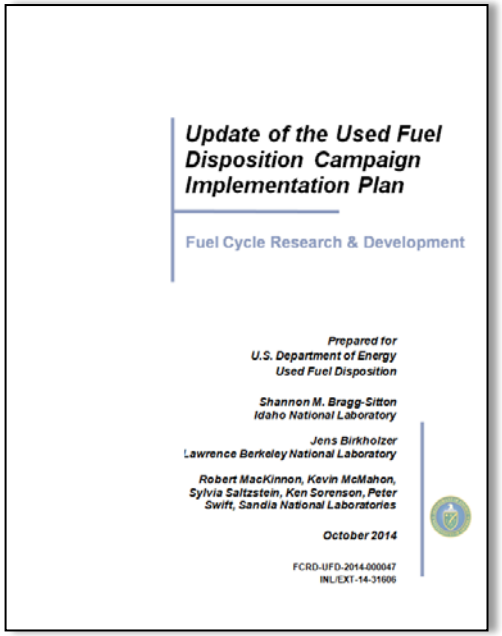
Used Fuel Disposition

Used Fuel Disposition R&D Campaign Mission

Campaign Mission: to identify alternatives and conduct scientific research and technology development to enable storage, transportation and disposal of used nuclear fuel and wastes generated by existing and future nuclear fuel cycles

Campaign challenge: to provide a sound technical basis for supporting the current DOE strategy for managing the back end of the nuclear fuel cycle, including the identification and evaluation of safe and secure options for storage, transportation, and permanent disposal of radioactive wastes resulting from existing and future fuel cycles.

Update of the Used Fuel Disposition Campaign Implementation Plan
FCRD-UFD-2014-0000474, October 2014



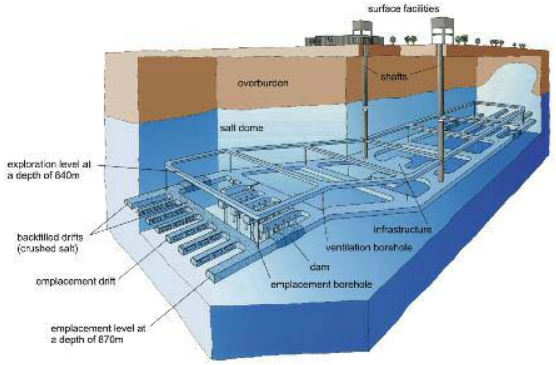
Campaign Strategic Focus: Storage and Transportation R&D

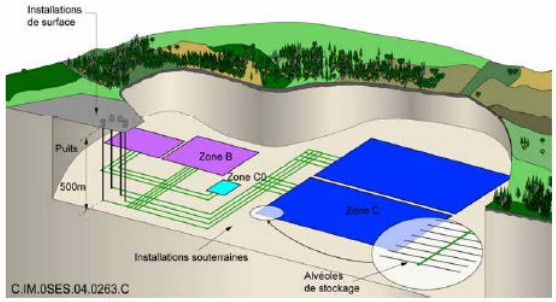
Prepare for extended storage and eventual large-scale transport of used nuclear fuel (UNF) and high-level waste

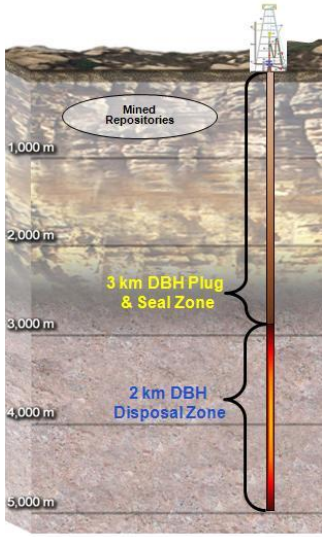
- **Develop the technical bases for:**
  - Extended storage of used nuclear fuel
  - Fuel retrievability and transportation after extended storage
  - Transportation of high-burnup used nuclear fuel

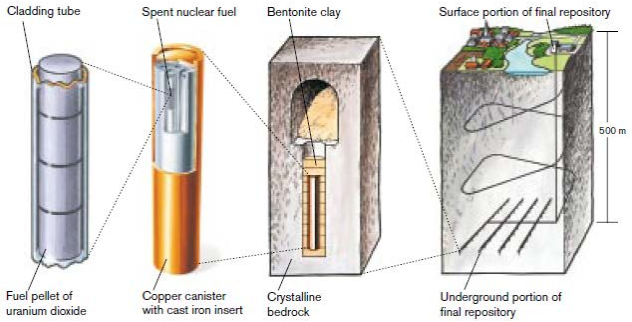
DOE's R&D Focus for UNF and HLW Disposal

- **Provide a sound technical basis for multiple viable disposal options in the US**
- **Increase confidence in the robustness of generic disposal concepts**
- **Develop the science and engineering tools needed to support disposal concept implementation**



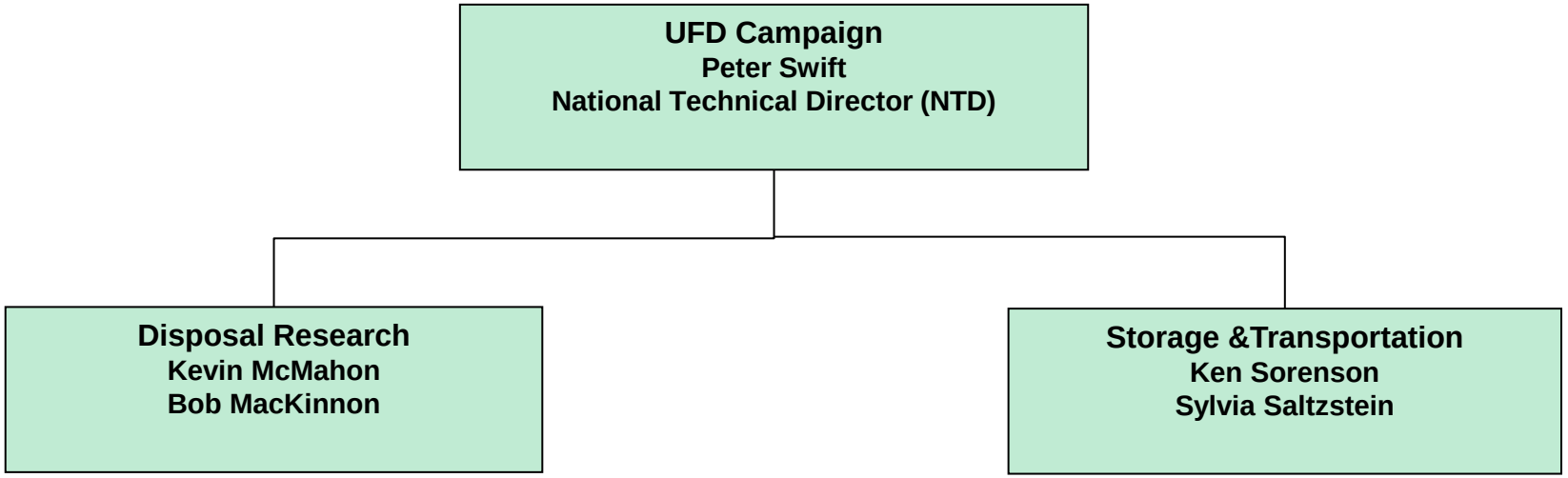






Used Fuel Disposition

FY2016 Organization of the Used Fuel Disposition Campaign



Host Rock Research: Argillite
Host Rock Research: Crystalline
Host Rock Research: Salt
Generic Disposal System Analysis
International Collaborations
Deep Borehole Disposal
Disposal of Dual Purpose Canisters
DOE Managed HLW and SNF Research

Deep Borehole Field Test (procurement managed directly by DOE)

Field Demonstration Support
Experiments
Analysis
Transportation
Security

High-burnup Confirmatory Data Project (industry-led, managed directly by DOE)

Used Fuel Disposition R&D Campaign Mission National Laboratories

The *DOE Office of Used Nuclear Fuel Disposition Research and Development and nine national laboratories participate in the DOE Office of Nuclear Energy's "Used Fuel Disposition Campaign"*

Campaign Mission: to identify alternatives and conduct scientific research and technology development to enable storage, transportation and disposal of used nuclear fuel and wastes generated by existing and future nuclear fuel cycles

Los Alamos NATIONAL LABORATORY

Pacific Northwest NATIONAL LABORATORY

Argonne NATIONAL LABORATORY

Sandia National Laboratories

BERKELEY LAB

SRNL SAVANNAH RIVER NATIONAL LABORATORY

INL Idaho National Laboratory

ornl OAK RIDGE NATIONAL LABORATORY

Science in the National Interest
Lawrence Livermore National Laboratory

Used Fuel Disposition Campaign External Collaborations

- **Collaboration among Fuel Cycle Technology Campaigns**
  - Full collaboration and shared resources with Nuclear Fuels Storage and Transportation Planning Project (NFST)
  - Support for Fuel Cycle Options Campaign
  - Close interactions with Material Recovery/Waste Form Campaign
    - *Waste form degradation modeling integration*
- **Collaboration with DOE-EM**
  - Canister concepts for deep borehole disposal
- **Industry (Advisory and Assistance Contracts)**
  - E.g., Areva; engineering services task for deep borehole field test
- **DOE/Industry Storage High-Burnup Data Project initiated FY13**
  - Dominion, Areva, Westinghouse
- **EPRI**
  - Extended Storage Collaboration Program (ESCP) (with NRC, utilities, vendors, and international organizations)
- **NEI**
  - Meetings to coordinate prioritization of funded activities

Used Fuel Disposition Campaign External Collaborations (cont.)

- **International Collaborations**
  - Participation in international Underground Research Laboratories in Europe and Korea and in multi-national disposal research activities
  - Bilateral agreements on storage and disposal R&D with Korea, Japan, China
  - MOU for salt disposal R&D with Germany
  - IAEA working groups in storage and transportation
  - Collaboration with Germany and Japan on extended performance of bolts and seals for bolted storage casks and on SS canister stress corrosion cracking
- **DOE NE University Programs**
  - UFD R&D is affiliated with 22 active NEUP research projects (not including FY15 awards)
    - *11 projects in Storage R&D*
    - *2 projects in Transportation R&D*
    - *6 projects in Disposal R&D*
    - *3 Integrated Research Projects in Storage R&D*
- **Other university collaborations (MIT, U. of Oklahoma, University of Sheffield UK)**

UFD Storage and Transportation R&D Selected FY15 Accomplishments

Selected Storage and Transportation FY15 Deliverables

- Test Plan for Sister Rod Characterization and Testing, M2FT-15IN08020111, March 2015
- Evaluate the Frequency for Gas Sampling for the High Burn-up Storage Demonstration Project, M2FT-15IN0802013, April 2015
- Conduct ring compression tests on HBU PWR cladding alloys at 350 C. M2FT-15AN0805011, September 2015
- Conduct cyclic bend tests of used nuclear fuel. M2FT-15OR0805031, September 2015.
- Stress Corrosion Cracking Investigation on a Full Scale Stainless Steel Canister Mock-up. M2FT-15SN0805051, August 2015.
- Thermal profile analyses of in-situ industry storage systems identified for inspection. M2FT-15PN0810049. September 2015.
- Development of Uncertainty Quantification Methodology as Applied to Storage and Transportation R&D. M2FT-15SN0810051. July 2015

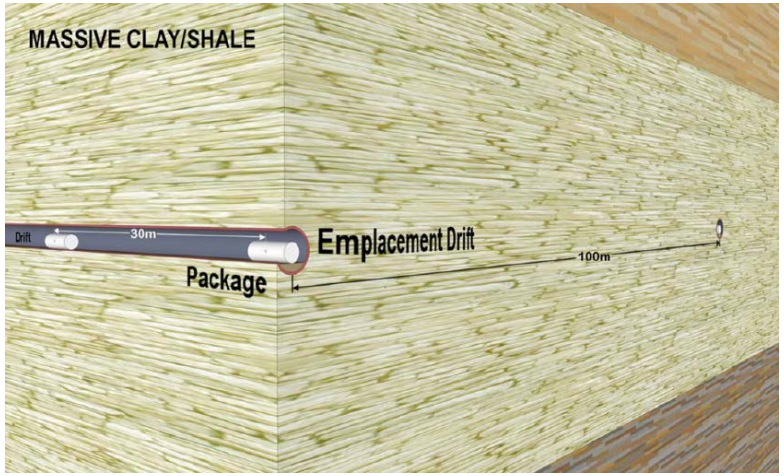
UFD Disposal R&D
Selected FY15 Accomplishments

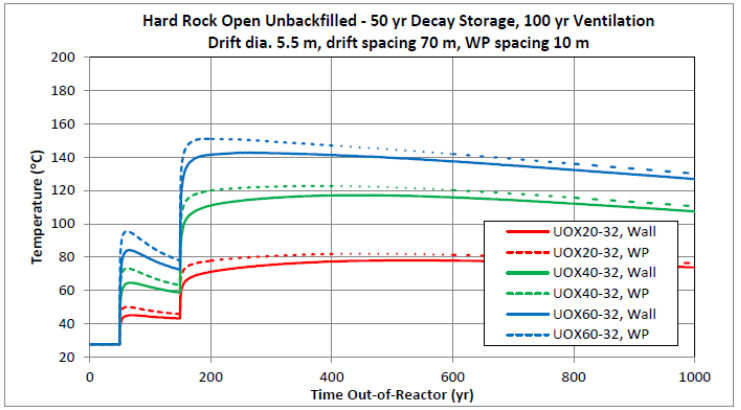
Selected Disposal Research FY15 Deliverables

- Evaluation of Used Nuclear Fuel Disposition in Clay-bearing Rocks, M2FT-15SN0806071, September 2015.
- Evaluation of Used Nuclear Fuel Disposition in Crystalline Rocks, M2FT-15SN0807071, September 2015.
- Application of Generic Disposal System Models. M2FT-15SN0808011, September 2015.
- International Collaboration Activities in Different Geologic Disposal Environments. M2FT-15LB0811012. September 2015.
- Investigations on Technical Feasibility of Direct Disposal of Dual-Purpose Canisters. M2FT-15SN0816021. May 2015.
- Site Evaluation for Deep Borehole Field Test. M2FT-15SN0817061. June 2015.
- Conceptual Design and Requirements for Characterization and Field Test Boreholes. M2FT-15SN0817081. September 2015.
- Deep Borehole Field Test Specifications. M2FT-15SN0817091. September 2015.
- Draft Test Plan for Phased Large-Scale Thermal Testing. M2FT-15LA0819016. April 2015.

Disposal Research FY15 Highlights

- **Evaluating Technical Feasibility of Direct Disposal of Dual Purpose Canisters (DPCs)**
  - Considerations
    - *Operational challenges (size and mass)*
    - *Thermal management*
    - *Post-closure criticality control*
- **Conclusions:**
  - Direct geologic disposal of some DPCs is feasible in some disposal concepts
    - *Operational challenges can be met*
    - *Thermal management can be achieved through aging, ventilation, and spacing*
    - *Post-closure criticality control may need to be addressed individually for each DPC*
  - *DPC disposal is not an all-or-nothing choice*





Disposal Research FY15 Highlights (cont.)

- **Deep Borehole Field Test**

  Request for Proposals Issued
  July 9, 2015

  DE-SOL-0008071

Three-Year UFD Campaign Objectives (2016-2019)

Storage and Transportation

- Support the high burn-up fuel full-scale storage demonstration project
- Develop understanding of how temperature and pressure affect cladding integrity in high-burnup UNF
  - *Predictive modeling*
  - *Experimentation*
- Develop understanding of how corrosion and stress corrosion cracking affect performance of stainless steel dry storage canisters
  - *Material and environmental data; predictive modeling*
- Characterize external loadings on UNF during normal conditions of transport

Disposal Research

- Field a deep borehole test
  - *Initiate drilling in 2016, complete testing in 2019*
- Complete evaluation of the direct disposal of dual-purpose canisters
- Develop experimental and modeling basis for understanding long-term performance of disposal systems in argillaceous rock, salt, crystalline rock, and deep boreholes
  - *Leverage international disposal R&D*
- Develop reference cases for generic disposal concepts

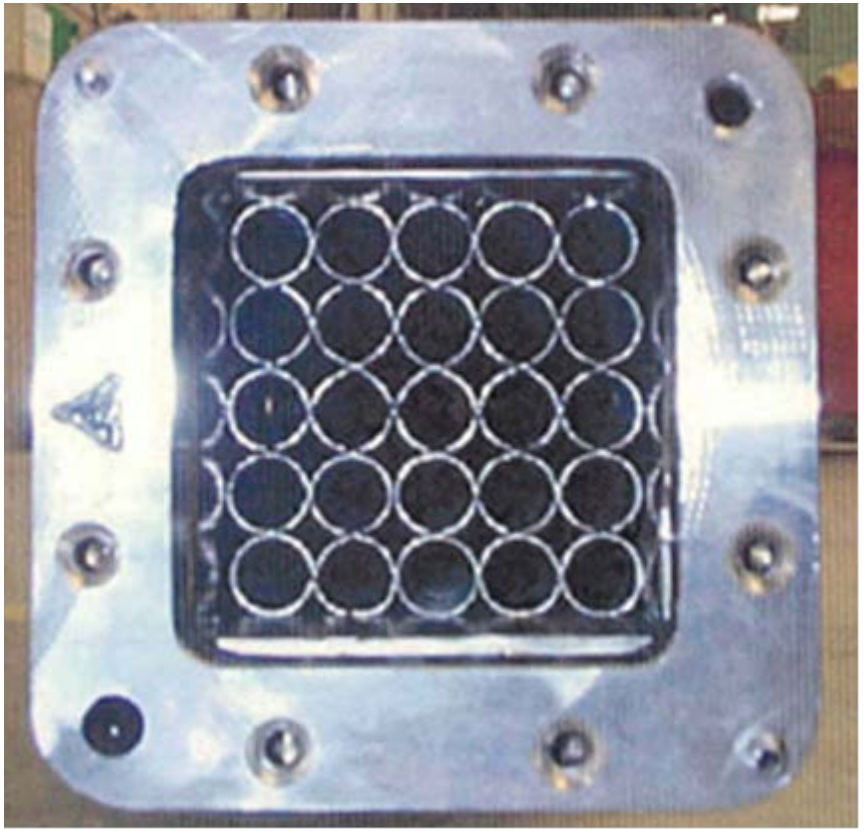
UFD R&D Campaign FY16 Activities

Selected UFD R&D 2016 Milestones

- **Selected 2016 Milestones: Storage and Transportation**
  - *Canister Mockup Weld Residual Stress Final Report (SNL, 6/30/2016)*
  - *High Heat Load Thermal Analysis (PNNL, 9/29/2016)*
  - *Sister Pin Test Plan (PNNL, 4/29/2016)*
  - *Documentation of Data Collection of CIRFT Tests on Rod Ends (ORNL, 9/15/2016)*
- **Selected 2016 Milestones: Disposal**
  - *Evaluation of Used Nuclear Fuel Disposition in Clay-bearing Rocks (SNL, 9/15/2016)*
  - *Evaluation of Used Nuclear Fuel Disposition in Crystalline Rocks (SNL, 9/21/2016)*
  - *International Collaboration Activities in Different Geologic Disposal Environments (LBNL, 9/23/2016)*
  - *Deep Borehole Field Test Conceptual Design Report (SNL, 6/30/2016)*
  - *Deep Borehole Field Test Laboratory and Borehole Testing Strategy (SNL, 8/31/2016)*
- **Selected 2016 Milestones: DOE Managed HLW and SNF Research**
  - *Draft Program Plan for the Permanent Disposal of High-Level Radioactive Waste and Spent Nuclear Fuel from Defense and Department of Energy Research and Development Activities (SNL, 07/29/2016)*
  - *Generic Organizational and Procedural Framework for DOE Managed HLW and SNF Licensing (SNL, 9/16/2016)*
- **There are a total of 20 Level 2 Milestones for UFD R&D Campaign in FY16 (one completed at this time)**

High Burnup Confirmatory Data Project - Highlights

- **Both INL and ORNL Transportation routes have been approved by NRC**
- **Areva rods pulled January 2015**
- **Westinghouse rods pulled June 2015**
  - Nine AREVA M5™ rods
  - Nine Westinghouse Zirlo™ rods
  - Four Westinghouse Low-tin Zircaloy-4 rods
  - Three Westinghouse standard Zircaloy-4 rods
- **Draft Sister Rod Test Plan has been completed and shared with others**
- **ORNL received 25 high burnup SNF rods from Dominions North Anna nuclear power plant**
  - Fuel rods extracted from 7 different fuel assemblies



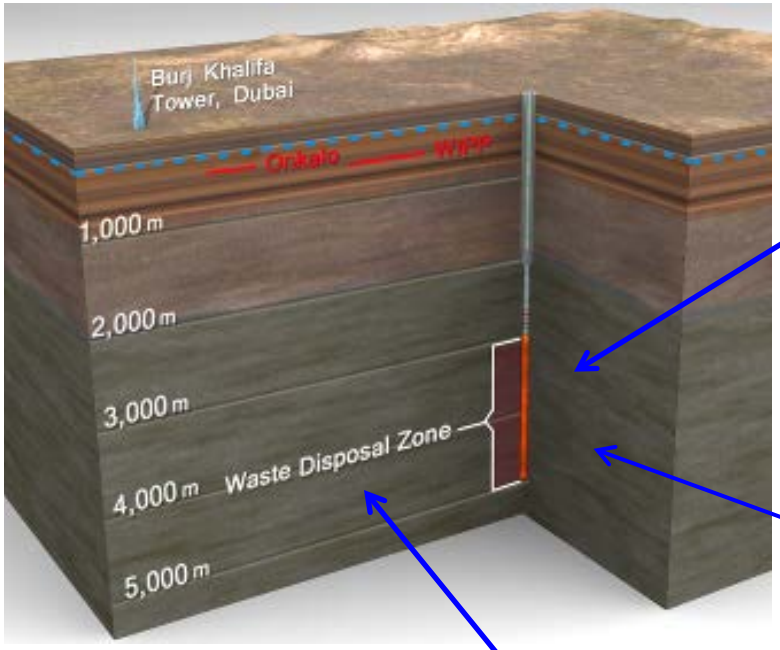
NAC LWT basket for shipping rods

Deep Borehole Disposal Concept: Why Deep Borehole Disposal?

- **Potential for robust isolation**
- **Gives DOE the flexibility to consider options for disposal of smaller waste forms in deep boreholes**
  - Potentially earlier disposal of some wastes than might be possible in a mined repository
  - Possible reduced costs associated with projected treatments of some wastes
- **Several DOE-managed small waste forms are potential candidates for deep borehole disposal (SNL 2014)**
  - Cesium and strontium capsules. 1,936 cesium and strontium capsules stored at the Hanford Site
  - Untreated calcine HLW currently stored at INL in sets of stainless steel bins within concrete vaults
  - Salt wastes from electrometallurgical treatment of sodium-bonded fuels could be packaged in small canisters as they are produced
  - Some DOE-managed SNF currently stored in pools at INL and SRS

Deep Borehole Disposal Concept – Safety and Feasibility Considerations

Long-Term Waste Isolation (hydrogeochemical characteristics)



Waste emplacement is deep in crystalline basement

- At least 1,000 m of crystalline rock (seal zone) overlying the waste disposal zone
- Crystalline basement within 2,000 m of the surface is common in many stable continental regions

Crystalline basement can have very low permeability

- limits flow and transport

Deep groundwater in the crystalline basement:

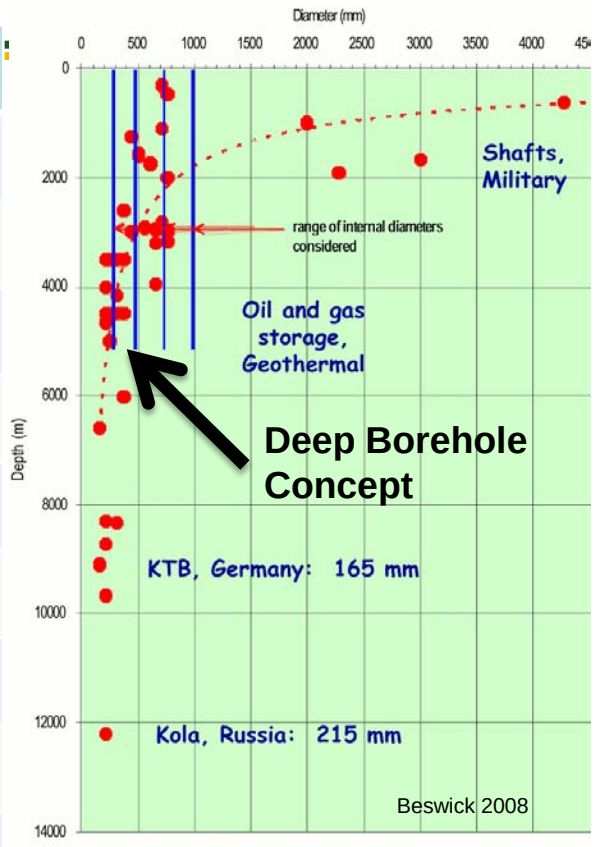
- Can have very long residence times – isolated from shallow groundwater
- Can be highly saline and geochemically reducing – enhances the sorption and limits solubility of many radionuclides
- Can have density stratification (saline groundwater underlying fresh groundwater) – opposes thermally-induced upward groundwater convection

Used Fuel Disposition

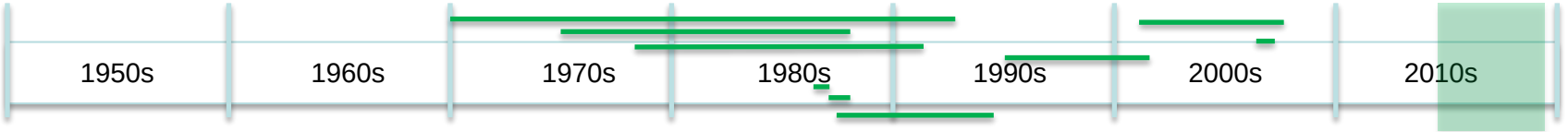
Deep Crystalline Drilling

Site	Bores	Location	Years	Depth [km]	Diam* [in]	Purpose
Kola SG-3	1	NW USSR	1970-1992	12.2	8½	Geologic Exploration + Technology Development
Fenton Hill	3	New Mexico	1975-1987	3, 4.2, 4.6	8¾, 9⅞	Enhanced Geothermal
Urach-3	1	SW Germany	1978-1992	4.4	5½	Enhanced Geothermal
Gravberg	1	Central Sweden	1986-1987	6.6	6½	Gas Wildcat in Siljan Impact Structure
Cajon Pass	1	California	1987-1988	3.5	6¼	San Andreas Fault Exploration
KTB	2	SE Germany	1987-1994	4, 9.1	6, 6½	Geologic Exploration + Technology Development
Soultz-sous-Forêts GPK	3	NE France	1995-2003	5.1, 5.1, 5.3	9⅝	Enhanced Geothermal
SAFOD	2	Central California	2002-2007	2.2, 4	8½, 8¾	San Andreas Fault Exploration
Basel-1	1	Switzerland	2006	5	8½	Enhanced Geothermal

*borehole diameter at total depth



Deep Borehole Field Test DBFT



Used Fuel Disposition

Objectives of the Deep Borehole Field Test

Synthesize field test activities, test results, and analyses into a comprehensive evaluation of concept feasibility

Evaluate site

Design and construct characterization borehole then field test borehole

Develop and test systems for handling, emplacing, and retrieving WPs

Design and test WPs

Emplacement hazard analysis

Characterize overlying sediments, fluids, and hydrologic conditions

Design seal system

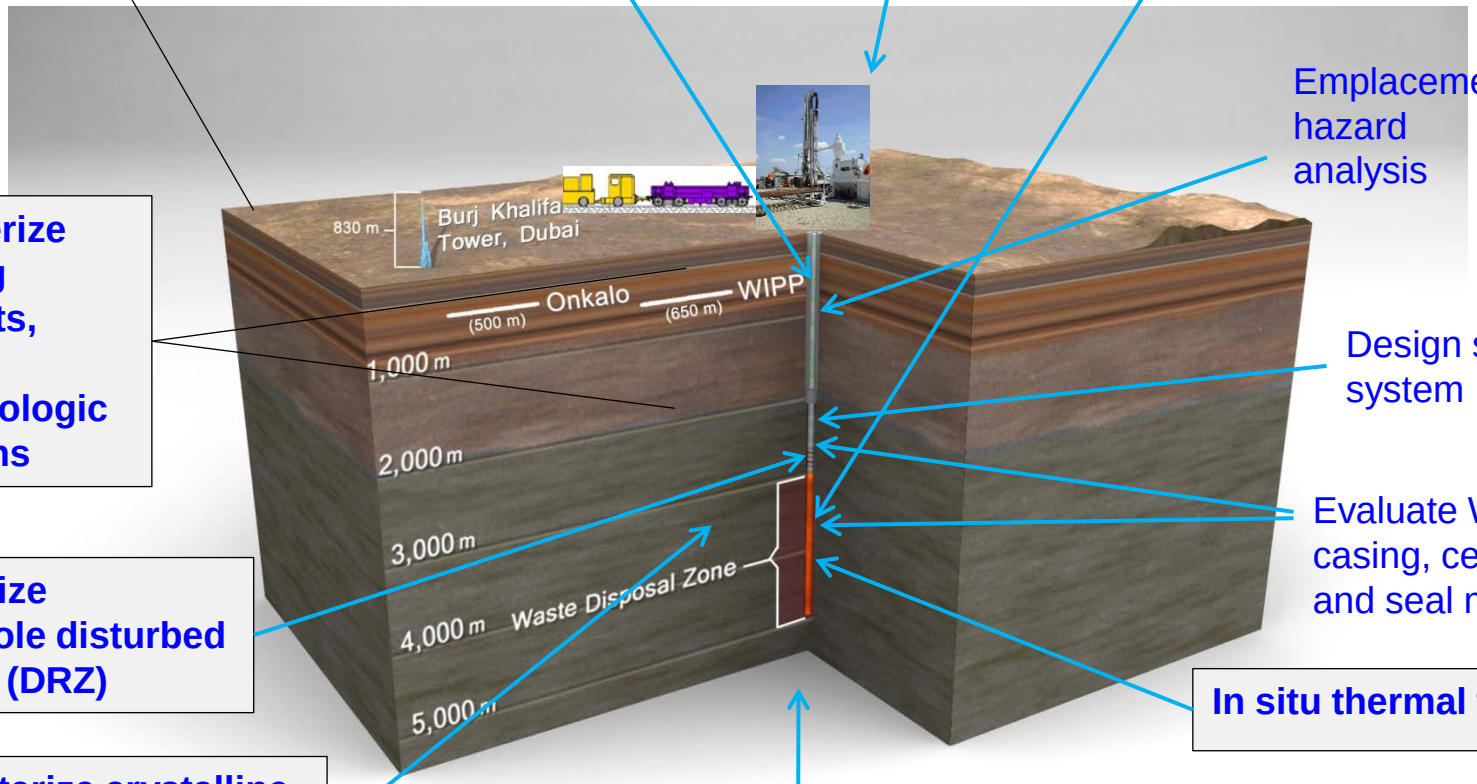
Evaluate WP, WF, casing, cement, and seal materials

Characterize the borehole disturbed rock zone (DRZ)

In situ thermal test

Characterize crystalline basement, fluids, and hydrologic conditions

Assess post-closure safety



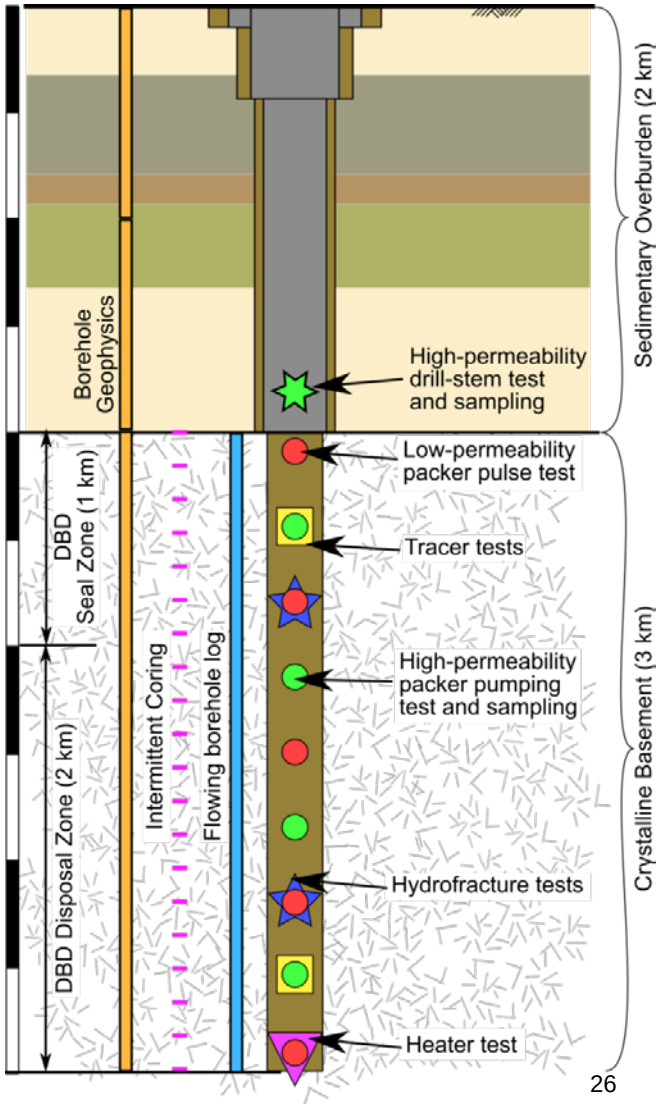
In no case will the US Government place or otherwise have nuclear material, waste, or other waste disposal material on the property (RFP 2015).

Used Fuel Disposition

Characterization Borehole (CB)

- Not all Char. Methods Included
  - Surface geophysics
  - Testing sedimentary sequence
  - No need to demonstrate in DBFT
- 8.5” diam. ~geothermal experience
- Core 150 m of Bedrock Section
- Testing/Sampling After Completion
  - Packer tool via work-over rig
  - At limits of current technology

Borehole designed to maximize likelihood of good samples

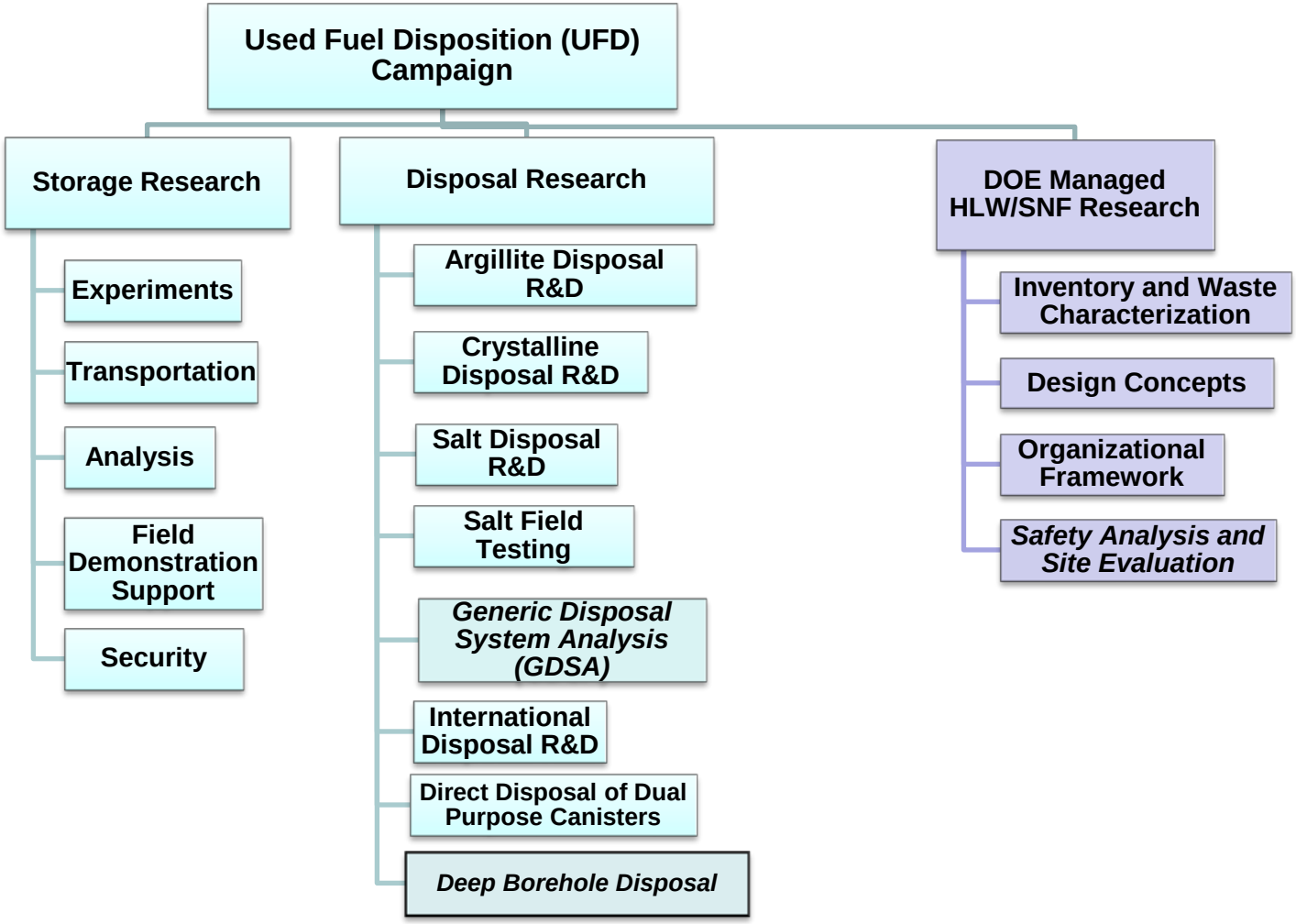


Deep Borehole Field Test
Acquisition of Site and Services

- **Request for Information solicited input and interest from States, local communities, individuals, private groups, academia, or any other stakeholders who were willing to host a DBH Field Test**
  - Posted to via Federal Business Opportunities (FedBizOps, www.fbo.gov) on October 24, 2014
  - Responses received on December 8, 2014 (45 days)
- **Sources Sought and Draft Request For Proposal (RFP)**
  - Posted on FedBizOps on April 7, 2015
  - Feedback received on May 5, 2015
- **Final RFP (Solicitation Number DE-SOL-0008071)**
  - Pre-solicitation notice posted on June 22, 2015
  - Final RFP posted on FedBizOps on July 9, 2015
  - Proposals due and received September 23, 2015
- **The DOE Awarded Contract to the team led by Battelle Memorial Institute**
  - Early January 2016
  - Local community opposed the DBFT being sited there
  - DOE and Battelle team are in process of finding a new site

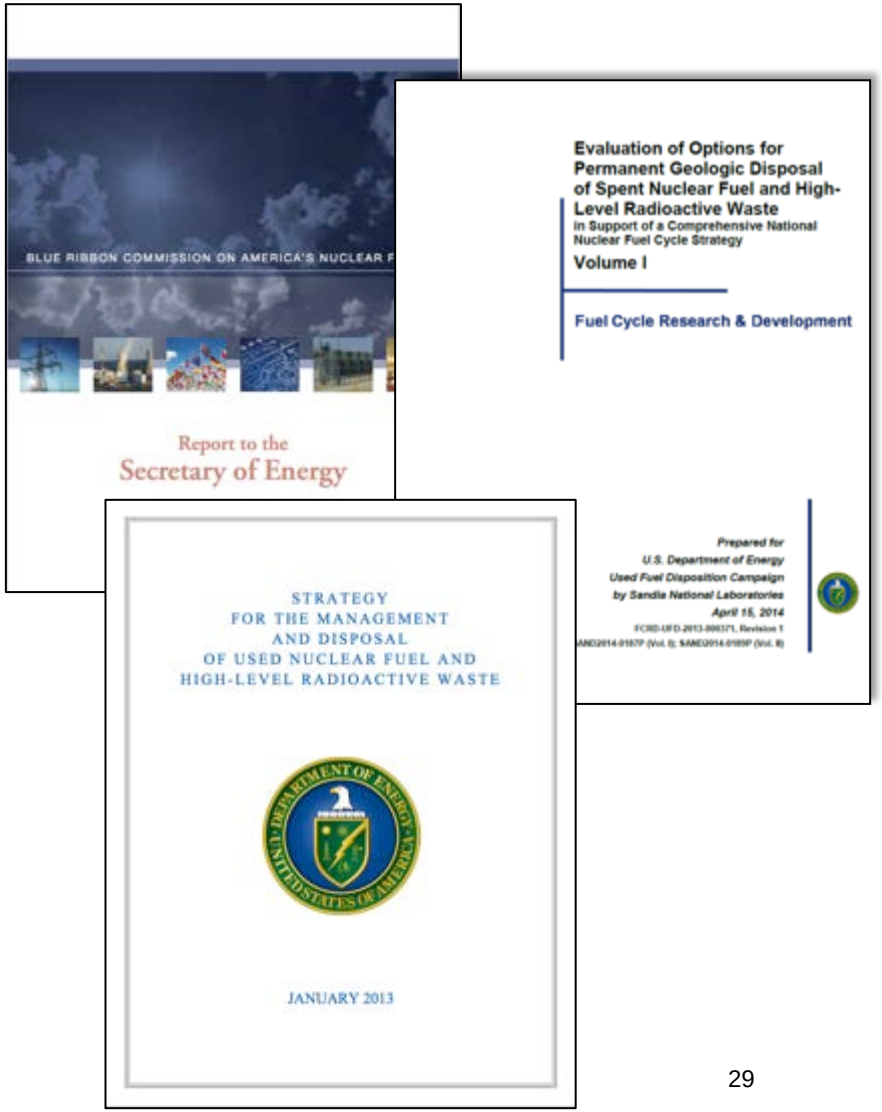
Used Fuel Disposition

DOE-Managed Spent Nuclear Fuel and High Level Waste Research Integration



Underlying Documents

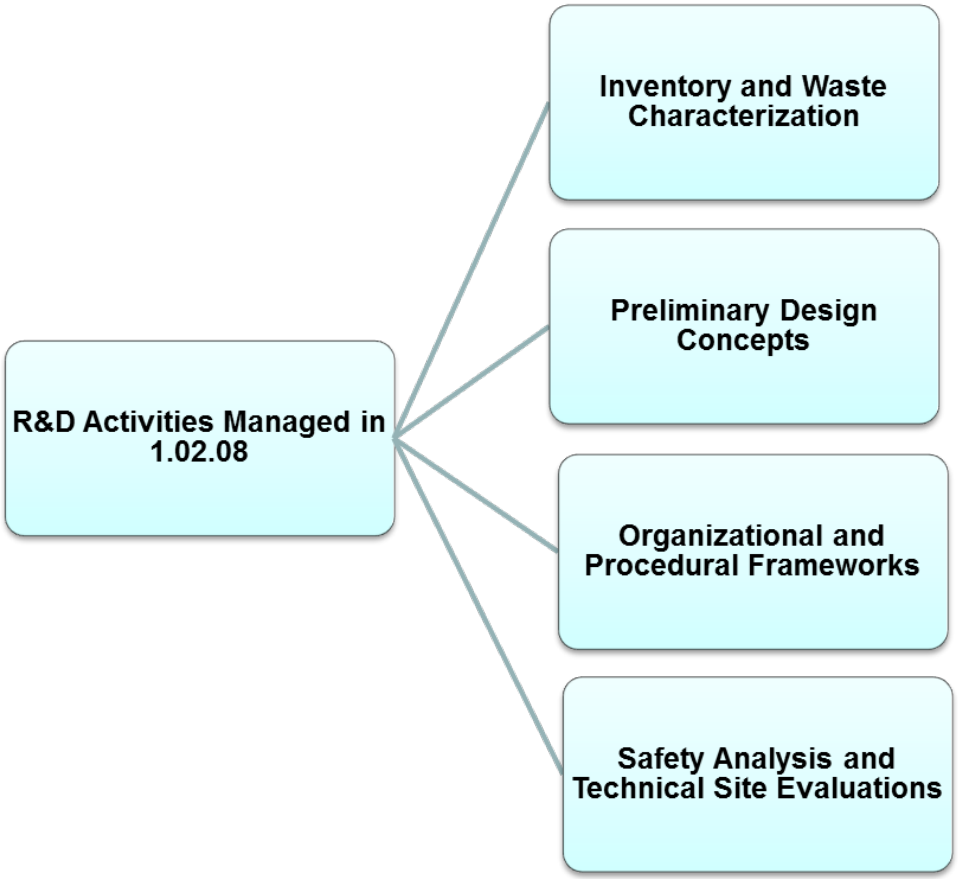
- **January 2012 Blue Ribbon Commission (BRC) on America's Nuclear Future report to the Secretary of Energy**
  - Recommends review of "single repository" policy, whereby defense-related and commercial wastes are co-mingled
- **2013 Administration releases "Strategy for the Management and Disposal of Used Nuclear and High-Level Radioactive Waste"**
  - Follows the BRC Report's recommendation to review repository policy
- **April 2014 UFD report "Evaluation of Options for Disposal…"**
  - Concludes that both commingled and separate repositories are technically feasible



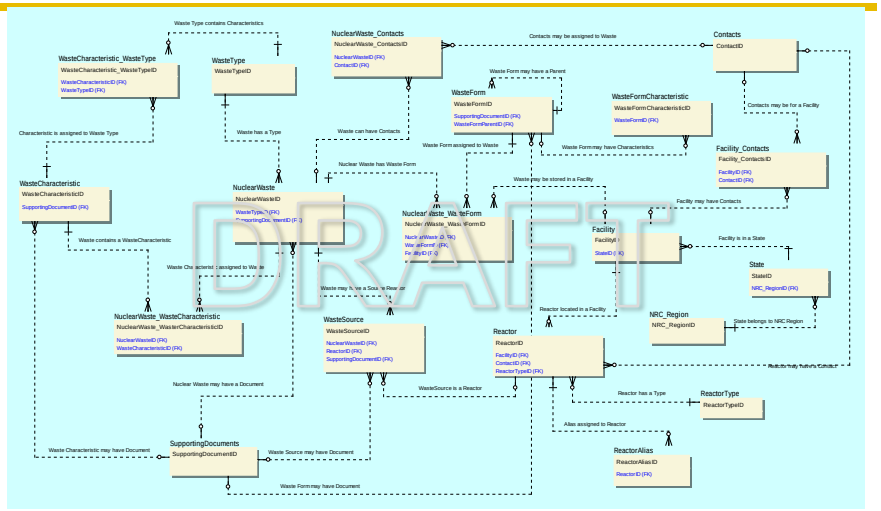
Underlying Documents

- **October 2014 DOE report "Assessment of Disposal Options…"**
  - Recommends that the DOE begin implementation of a phased, adaptive, and consent-based strategy with development of a separate repository for some DOE-managed HLW and SNF
  - Also recommends the DOE retain flexibility to consider deep borehole disposal of some smaller DOE-managed waste forms
- **March 2015 DOE report "…Separate Disposal of Defense High-Level Radioactive Waste"**
  - Presents the basis for a decision in the context of the Nuclear Waste Policy Act

Structure of Technical Work Areas



Inventory and Waste Characterization: Complete & Populate Online Waste Library (OWL)

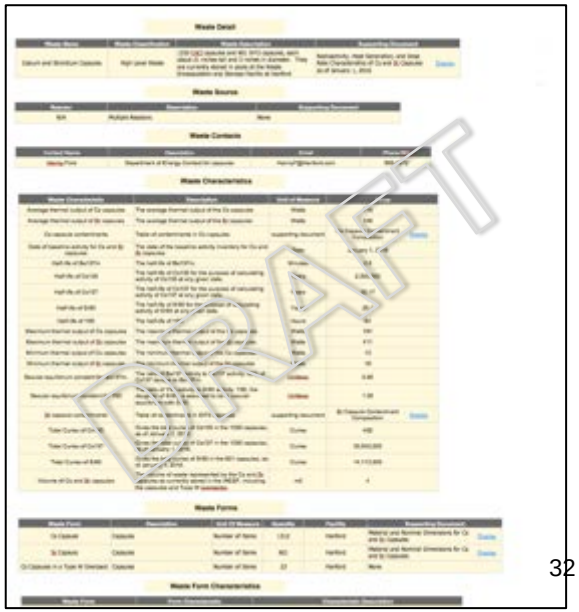


SCOPE:

The on-line waste library (OWL) will be implemented to contain detailed **cross-linked information**, both **technical** and **organizationa**l, regarding DOE-managed high-level waste (HLW) and spent nuclear fuel (SNF) (D-wastes), and other DOE-managed radioactive wastes that are likely candidates for deep geologic disposal, with **links to the current supporting documents** for the data (where possible).

OBJECTIVES:

- Finalize the initial design of the information system that implements the database
- Implement the database onto a platform with account access available to a prototype group (i.e., DOE and National Laboratory participants)
- Populate the database with at least a portion of the primary technical data for the waste types/forms.

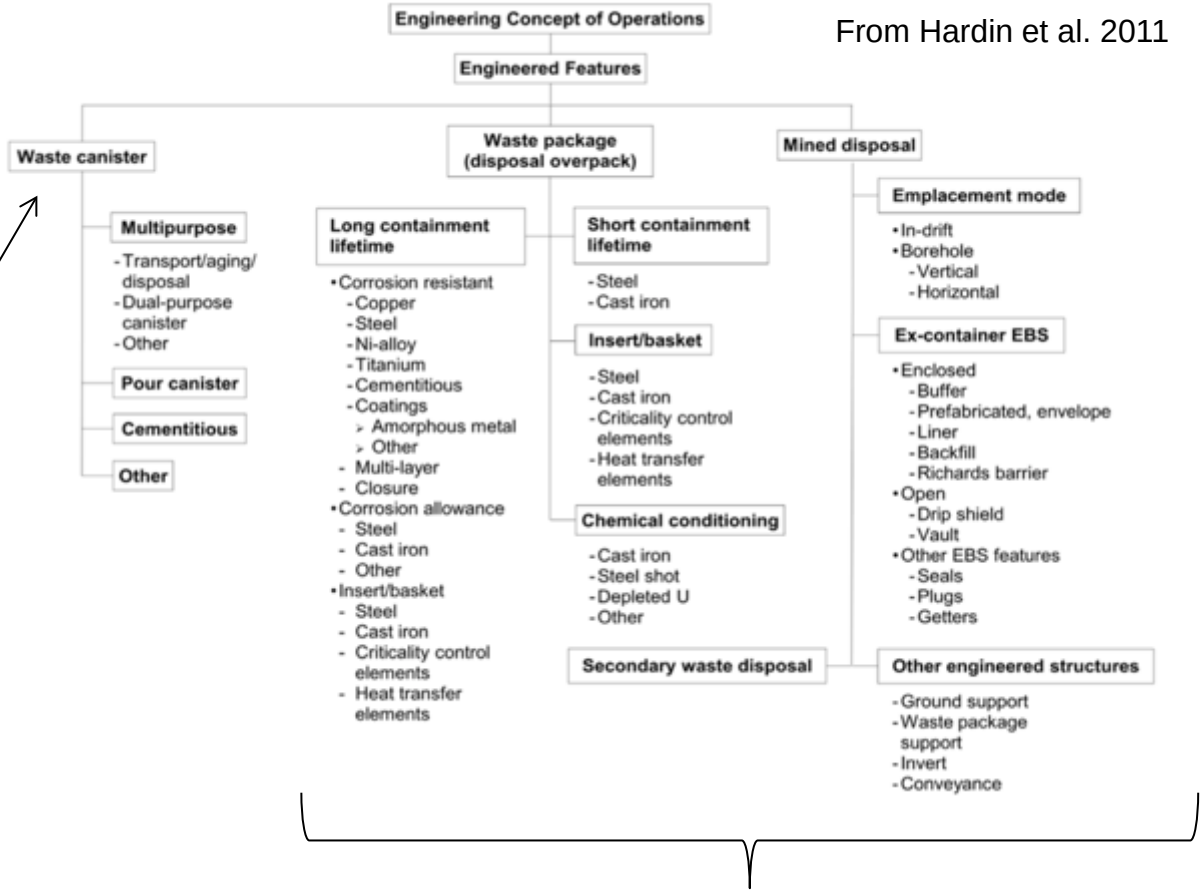


Creating a Design Concept

From Hardin et al. 2011

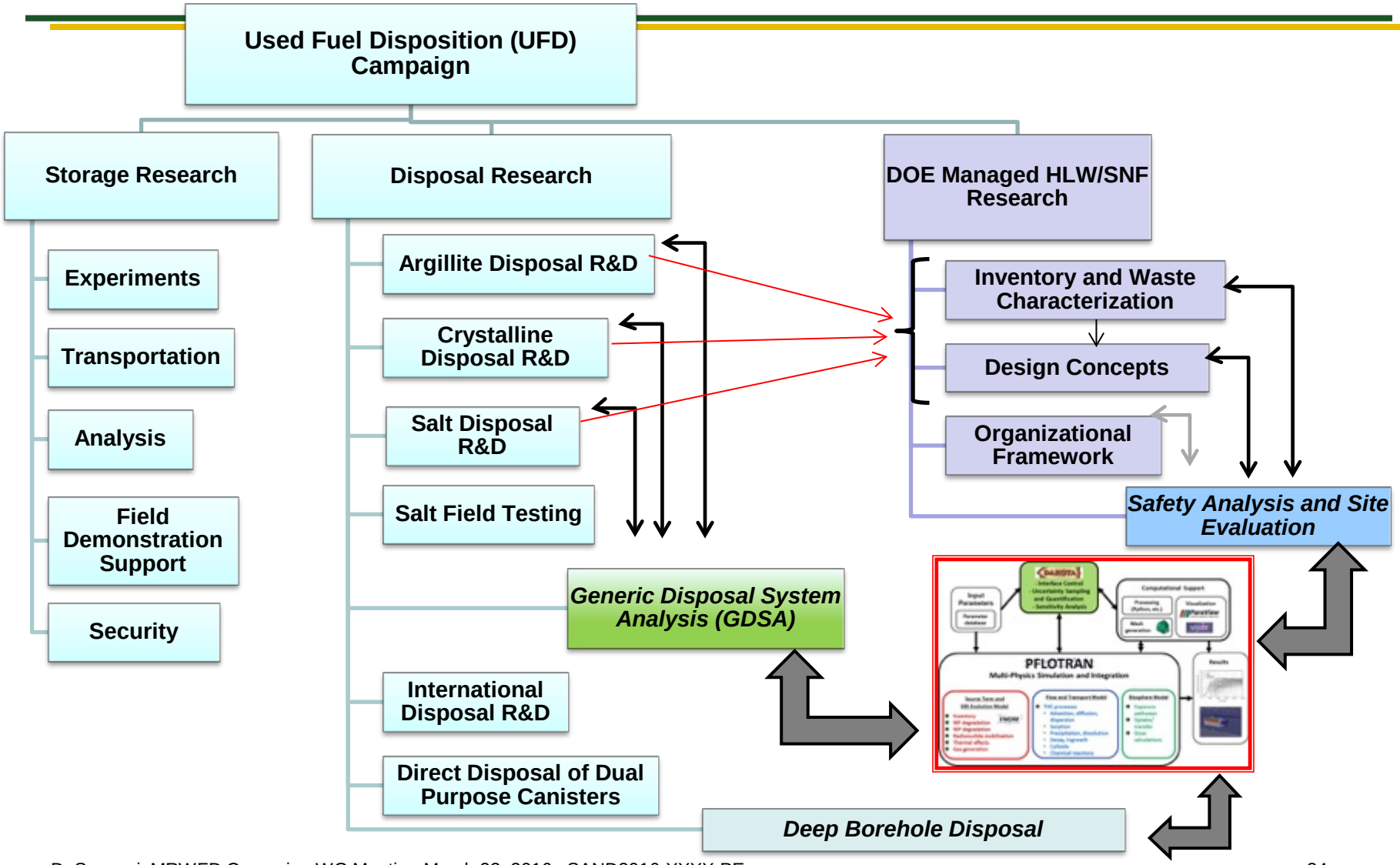
Inventory
- Dimensions
- Quantity
- Thermal output

Design Concepts
- Packing spacing



Used Fuel Disposition

Integration Linkages

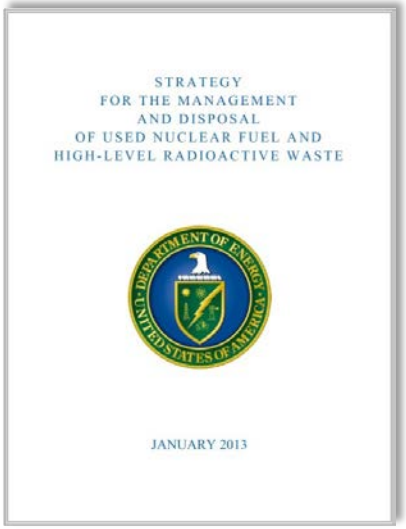


UFD R&D Outlook and Conclusions

Long-Term UFD R&D Campaign Objectives

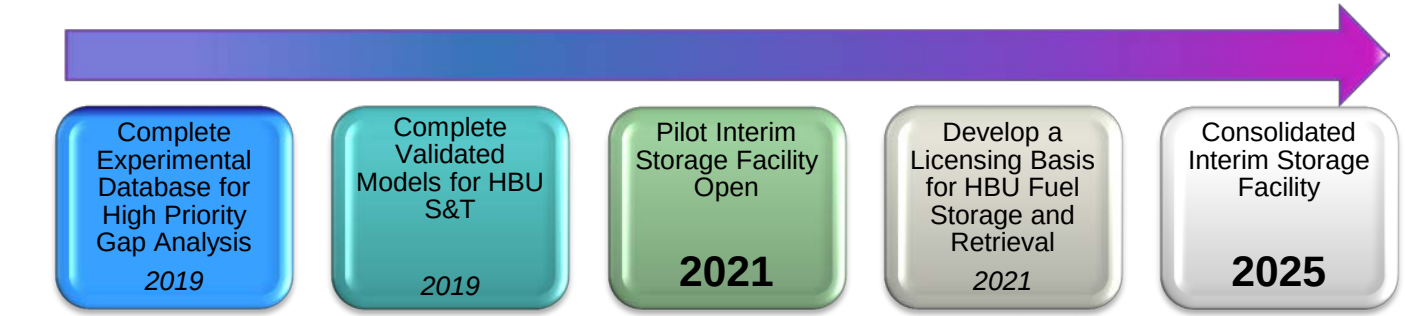
- Support the implementation of a full-scale NRC-licensed confirmatory storage demonstration facility, in collaboration with industry
- Develop the technical basis necessary to support eventual transportation of used nuclear fuel, including high-burnup fuel
- Support the Nuclear Fuel Storage and Transportation Planning Project with implementation of integrated storage, transportation, and disposal concepts

Support the Administration's 2013 *Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste*

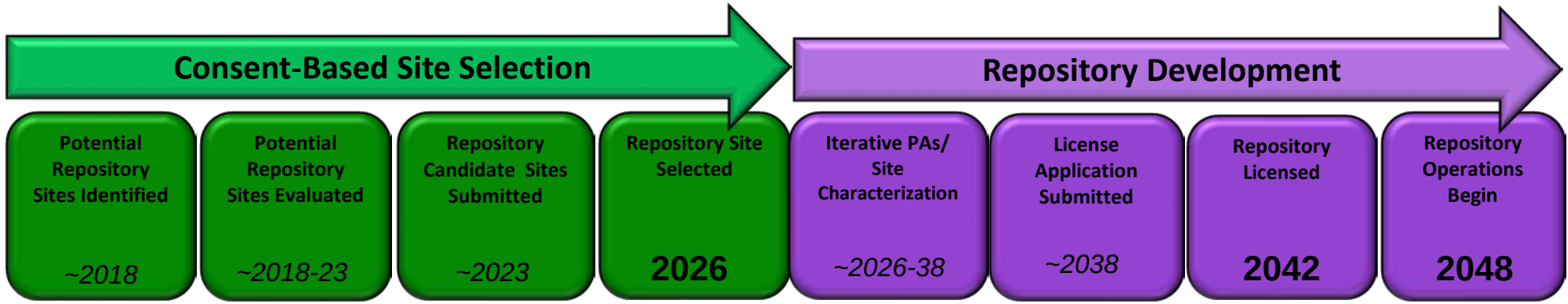


Used Fuel Disposition

R&D Path to Support DOE Waste Management Strategy



Storage & Transportation R&D supports 2025 Consolidated Interim Storage Facility



Approximate target dates (in *italics*) needed to meet milestones (in bold) set out in the 2013 DOE *Strategy*

Disposal R&D supports 2026 Repository Site Selection and 2042 Repository Licensing

Used Fuel Disposition R&D Concluding Remarks and Outlook

- **Will the current R&D Portfolio achieve near-term objectives?**
  - For Storage and Transportation R&D: Yes
    - *Storage demonstration project is still in very early stages*
    - *Uncertainty remains about where sister rods will be shipped and tested*
  - For Disposal R&D: yes, but only for generic concepts
    - *Significant accomplishments are within reach in disposal R&D*
      - E.g., increased confidence in engineered barrier designs and robust natural system performance, improved system-level modeling framework
    - *Field demonstration of deep borehole disposal is achievable*
- **Will the current R&D Portfolio achieve the long-term strategic goals?**
  - For Storage and Transportation R&D: uncertain
    - *Commitment to storage demonstration and RD&D must be sustained for many years*
  - For Disposal R&D: yes, but only with resolution of national policy issues
    - *R&D is needed, but is not sufficient to address disposal issues*

Used Fuel Disposition

Contact Information

David Sassani
Sandia National Laboratories
MS 0747, PO Box 5800
Albuquerque, NM 87185-0747
Tel: 505 284 8967
Email: dsassan@sandia.gov

BACKUP MATERIALS

DOE-NEI PRIORITIES REVIEW
HIGHLIGHTS

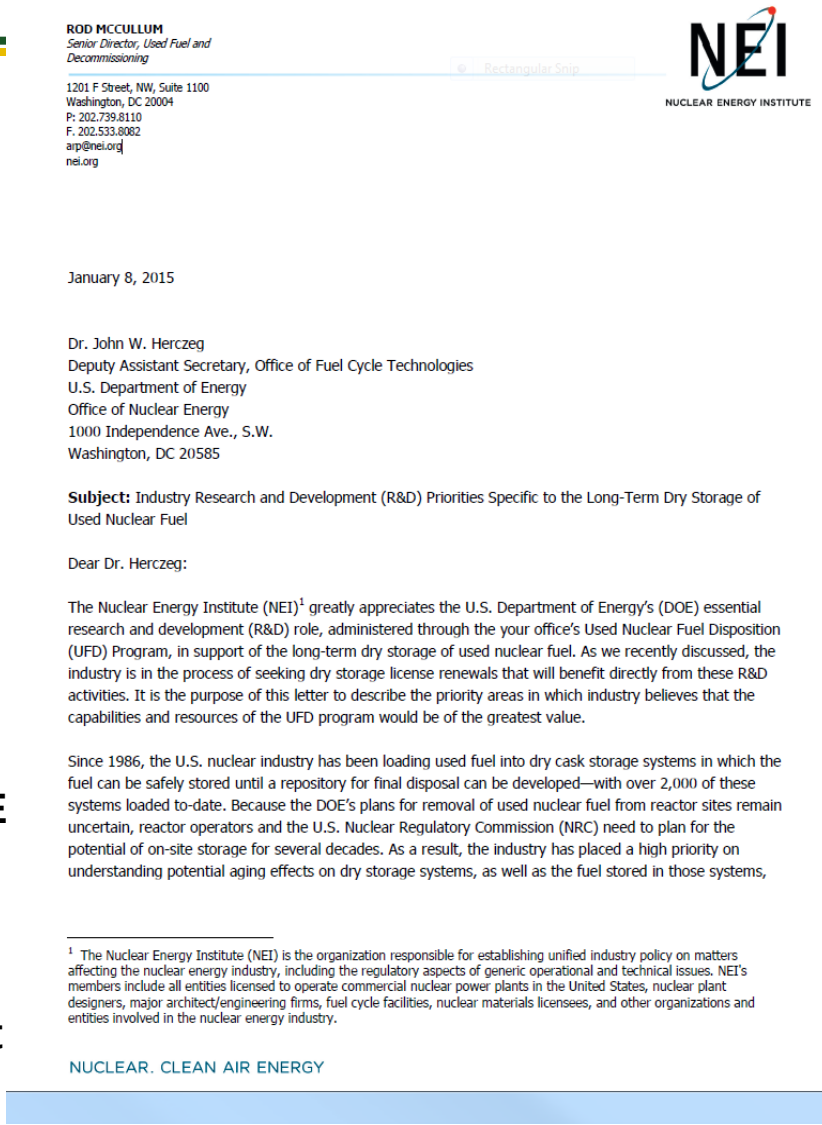
DOE and the Nuclear Energy Institute (NEI) hold periodic meetings to discuss relative priorities associated with the DOE UFD ST R&D program and industry needs.

- **NEI partners include: EPRI, utilities**
- **DOE partners include: Lab team and NEUP**

There is good consistency relative to identified priorities in the UFD program based on our technical gaps and prioritization studies compared with industry needs.

The major priorities being addressed by both DOE industry are:

- **Closing the gaps on cladding behavior**
- **Addressing stress corrosion cracking in spent dry storage stainless steel canisters**



ROD MCCULLUM
Senior Director, Used Fuel and Decommissioning

1201 F Street, NW, Suite 1100
Washington, DC 20004
P: 202.739.8110
F. 202.533.8082
arp@nei.org
nei.org

NUCLEAR ENERGY INSTITUTE

January 8, 2015

Dr. John W. Herczeg
Deputy Assistant Secretary, Office of Fuel Cycle Technologies
U.S. Department of Energy
Office of Nuclear Energy
1000 Independence Ave., S.W.
Washington, DC 20585

Subject: Industry Research and Development (R&D) Priorities Specific to the Long-Term Dry Storage of Used Nuclear Fuel

Dear Dr. Herczeg:

The Nuclear Energy Institute (NEI)[1] greatly appreciates the U.S. Department of Energy's (DOE) essential research and development (R&D) role, administered through the your office's Used Nuclear Fuel Disposition (UFD) Program, in support of the long-term dry storage of used nuclear fuel. As we recently discussed, the industry is in the process of seeking dry storage license renewals that will benefit directly from these R&D activities. It is the purpose of this letter to describe the priority areas in which industry believes that the capabilities and resources of the UFD program would be of the greatest value.

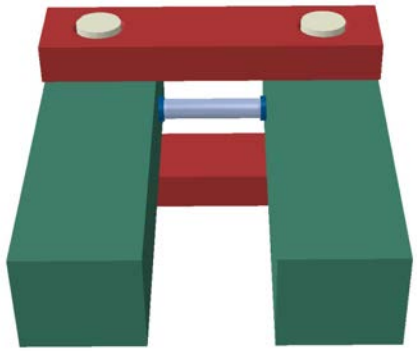
Since 1986, the U.S. nuclear industry has been loading used fuel into dry cask storage systems in which the fuel can be safely stored until a repository for final disposal can be developed—with over 2,000 of these systems loaded to-date. Because the DOE's plans for removal of used nuclear fuel from reactor sites remain uncertain, reactor operators and the U.S. Nuclear Regulatory Commission (NRC) need to plan for the potential of on-site storage for several decades. As a result, the industry has placed a high priority on understanding potential aging effects on dry storage systems, as well as the fuel stored in those systems,

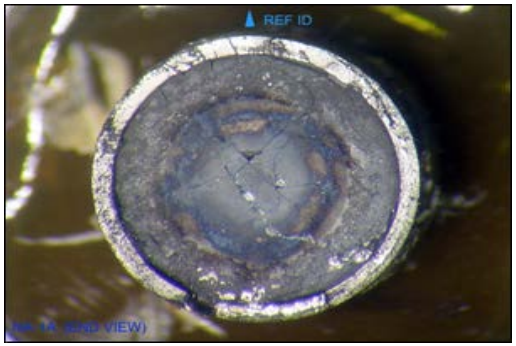
[1] The Nuclear Energy Institute (NEI) is the organization responsible for establishing unified industry policy on matters affecting the nuclear energy industry, including the regulatory aspects of generic operational and technical issues. NEI's members include all entities licensed to operate commercial nuclear power plants in the United States, nuclear plant designers, major architect/engineering firms, fuel cycle facilities, nuclear materials licensees, and other organizations and entities involved in the nuclear energy industry.

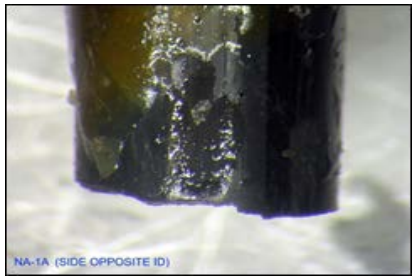
NUCLEAR. CLEAN AIR ENERGY

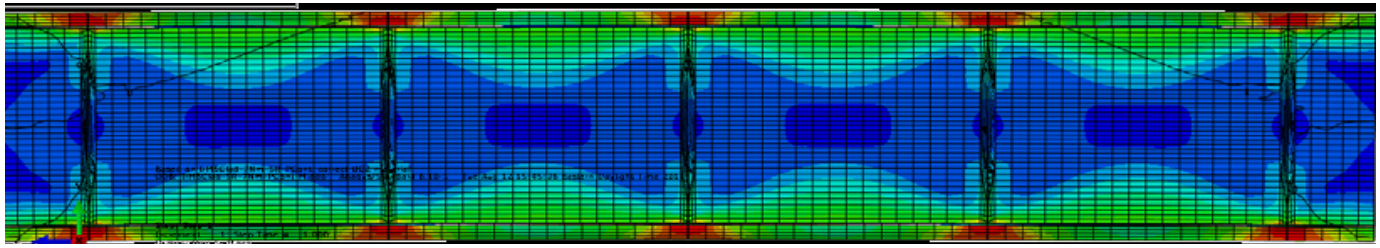
Storage and Transportation Research FY15 Highlights

- **High-burnup cladding performance**
  - Ongoing testing and modeling (ORNL, ANL) to continue to provide information about cladding performance
  - ORNL hot cell tests show importance of pellet-pellet and pellet-clad bonding, allowing rods to withstand greater bending fatigue than anticipated







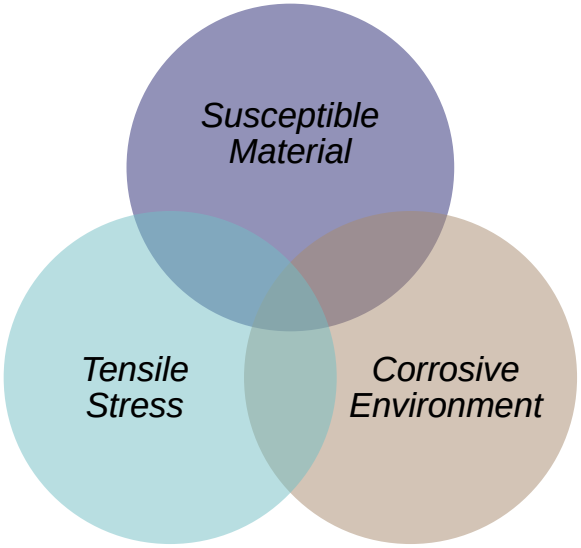


Storage and Transportation Research FY15 Highlights (cont.)

Stress Corrosion Cracking of Stainless Steel Storage Canisters

Questions to be answered:

1. Will a chloride bearing environment form on the surface of the containers?
2. Is the material of construction for fielded interim storage containers susceptible?
3. Is there a sufficiently large tensile stress to support crack initiation and propagation in fielded interim storage containers?



Preliminary Observations:

Be prepared to inspect the canister surfaces

Storage and Transportation FY15 Highlights (cont.)

Is there a Corrosive Environment for Stress Corrosion Cracking?

Dust sampling at Calvert Cliffs, Hope Creek, and Diablo Canyon

Ion	EPRI #1 filter	EPRI #1 pad	EPRI #4 filter	EPRI #4 pad
Na^{+}	19.2	14.8	n.d.	11.3
K^{+}	18.1	13.7	1.05	7.75
Ca^{+2}	77.1	20.6	24.1	153
Mg^{+2}	16.9	6.0	1.95	17.6
F^{-}	0.30	0.61	n.d.	n.d.
Cl^{-}	5.64	n.d.	n.d.	3.10
		9.09	4.34	14.2
		51.5	48.0	291
		2.05	0.45	n.d.
		118	80	498

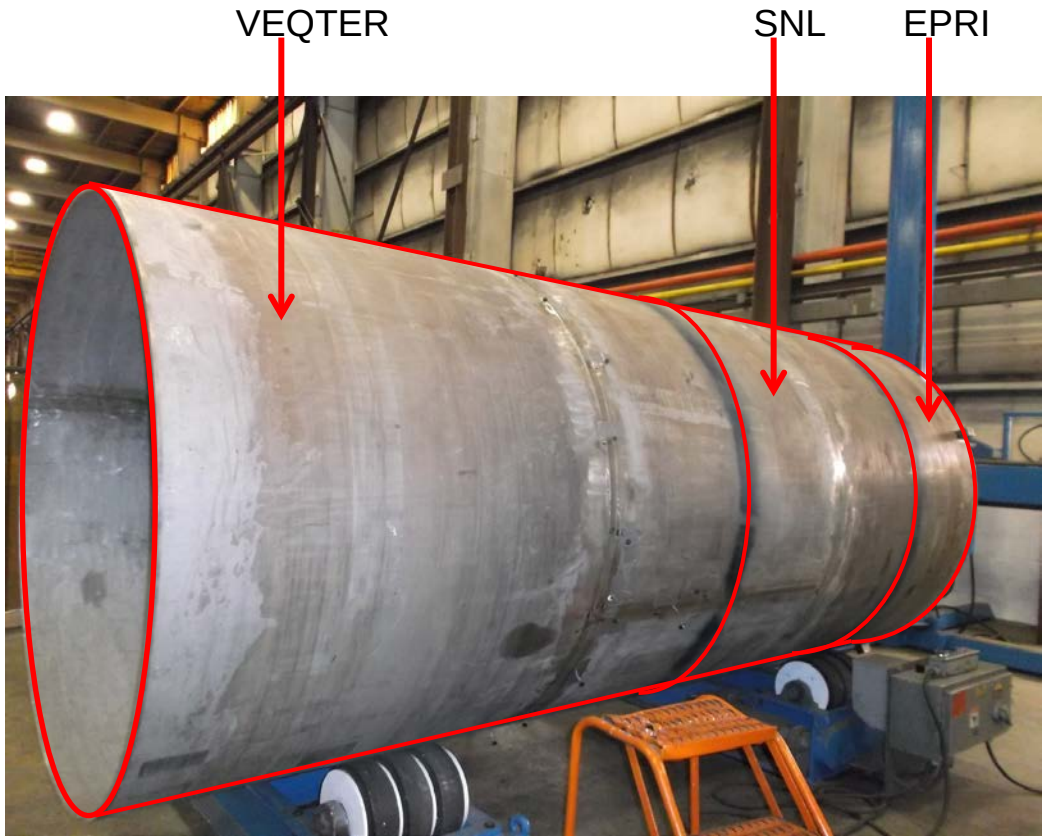
Results

Data: Chloride bearing salts are likely in some locations

Storage and Transportation Research FY15 Highlights (cont.)

Are there Tensile Stress Conditions for Stress Corrosion Cracking?

Full-diameter canister mockup undergoing testing at VEQTER in the UK



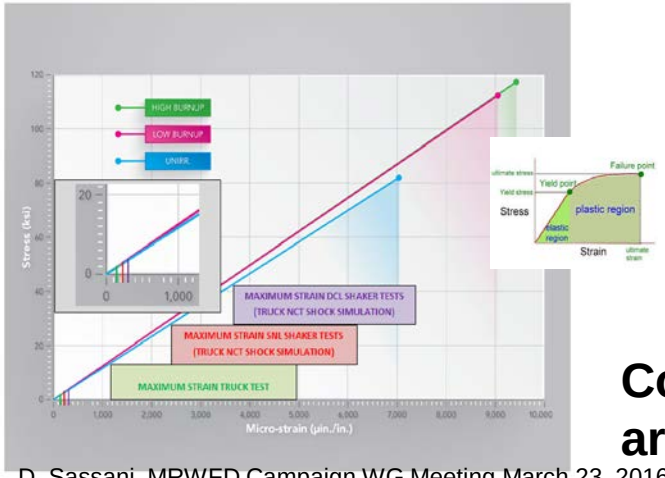
FY16 work will quantify residual stress at welds, weld repairs, heat affected zones, and away from welds.

Storage and Transportation FY15 Highlights (cont.)

Loading on Fuel Assemblies During Normal Conditions of Transport

Three series of tests using a surrogate PWR assembly

- Tests on a vertical acceleration shaker table at SNL
- Over-the-road truck test
- Tests on a commercial seismic shaker with six degrees of motion



Conclusions: strains during normal transport are far below yield and failure limits for cladding

Used Fuel Disposition

UFD Management & Integration

OBJECTIVES:

- Provide program management, integration, and technical support for the Used Fuel Disposition Campaign. Provide technical coordination for UFDC R&D efforts at participating laboratories under the FCR&D Program.
- Interact with the Nuclear Energy Advisory Committee, the Nuclear Waste Technical Review Board, and other internal and external review and advisory groups as needed. Support DOE NE University Programs as needed.

SCOPE:

- NTD labor
- Admin and technical staff support labor
- Project controls support labor
- Travel
- CAM Labor to support campaign-level planning & management

UFD Storage and Transportation Research
Experiments

OBJECTIVES:

Conduct separate effects tests and small-scale tests that have been identified in the Used Nuclear Extended Storage and Transportation Research and Development Review and Plan (FCRD-UFD-2014-000050). Develop data necessary to further understand fundamental materials degradation issues associated with components (including the fuel) of long-term storage systems (including the baseline sister pin testing) and subsequent transportation of used nuclear fuel. This data also serves an important benchmarking function for the validation and verification of predictive models.

SCOPE:

Support measurement of data to determine the Ductile-Brittle Transition Temperature (DBTT) for various high burnup cladding materials lower temperatures (e.g., 350º C); conduct in-cell bend tests on lower burnup sections of high burnup spent fuel; conduct SCC investigations on full-scale (diameter) mockup in collaboration with industry and support ASME committee work on SCC, conduct thermohydraulic testing of a full-scale BWR surrogate assembly at pressures and temperatures relevant to existing licensed dry storage canister designs.

UFD Storage and Transportation Research
Transportation

OBJECTIVES:

Assess the retrievability of used fuel after long term storage and evaluate the ability to transport high-burnup fuel.

1. Extend the truck and rail Normal Conditions of Transport loading investigations to planning for a full-scale rail test plan.
2. Integrate results of high burnup rod testing at ORNL, assembly modeling at PNNL, and assembly testing at SNL to strengthen the technical justification for eventual UNF transport.

SCOPE:

- Continue Normal Conditions of Transport (NCT) analysis efforts, focusing on planning to conduct a full-scale rail test. Activities include: planning for the availability of a full-scale cask and associated hardware including surrogate assemblies, development of a comprehensive test plan to populate a representative set of rail shock and vibration data. Integrate existing data across the labs to strengthen the technical basis for safe transport of Used Nuclear Fuel.

UFD Storage and Transportation Research
Analysis

OBJECTIVES:

Conduct analyses, integrate experimental data, and develop the technical basis for extended long term storage and subsequent transportation of nuclear used fuel. Provide thermal and mechanical computations for operational conditions related to long term storage and subsequent transportation of used nuclear fuel. In addition, develop separate phenomenological models to predict behavior of specific high priority gap technical issues (e.g., stress corrosion cracking) that can be integrated into existing larger platform models. The experimental data obtained will provide an important benchmarking basis for justifying the predictive value of the models and analyses.

SCOPE:

- Conduct thermal analyses for NAC and TN-40 storage systems
- Complete thermal profile analyses for the DOE/EPRI High Burnup Spent Fuel Data Project
- Refine uncertainty quantification methods to support understanding of specific parameter uncertainties and margins of safety in the development of a SCC methodology to support the ASME committee work.

UFD Storage and Transportation Research
Field Demonstration Support

OBJECTIVES:

Support the successful implementation of the DOE/EPRI High Burnup Spent Fuel Data Project and associated R&D to support the project. The lab support is focused on technical interactions with the DOE and DOE contractor team, assessing the balance between advancing the science of storage with licensing risk, support Sister Pin Test Plan development of baseline experiments, evaluation of sensor and monitoring technologies to support data collection for the demonstration project, and interfacing on a regular basis with the NRC on the technical aspects of the project.

SCOPE:

Scope includes identification and sequencing of required near-term testing, facility capabilities and necessary up-grades, planning for sister rod acquisition, in-service inspection, and integration of near-term testing with confirmatory in-situ monitoring and inspection. This work will include collaboration with industry on obtaining and analyzing in-situ environmental data associated with used fuel SS canister corrosion and stress corrosion cracking, including ultrasonic testing.

Used Fuel Disposition

Sister Rod Data Gaps to be Considered

Detailed planning to address data that need to be obtained from sister rod experiments is currently under way. This test plan will be widely reviewed by the DOE, DOE labs, the NRC, and industry. Examples of tests that may be conducted include:

- **Fuel rod internal pressures**
- **Mechanical properties of the fuel rod cladding**
- **Pellet-clad interaction (PCI)**
- **Cladding – annealing of radiation damage**
- **Cladding – H_2 effects, reorientation and embrittlement**
- **Cladding – oxidation**
- **Cladding – creep**

Donor Assemblies and Fuel Rods

	Fuel Information																								
Assembly	30A					5K7				6U3							3F9			3D8		3A1 (2 Cycles)		F35 (4 Cycles)	
Cladding and initial enrichment	M5 Cladding, 4.55 wt% U-235					M5 Cladding, 4.55 wt% U-235				Zirlo Cladding, 4.45 wt% U-235							Zirlo Cladding, 4.25 wt% U-235			Zirlo Clading 4.2 wt% U-235		Low-Tin Zircaloy-4 Clad, 4 wt% U-235		Zircaloy-4 Cladding 3.59 wt% U-235	
Sister Rod	G9	K9	D5	E14	P2	P2	C5	K9	D14	I7	M9	K9	L8	O5	M3	P16	N5	D7	P2	E14	B2	B16	F5	P17	K13
Key Characteristics	Sister rod to assembly rod in assembly 57A lance position - close proximity to peak (hotest) rod position (I-7) in the cask	Sister rod to assembly rod in assembly 57A lance position - close proximity to peak (hotest) rod position (I-7) in the cask	D5 & E14 rods represents locations next to guide tubes that saw burnable poisons (E14) and ones that saw none (D5), this will influence power output during irradiation so pins are expected to have different characteristics even though they have burnups that are very close	See Rod D5	Next to area with core baffle jetting; based on final location in core for last irradiation cycle	Next to area with core baffle jetting; based on final location in core for last irradiation cycle being close to the canister edge in 3K7	Equivalent to the rod with peak burnup in othe sister assembly (3K7)	Sister rod to rod with proximity to thermocouple in assembly (3K7)	Approximately average assembly burnup	This rod mimics the 3 rods that will be isolated and heated to mimic conditions in the cask	Rod is next to a thermocouple lance position	Rod is next to a thermocouple lance position	Rod is next to a thermocouple lance position	Baseline rod at close to max burnup	Basline rod for comparison to 3U4 near max burnup in middle ring zone	Baseline rod for comparison to rod that should see fastest cooling rate in 3U6 (outer zone)	Pin for baseline parameters (selected based on matchup with sister assemblies)	Approximately average assembly burnup for baseline parameters	Approximate lowest burnup in assembly and close to edge of assembly	Highest burnup rod in assembly	Close to lowest burnup rod in assembly (selected based on pulling restriction)	Lowest burnup rod in assembly; reasonably close to outer edge of assembly	Highest burnup rod in assembly; reasonably close to center of assembly	Edge rod (likely to be of most interest from science standpoint)	Inner region rod for comparison against other Zirc-4 rods
Planned Testing	Isolation/Heated	PIE	PIE	PIE	PIE	PIE	PIE	Isolation/ Heated	PIE	PIE	Isolation/ Heated	Isolation/ Heated	Isolation/ Heated	PIE	PIE	PIE	PIE	PIE	PIE	PIE	PIE	PIE	PIE	PIE	PIE
Sister Assemblies	57A	57A	57A	57A		5K6,3K7,5K1	5K6,3K7,5K1	5K6,3K7,5K1	5K6,3K7,5K1	3U4,3U9,3U6	3U4,3U9,3U6	3U4,3U9,3U6	3U4,3U9,3U6	3U4,3U9,3U6	3U4,3U9,3U6	3U4,3U9,3U6	4F1,3F6,6F2	4F1,3F6,6F2	4F1,3F6,6F2	5D9,5D5	5D9,5D5	0A4	0A4	None (F40)	None (F40)
Sister to this Rod in the Sister Assembly	I-7	I-7							C-4(5K6)	I-7(3U4); I-11(3U9); I-11(3U-6)	E-9(3U4)	K-9(3U9)	F-10(3U6)	C-5(3U4); O-13(3U9); C-13(3U6)	E-3(3U4)	B-2(3U6)	N-5(4F1); N-5(3F6); N-5(6F2)	D-7(4F1); D-7(3F6); D-7(6F2)		M-4(5D5); N-13(5D9)	P-16(5D5); B-16(5D9)	B-16	F-5		

Characterization and Testing	G9	K9	D5	E14	P2	P2	C5	K9	D14	I7	M9	K9	L8	O5	M3	P16	N5	D7	P2	E14	B2	B16	F5	P17	K13
Full-Length High Resolution Visual Examination	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Eddy Current Oxide Thicknes	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Eddy Current Clad Defects	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rod Bow Determination	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rod Length	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rod Profilometry	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Gamma Scan	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Neutron Radiography		X	X				X						X	X			X			X					
Thermal Heat Treatment for Hydride Reorientation	X							X			X	X	X												
Pin Puncture, Interal Rod Pressure, Fission Gas Sampling	X	x	X	X	X	X	X	X	X	X	X	X	X	X	X		X			X			X	X	
Fission Gas Analysis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X			X			X	X	
Isotopics (composition, burnup)	X		X	X	X			X		X	X			X	X		X								
Total Hydrogen in Clad	X	X	X	X	X			X		X	X			X	X		X								
Optical Microscopy	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X			X			X	X	
Optical Microscopy Hydrides	X	X	X	X	X		X	X	X	X	X	X	X	X	X		X			X			X	X	
SEM	X	X			X			X		X	X				X		X								
TEM	?							?		?	?						?								
FIB Mechanical Properties of rim, bond layer	X	X						X			X	X					X								
RCT	X	X	X		X		X	X	X	X	X			X			X								
CIRFT	X	X	X		X		X	X	X	X	X			X			X								
4-Point Bend	X	X	X		X		X	X	X	X	X			X			X								
Hardness Testing	X	X	X		X		X	X	X	X	X			X			X								
Fuel Density	X	X	X		X		X	X	X	X	X			X			X								
Retained Water on Clad	X	X						X		X	X												X	X	
Capture Fuel Fines from a Ruptured Pin					X									X											

Preliminary matrix for testing 25 sister rods

Considerations of budget relative to other high-priority technical gaps, anticipated funding, and schedule all have to be considered in making decisions relative to what testing will be performed, and on what schedule.

UFD Storage and Transportation Research
Security

OBJECTIVES:

Assess the impact of the spent fuel security during transportation, as well as how material attractiveness issues affect physical protection strategies and requirements. Coordinate with the MPACT campaign and NFST on security issues associated with storage.

SCOPE:

Collaborate with DOE and NRC subject matter experts regarding security of extended storage and subsequent transportation of UNF. Continue to assess the impact of NRC rule-making with regards to security implications for commercial spent fuel storage and transportation.

UFD Disposal Research
Argillite Disposal R&D

OBJECTIVES:

Work activities in this control account address the long-term thermal, hydrological, chemical, and physical behavior of used nuclear fuel in the near- and far-field of argillite disposal concepts.

SCOPE:

- Evaluate Thermal/Hydrological/Mechanical/Chemical (THMC) processes in the near- and far-field, including backfilled engineered and natural barrier systems (EBS/NBS) materials relevant to argillite disposal environment for used nuclear fuel.
- Development of thermodynamic databases (ambient and elevated temperatures) for EBS/NBS materials and their implementation in various modeling efforts such as chemical equilibria, sorption, and reactive transport.
- Conduct experimental work on waste package material degradation and interaction with clay to inform EBS/NBS chemical and transport models.
- Support close integration of R&D activities with GDSA for development of PA modeling for disposal in argillite.
- Coordinate the scope, activities, and results for use across the UFD and integrate such efforts with those in other UFD DR and ST work activities.
- International collaboration: SKB Task Force (EBS), FEBEX-DP, CI (Mont Terri)

UFD Disposal Research
Crystalline Disposal R&D

OBJECTIVES:

Work activities in this control account address the long-term thermal, hydrological, chemical and physical behavior of used fuel in the near and far field of crystalline rock disposal concepts.

SCOPE:

- Model fluid flow and transport in fractured crystalline rocks to demonstrate the potential application of a discrete fracture network model to actual field testing data obtained from international collaborations
- Evaluate THMC behaviors in clay-based backfill and buffer materials and develop THMC modeling capabilities to assess engineered barrier system (EBS) responses to different temperatures and pressures; evaluate impacts of the interaction between EBS and crystalline host rock.
- Conduct experimental investigation of radionuclide interactions with natural and engineered materials in a crystalline disposal environment, and develop process models, informed by observations, that can be readily incorporated into field-scale radionuclide transport models.
- Support the development of a total system performance assessment model for a generic crystalline repository and ensure close integration with other work packages.
- International collaboration: DECOVALEX, KAERI, BRIE

UFD Disposal Research
Salt Disposal R&D

OBJECTIVES:

2016 salt disposal R&D focuses on mechanical properties of salt, mechanisms of radionuclide transport in salt, and modeling of coupling of thermal, mechanical, hydrological, and chemical processes.

SCOPE:

- Experimental investigations of chemistry issues for heated salt and high-level waste
- Experimental investigations of the transport properties of salt and salt mixed with clay.
- Experimental investigations of the mechanical properties of salt
- Benchmark testing of thermal, mechanical, hydrological, and chemical coupled process models
- International collaboration: US/German salt host-rock repository collaborations in research, design and operations (200k)

UFD Disposal Research
Salt Field Testing

OBJECTIVES:

Refine tools that help plan and, if possible, initiate field tests in underground research facilities in salt.

SCOPE:

- Conduct benchmarking with FEHM, PFLOTRAN and TOUGH (LANL, LBNL)

UFD Disposal Research
Generic Disposal System Analysis

OBJECTIVES:

Develop a disposal system modeling and analysis capability that supports the prioritization of Disposal Research (DR) R&D and the evaluation of disposal system performance, including uncertainty, for a range of disposal options (e.g., salt, argillite, crystalline, deep borehole). The system-level modeling capability will: integrate updated conceptual models of subsystem processes and couplings developed under this and other DR work packages; be used to evaluate DR R&D priorities; leverage existing computational capabilities (e.g., meshing, visualization, high-performance computing (HPC)) where appropriate; and be developed and distributed in an open source environment.

SCOPE:

- Upgrade models for baseline isotope behavior (e.g., phase-partitioning, decay, release)
- Integrate subsystem conceptual models, developed under other DR work packages, into the GDSA-PA system model architecture (e.g., colloid transport, non-Darcy flow, discrete fracture model, waste package degradation)
- Perform simulations of selected reference case demonstration problems and conduct sensitivity analyses to inform R&D planning.

UFD Disposal Research
International Research Coordination

OBJECTIVES:

Coordinate, facilitate, and conduct international collaborative disposal research to benefit from international knowledge base with regards to various geologic disposal environments

SCOPE:

- Fees for international activities with UFD participation (e.g., Mont Terri Project, DECOVALEX Project, SKB Task Forces, FEBEX-DP) ($225k)
- Coordination and facilitation of UFD-supported R&D activities among participating national laboratories and comparable initiatives/programs outside the US ($225k)
- Support for World Wide Review Summary of international programs ($75k)
- Hosting of and participation in international bilateral collaborations and workshops (e.g., DECOVALEX, JFCS, KURT) ($75k)

UFD Disposal Research
Disposal of Dual Purpose Canisters

OBJECTIVES:

Perform generic evaluations of the feasibility of geologic disposal of used nuclear fuel in dual-purpose storage and transportation canisters

SCOPE:

Update the UNF-ST&DARDS template repository at ORNL to include the templates representing the two stylized degradation cases for the additional PWR fuel canisters (approximately 1,000 canisters) for which new information is available from GC-859. This will include an update of the unified database with criticality calculation results. This update will include both dual-purpose canisters (DPCs) and storage-only canisters with similar weld-sealed construction, that contain PWR fuel. (The BWR fuel canisters from GC-859 will be updated at a future time when the best representation of axial burnup profiles is known.) (SRNL)

UFD Disposal Research
Deep Borehole Field Test (Roll-up Control Account)

OBJECTIVES:

- Plan and initiate a field test of the deep borehole disposal concept

SCOPE:

- Integrate and evaluate site geoscience data
- Develop site characterization and characterization borehole test plans
- Develop conceptual design and specifications for the field test borehole and for emplacement system testing
- Manage and integrate DBFT activities to support project goals and deep borehole disposal concept evaluation
- International: $100k at LBNL to support the Swedish BH work, $200k at SNL for Sheffield, and $140k at SNL for KAERI/KURT

UFD Disposal Research
Deep Borehole Field Test – Site Geoscience Data Evaluation Task

OBJECTIVES:

- Integrate existing geoscience data for the DBFT site with additional collected site characterization data to evaluate thermal-hydro-mechanical-chemical (THMC) conditions at depth.

SCOPE:

- Consolidate existing data for DBFT site geologic conditions into coherent/comprehensive representation
- Integrate additional collected site characterization data into the existing site data representation
- Evaluate the THMC conditions in the crystalline basement at the site in the context of the preferred conditions for a safe, successful disposal concept

UFD Disposal Research
Deep Borehole Field Test – Site Characterization Task

OBJECTIVES:

- Develop plans, supported by process modeling, for downhole testing in the characterization borehole

SCOPE:

- Develop geomechanical and hydrological numerical models of both generic and site-specific conditions to inform (a) downhole test design, and (b) process modeling to support the system performance assessment model
- Develop testing plans for borehole and laboratory tests

UFD Disposal Research
Deep Borehole Field Test – Field Test Engineering Task

OBJECTIVES:

- Develop conceptual design and specifications for the field test borehole and for emplacement system testing

SCOPE:

- Complete engineering reviews of waste package and emplacement system concepts
- Perform additional priority engineering analyses focusing on important mechanisms including the sinking velocity for conceptual package designs
- Identify and evaluate alternative concepts for disposal borehole construction (including casing type, cementing, construction and emplacement fluids, and support matrices), and determine the implications for the DBFT
- Issue a conceptual design report that includes the FY15 conceptual design documentation, input from the FY15 expert panel and the engineering services support contractor, and input from the priority engineering analyses

UFD Disposal Research
Deep Borehole Field Test – Project Integration and Concept Evaluation

OBJECTIVES:

- Manage and integrate DBFT activities being performed by multiple organizations to support DBFT project goals and deep borehole disposal concept evaluation.

SCOPE:

- Manage and integrate DBFT activities including: site characterization and data evaluation, modeling, technical coordination with industry contractors, legal and regulatory requirements, quality assurance, and scheduling
- Develop a system performance assessment model to support test design and concept evaluation
- Characterize DOE-managed waste forms and canisters

UFD Disposal Research
Collaborative International Research (not a separate control account)

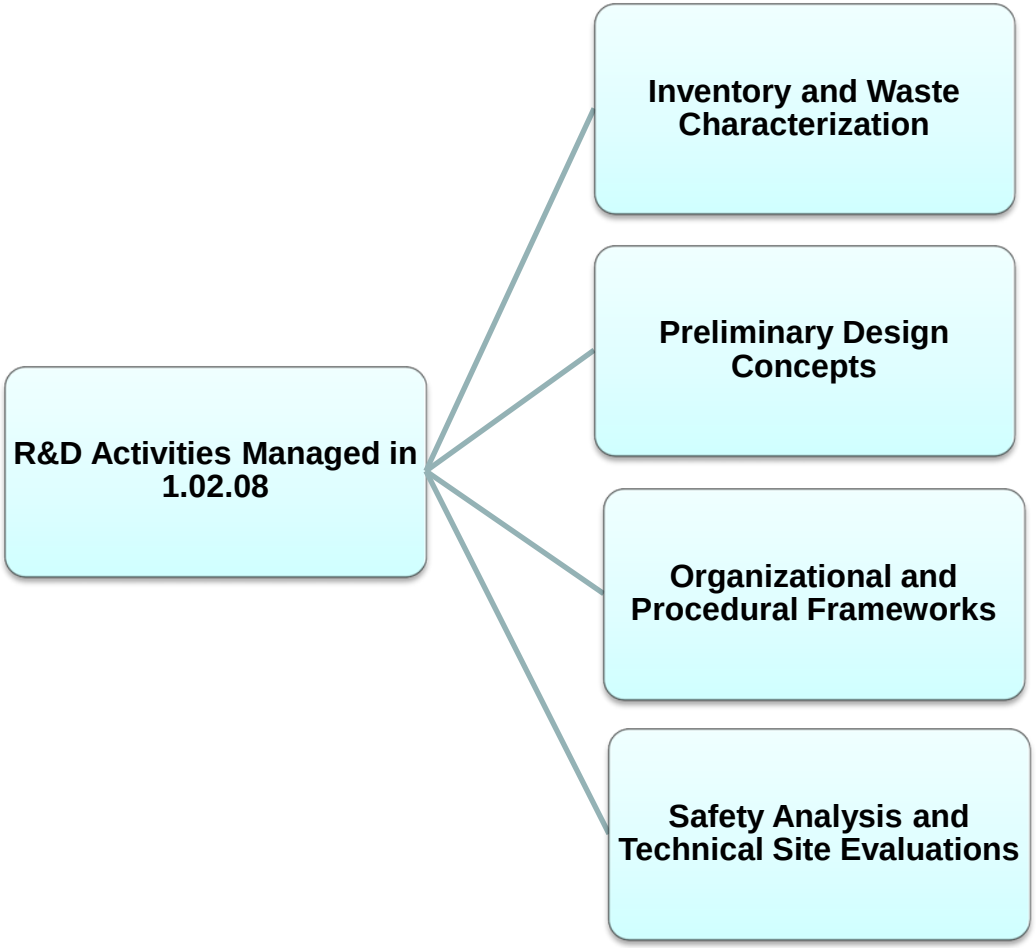
OBJECTIVES:

Engage in collaborative disposal research with international partners. Work is funded and managed through the relevant campaign control accounts (e.g., Argillite, Crystalline, Salt Disposal R&D and Deep Borehole Disposal), and uses cooperative agreements established and maintained through the International Research Coordination control account.

SCOPE:

- Argillite: Thermal/hydrologic/mechanical modeling of behavior of clay, collaborative modeling of EBS behavior (DECOVALEX, Mont Terri and Horonobe), (in Argillite Disposal R&D)
- Crystalline: Modeling of the evolution of clay buffer materials in crystalline media (Sweden “BRIE” test, FEBEX-DP), Colloid transport tests and modeling in fractured crystalline rock (CFM test at Grimsel, Switzerland); DECOVALEX modeling studies; Studies related to SKB Task Forces; Testing at KAERI Underground Research Tunnel (KURT). (in Crystalline Disposal R&D)
- Salt: International collaborations with Germany including salt core testing and thermo-mechanical model benchmark testing (in Salt Disposal R&D)
- Deep Borehole: LBNL to support the Swedish BH work, SNL work with Sheffield and KAERI/KURT (Deep Borehole Field Test)

DOE-Managed HLW and SNF Research



DOE Managed HLW and SNF Research: Summary of FY16 L2 Milestones

- **Inventory and Waste Characterization**
  - The On-line Waste Library (OWL): Usage and Status Report (SNL, 9/23/2016)
- **Preliminary Design Concepts for the Inventory in Select Media**
  - Status of Progress Made Toward Preliminary Design Concepts for the Inventory in Select Media for DOE Managed HLW/SNF (SNL, 9/16/2016)
- **Organizational and Procedural Frameworks**
  - Draft Program Plan for the Permanent Disposal of High-Level Radioactive Waste and Spent Nuclear Fuel from Defense and Department of Energy Research and Development Activities
  - Generic Organizational and Procedural Framework for DOE Managed HLW and SNF Licensing (SNL, 9/16/2016)
- **Safety Analysis and Technical Site Evaluations**
  - Status of Progress Made Toward Safety Analysis and Technical Site Evaluations for DOE Managed HLW and SNF (SNL, 11/03/2016)

DOE Managed HLW and SNF Research: *Inventory and Waste Characterization*

OBJECTIVES:

Work activities in this control account address the technical elements necessary to delineate the inventories of waste forms for disposal and their expected behavior in various disposal concepts.

SCOPE:

- Organize and coordinate information on both waste forms to be disposed and repository concepts for disposal to inform safety assessments (WP1)
- Develop a listing and inventory of DOE-managed HLW and SNF radioactive wastes which were assessed in the disposal options evaluation work and identify any additional waste forms to be added (WP2)
- The on-line waste library will be constructed for information on DOE-managed HLW, SNF, and other wastes that are potential candidates for deep geologic disposal, with links to supporting documents (WP3)
- Characterize long-term performance of alternative waste forms (WP4)

DOE Managed HLW and SNF Research: *Preliminary Design Concepts for the Inventory in Select Media*

OBJECTIVES:

Work activities in this control account address the technical elements necessary to evaluate the preliminary design concepts for the inventory within select media. Specific geologic media under consideration are those currently investigated within the Used Fuel Disposition Campaign (argillite, crystalline, deep borehole, and salt).

SCOPE:

- Assess feasibility and applicability of Engineered Barrier Systems (EBS) concepts in select geologic media for the technical challenges specific to the inventory. A particular emphasis will be placed on analyzing thermal conditions and their effect on the inventory's compatibility with EBS concepts/disposal media. (WP1)
- Investigate and evaluate options for both disposal overpack and waste package design. (WP2)

DOE Managed HLW and SNF Research: *Organizational and Procedural Frameworks*

OBJECTIVES:

Work activities in this control account address development of generic organizational and procedural frameworks aligned with DOE Managed HLW and SNF licensing efforts.

SCOPE:

- Identify the principal elements of a generic repository licensing organization infrastructure such as: information management; quality assurance; systems engineering, including associated IT infrastructure architecture needs, based on prior SNL experience
- Identify the principal operating procedures for a generic repository licensing organization: such as: information management, organizational assurance and quality assurance, based on prior SNL experience.
- Identify and initiate regulatory interactions related to organizational and procedural frameworks

DOE Managed HLW and SNF Research: *Safety Analysis and Technical Site Evaluations*

OBJECTIVES:

Work activities in this control account address the technical elements necessary to establish the safety case associated with select repository sites.

SCOPE:

- Complete reference cases for selected geologic media currently under investigation within the Used Fuel Disposition Campaign (argillite, crystalline, deep borehole and salt). (WP1)
- Perform Features, Events and Processes (FEPS) analyses for the selected geologic media. (WP2)
- Create definitions for generic safety performance objectives. (WP3)
- Evaluate alternative Engineered Barrier Systems (EBS) concepts and provide testing to support the evaluations. (WP4)
- Develop a total systems performance assessment (TSPA) for repositories in selected media. (WP5)
- Develop a technical site evaluation plan. (WP6)
- Perform regional geologic evaluations for technical site selection options. (WP7)