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SAND2014-18792PE

Used Nuclear Fuel Disposition R&D Campaign Overview

Peter Swift
National Technical Director
Used Fuel Disposition R&D Campaign

2014 Fuel Cycle Technologies Annual Review Meeting
November 4-6, 2014
Idaho Falls, ID

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Outline

- **The Campaign Overview**
  - Mission
  - Long-term Objectives (10-20 years)
  - Near-term Milestones (1-3 years)
  - Organization of the Current R&D Portfolio
  - Selected accomplishments for FY14
  - Summary of activities planned for FY15
  - Conclusion
- **Introduction to the following Used Fuel Disposition R&D presentations**
  - Experimental Program on Used Fuel Disposition in Crystalline Rocks
    - Yifeng Wang, Sandia National Laboratories
  - Improving the Understanding of Coupled Thermal-Mechanical-Hydrologic Behavior of Consolidating Granular Salt
    - Melissa Mills, Sandia National Laboratories
  - Mechanical Performance of Storage and Transportation Casks after Long-Term Exposure
    - Luis Ibarra, University of Utah, NEUP projects 12-3756 and 13-5106
  - An Integrated Approach to Closing the Technical Data Gap Cladding – Hydride Reorientation and Embrittlement
    - Brady Hanson, Pacific Northwest National Laboratory

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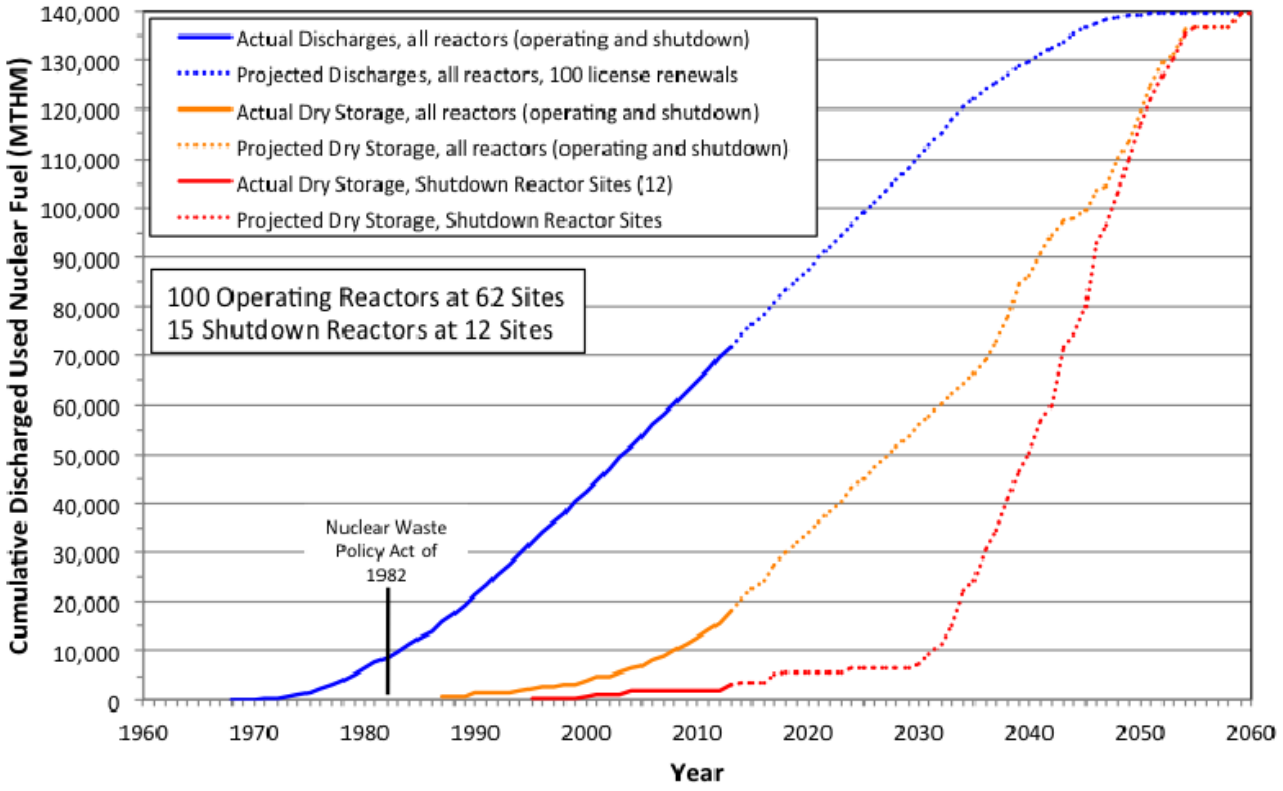
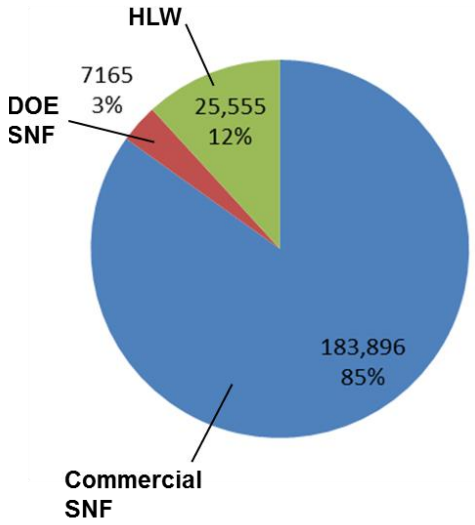
Historical and Projected Spent Nuclear Fuel (SNF) and High-Level Radioactive Waste (HLW) in the United States



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

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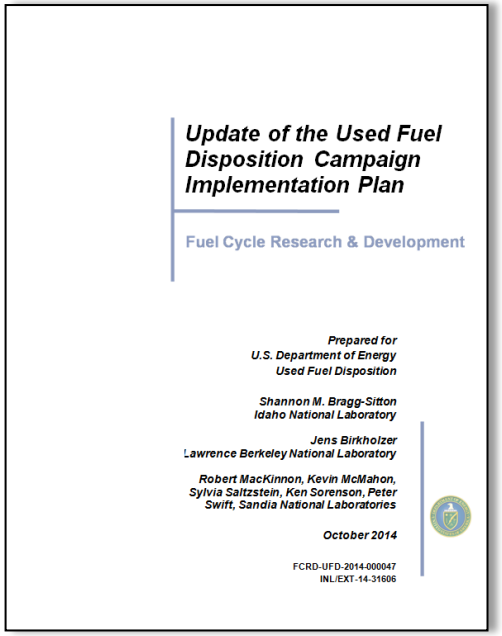
UFD Mission

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

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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 basis for:**
  - Extended storage of used nuclear fuel
  - Fuel retrievability and transportation after extended storage
  - Transportation of high-burnup used nuclear fuel

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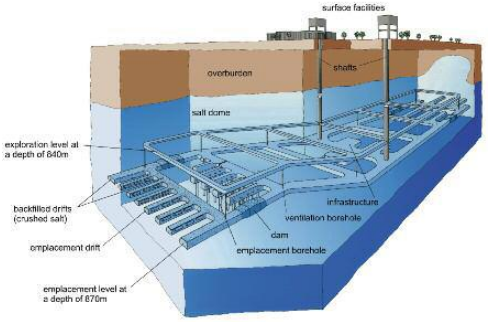
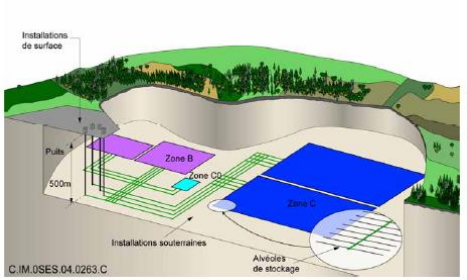
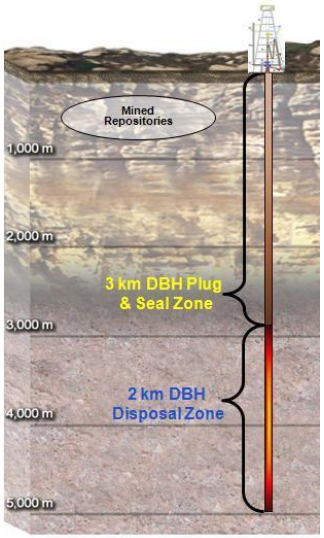
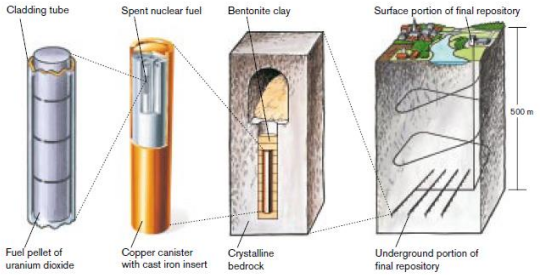
UFD Campaign Strategic Focus: Disposal R&D

- 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









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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 modeling work transitioning from MR/WF to UFD in FY14
- **Collaboration with DOE-EM**
  - Salt disposal research (joint activities with DOE-EM Carlsbad Field Office)
- **Industry (Advisory and Assistance Contracts)**
  - Areva, Shaw/Westinghouse, GE Hitachi, EnergySolutions, Enercon, CH2M Hill
- **DOE/Industry Storage Demonstration Collaboration initiated FY13**
  - Separate presentation by Ned Larson
- **EPRI**
  - Extended Storage Collaboration Program (ESCP) (with NRC and international groups)

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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
- **DOE NE University Programs**
  - 2010: 1 NEUP grant relevant to UFD, in storage (U. of Michigan)
  - 2011: 3 NEUP grants relevant to UFD: 2 storage, 1 disposal
    1 Integrated Research Project in storage R&D
  - 2012: 9 NEUP grants relevant to UFD: 6 storage/transportation, 3 disposal
  - 2013: 7 NEUP grants relevant to UFD: 3 storage, 2 transportation, 2 disposal
  - 2014: 2 Integrated Research Projects in storage R&D
- **Other university collaborations (MIT, U. of Oklahoma, UNLV, University of Sheffield UK)**

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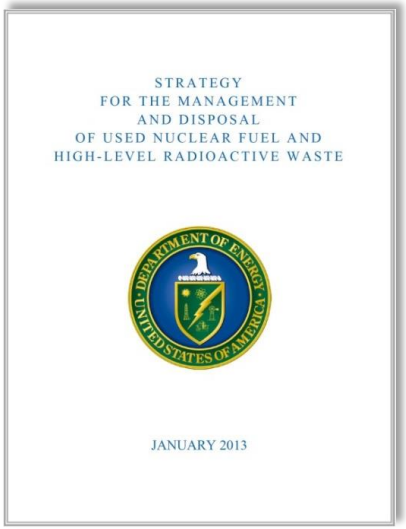
Long-Term UFD R&D Campaign Objectives

- 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
- Collaborate with the Nuclear Fuel Storage and Transportation Planning Project to implement 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*



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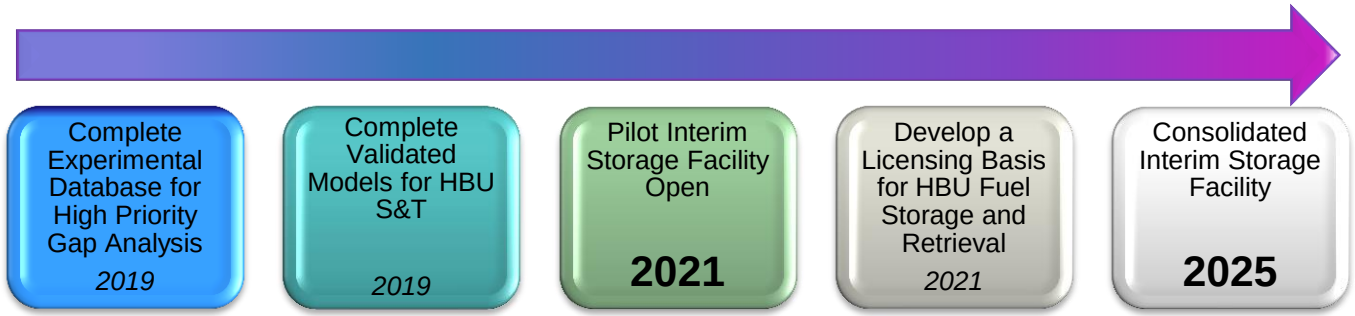
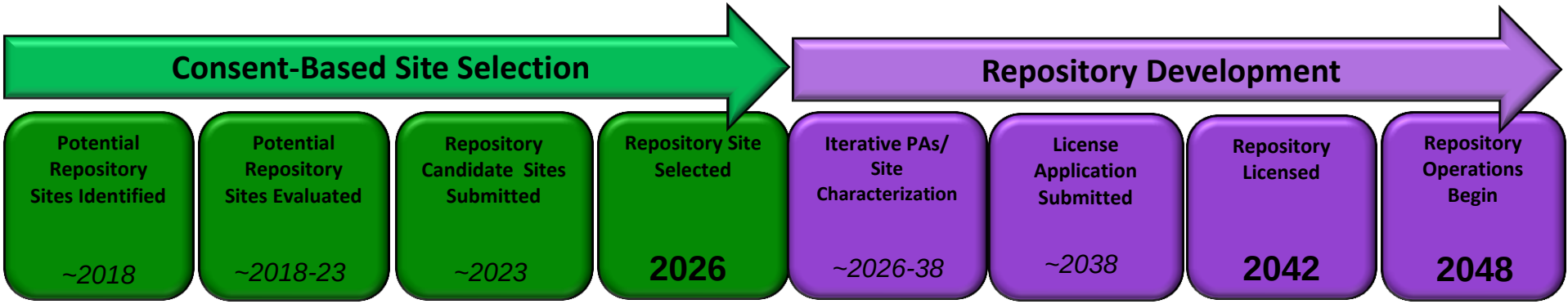
R&D Path to Support DOE Waste Management Strategy



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

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Selected UFD R&D 2015 Milestones

- Selected 2015 Milestones: Storage and Transportation
  - *Lower Temperature Ring Compression Testing of PWR Cladding (ANL, 8/28/2015)*
  - *Results of Bend Tests for Used Nuclear Fuel (ORNL, 9/04/2015)*
  - *Stress Corrosion Cracking Investigations on Full Scale Stainless Steel Canister Mock-up (SNL, 8/21/2015)*
  - *Thermal Analysis of Two Licensed Storage Systems (PNNL, 6/26/2015)*
  - *Surrogate Assembly Test Simulating Normal Conditions of Rail Transport (SNL, 9/11/2015)*
- Selected 2015 Milestones: Disposal
  - *International Collaboration Activities in Different Geologic Disposal Environments (LBNL, 9/25/2015)*
  - *Summary of Investigations on Technical Feasibility of Direct Disposal of Dual-Purpose Canisters (SNL, 05/15/2015)*
  - *Site Selection for the Deep Borehole Field Test (SNL, 5/4/2015)*
  - *Conceptual Design and Requirements for the Characterization Borehole and Test Borehole (SNL, 9/29/2015)*

18 proposed Level 2 Milestones for UFD R&D Campaign in FY15

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UFD Near-Term Objectives (2015-2018)

- **Provide technical expertise to inform policy regarding management of UNF and radioactive waste**
- **Develop the technical basis for extended long-term storage of UNF and high-level nuclear waste to identify long-term research and development needs**
- **Develop the technical basis for retrievability and transportation of high burnup UNF**
- **Develop a comprehensive understanding of the current technical basis for disposal of UNF and high-level nuclear waste in a range of potential disposal environments to identify long-term R&D needs.**
- **Develop advanced, predictive computational models, with experimental validation, for:**
  - Evaluation of UNF performance under normal conditions of storage and transportation
  - Evaluation of disposal system performance in a variety of generic disposal system concepts and environments

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Organization of the Used Fuel Disposition Campaign R&D Portfolio

UFD Campaign
Peter Swift
National Technical Director (NTD)

Disposal Research
Kevin McMahon
Bob MacKinnon

Storage &Transportation
Ken Sorenson
Sylvia Saltzstein

Engineered Material Performance
Host Rock Research: Argillite
Host Rock Research: Crystalline
Host Rock Research: Salt
Generic Disposal System Analysis
International Collaborations
Regional Geology
Deep Borehole Disposal
Disposal of Dual Purpose Canisters

Field Demonstration Support
Experiments
Engineering Analysis
Transportation
Security

Major Activities	FY 2014 Funding
Management and Integration	$900,000
Storage and Transportation Research	$10,557,000
Disposal Research	$11,705,000
DOE-managed Industry Storage Cask Demonstration	$3,800,000
Total	**$26,962,000**

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UFD Storage and Transportation R&D Selected FY14 Accomplishments

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Major FY14 Accomplishments Storage and Transportation Research

- **Supported the industry storage cask demonstration**
  - Support for finalization of the EPRI Test Plan
  - R&D in support of non-destructive evaluations of the demonstration cask
  - Selection and eventual placement of assemblies and thermal instrumentation
  - Support planning for cask lid design, licensing issues, and approval of final design
- **Completed cladding bend test on irradiated Zirc-4 and M5 cladding**
  - Results showed that the irradiated fuels can withstand millions of bending cycles at potentially higher than representative loading levels before breaking
  - Results indicate that pellet-clad interaction (PCI) provides added strength to high burnup used fuel.
- **50 mile over-the-road truck test to confirm Normal Conditions of Transport (NCT) loadings on used fuel**
  - Results further confirm that stresses and strains seen by the fuel and assembly are well below those where damage is predicted
  - Coupled with the cladding bend tests, early indications look promising that high burnup embrittled fuel will withstand NCT
- **Obtained salt and dust samples from operating dry storage canisters in marine and inland locations**
  - Results show less salt than expected, but enough to be of concern
- **Updated technical gap and prioritization report**
  - Addresses new and emerging R&D issues (e.g., higher prioritization on canister SCC)
  - Validates original technical gap and prioritization reports

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Storage and Transportation R&D Guided by the 2012 Gap Analysis:

Work focused in the red areas.

System Component	Issue	Importance of R&D
Cladding	Annealing of Radiation Effects	Medium
	Oxidation	Medium
	H_2 effects: Embrittlement	High
	H_2 effects: Delayed Hydride Cracking	High
	Creep	Medium
Assembly Hardware	Stress corrosion cracking	Medium
Neutron Poisons	Thermal aging effects	Medium
	Embrittlement and cracking	Medium
	Creep	Medium
	Corrosion (blistering)	Medium
Canister	Atmospheric corrosion (marine environment)	High
	Aqueous corrosion	High

Source: Gap Analysis to Support Extended Storage of Used Nuclear Fuel, January 2012

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Storage and Transportation R&D Guided by the 2012 Gap Analysis:

Work focused in the red areas.

System Component	Issue	Importance of R&D
Bolted Direct Load Casks	Thermo-mechanical fatigue of bolts/seals	Medium
	Atmospheric corrosion (marine environment)	High
	Aqueous corrosion	High
Overpack and Pad (Concrete)	Freeze/Thaw	Medium
	Corrosion of steel rebar	Medium

Cross-cutting or General Gaps

- ***Temperature profiles for fuel*** — ***High***
- ***Drying issues*** — ***High***
- ***Monitoring*** — ***High***
- ***Subcriticality*** — ***High***
- ***Fuel transfer options*** — ***High***
- ***Re-examine INL dry cask storage*** — ***High***

Identification of these data gaps are used to inform new initiatives for FY15

Source: Gap Analysis to Support Extended Storage of Used Nuclear Fuel, January 2012

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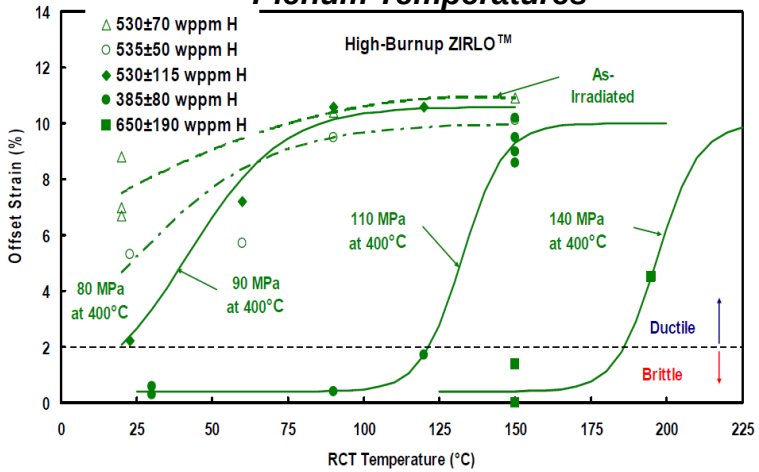
FY14 S&T Experiments:
High Burnup Fuel Cladding Material Properties

- **Separate effects test to determine effects of hydrides, hydride reorientation, radiation damage, thermal annealing, and clad thinning on materials properties and performance.**

- **Hydrides and reorientation**
  - Ring Compression Tests and determination of Ductile-Brittle Transition Temperature (ANL)
  - Cladding bend test and effects of fuel/clad bonding and pellet/pellet interfaces (ORNL)

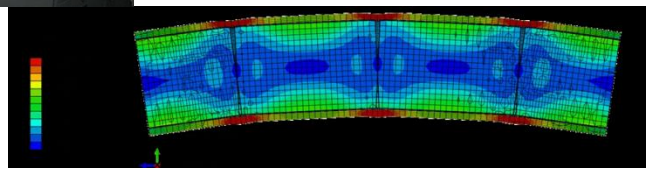
- **Radiation damage and thermal annealing**
  - Irradiate cladding in HFIR reactor at ORNL without all other effects.

DBTT data for Zirlo clad with Varying Internal Plenum Temperatures



Billone, Argonne National Laboratory, EPRI ESCP Meeting, Dec. 2013

Used fuel rod stiffness Experiments (in hot cell and out) and analyses of stress distribution



Jy-An, Wang; Oak Ridge National Laboratory, WM2014 Conference, March 2014

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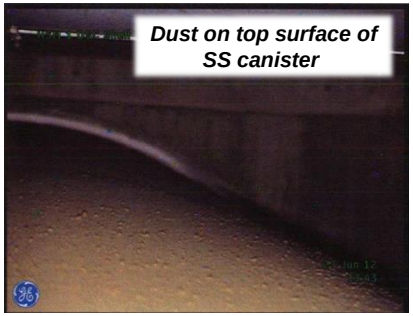
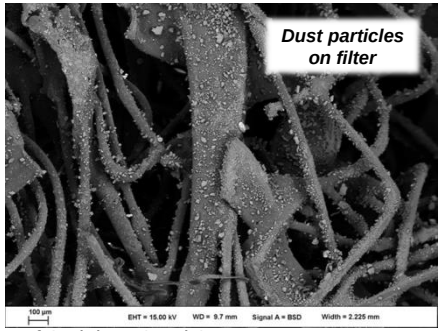
FY14 S&T Experiments:
Stainless Steel Canister Corrosion

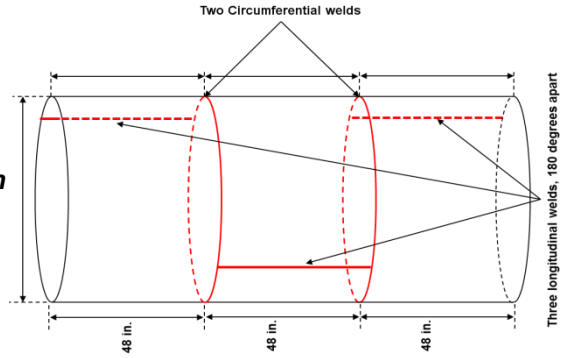
Purpose: Better understand canister degradation, support Aging Management Plans, and license extensions.

- Develop data to understand initiating conditions for corrosion conditions and progression of SCC-induced crack growth
- Obtain site data to assess atmospheric conditions and compare with initiating conditions.
- Procure a full scale (diameter) welded SS canister to investigate residual stresses due to plate rolling and welding.





Enos, et al., Data Report on Corrosion Testing of Stainless Steel SNL Storage Canisters, FCRD-UFD-2013-000324



Conceptual design for full-scale (diameter) SS welded canister

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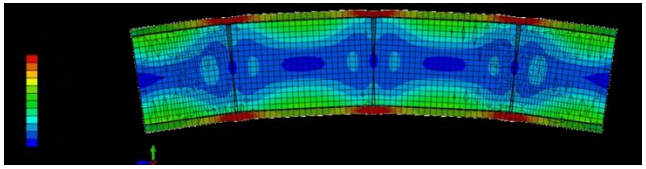
FY14 S&T Analysis

Predictive modeling

- Thermal Analysis (PNNL) to predict cool down, Ductile-to-Brittle Transition, deliquescence, etc.
  - HBU Demonstration fuel selection and cool down
  - Modern, high heat load, high capacity systems
  - In-service inspections validation data
- Hybrid hydride reorientation model (SNL)
- Structural uncertainty analysis at assembly and canister level (PNNL)
- Finite element analysis validation and application to out-of-cell testing (ORNL)

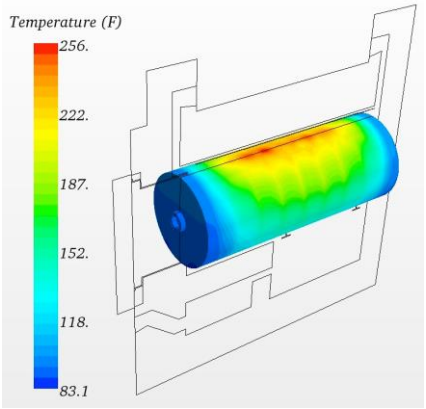
Thermal profile analyses

- Detailed thermal analyses for 2-3 licensed dry storage systems (PNNL FY15)

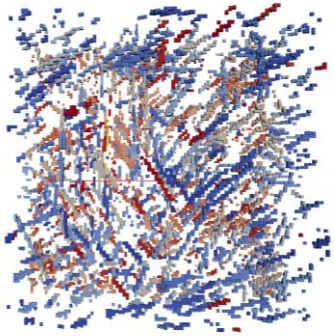


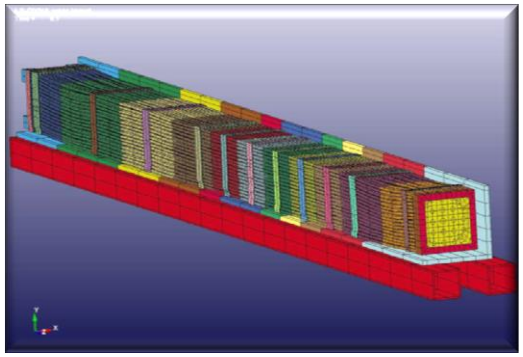
Jy-An, Wang; Oak Ridge National Laboratory, WM2014 Conference, March 2014

CFD Thermal Analysis of Dry Storage Casks
Suffield, et al, PNNL-21788

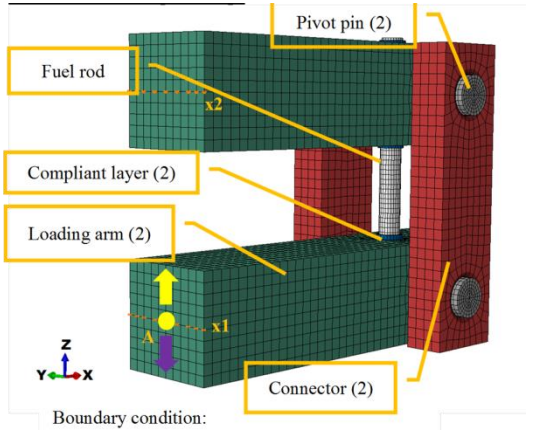


Model for Simulation of Hydride Precipitation, Tikare et al, FCRD-UFD-2013-000251.





FE Models of Assembly
Klymyshyn, et al, PNNL, FCRD-UFD-2013-000168



FE Model of Rod Bend Tests
Jy-An Wang et al, ORNL

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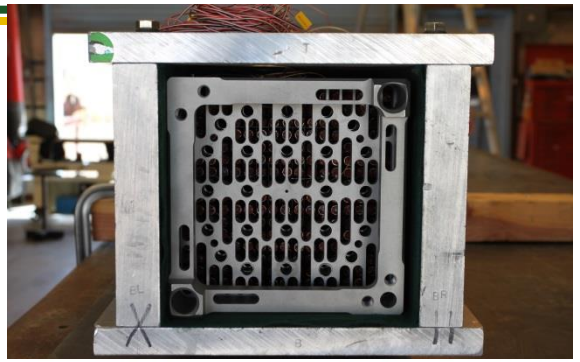
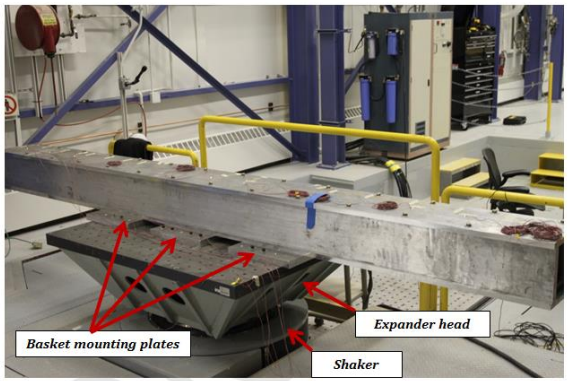
Transportation:

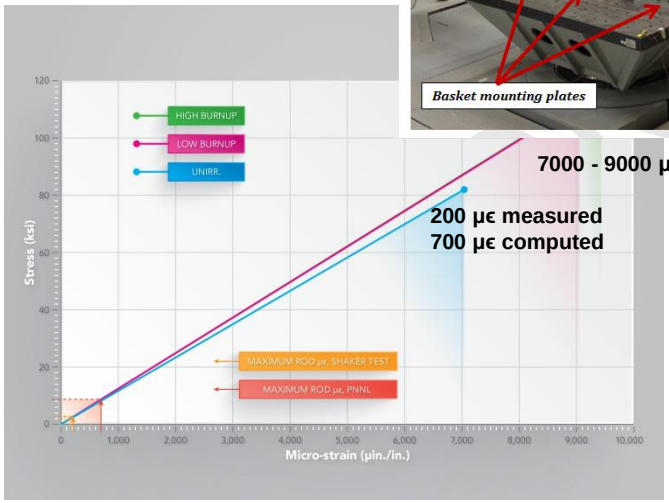
Normal Conditions of Transport – Loading on Fuel Assemblies

- **A surrogate assembly was subjected to a 50-mile over-the-road test on a real truck with representative weight**
  - Data results were >10 times below yield strength
  - The strains measured in both were an order of magnitude lower than the elastic Zircaloy rod yield strength and well below the fracture toughness value for brittle behavior
  - Strains were commensurate with strains obtained from the FY13 shaker table test

- **If high burnup fuel can maintain its integrity during transport, pressure will be taken off experimental R&D efforts associated with hydride effects on cladding strength and ductility.**







Data collection and analysis for NCT loads on a surrogate fuel assembly

Sorenson, K., Determination of Loadings on Spent Fuel Assemblies During Normal Conditions of Transport, SAND2014-2043P.

UFD Disposal R&D
Selected FY14 Accomplishments

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Major FY14 Accomplishments Disposal Research

- **Completed *Evaluation of Options for Permanent Geologic Disposal of Used Nuclear Fuel and High-level Radioactive Waste Inventory in Support of a Comprehensive National Nuclear Fuel Cycle Strategy***
  - Conclusion: multiple disposal options are available for all existing and currently projected waste forms except sodium-bonded fuels, for which more information is needed
- **Multiple international collaborations are ongoing and are an integral part of UFD's disposal R&D**
- **Updated analyses of dual-purpose canister (DPC) disposal alternatives indicate that DPC direct disposal could be technically feasible, at least for certain disposal concepts**
- **Identified RD&D needs for evaluating feasibility of deep borehole disposal of small HLW waste forms, providing the foundation for planning a deep borehole field test**

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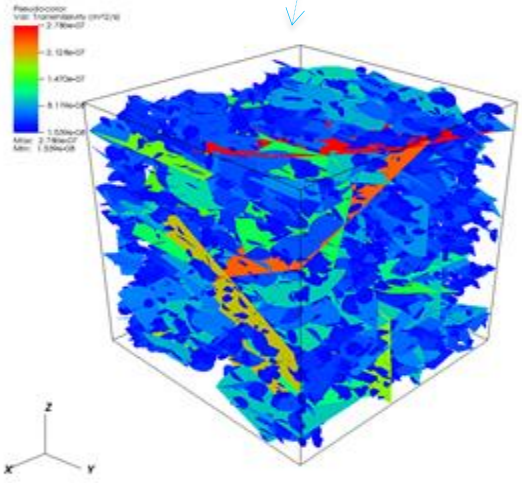
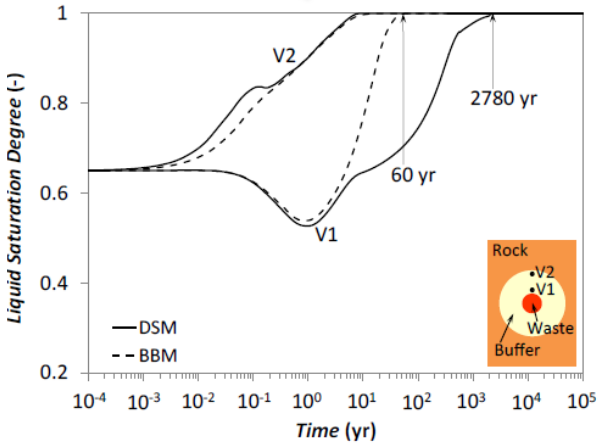
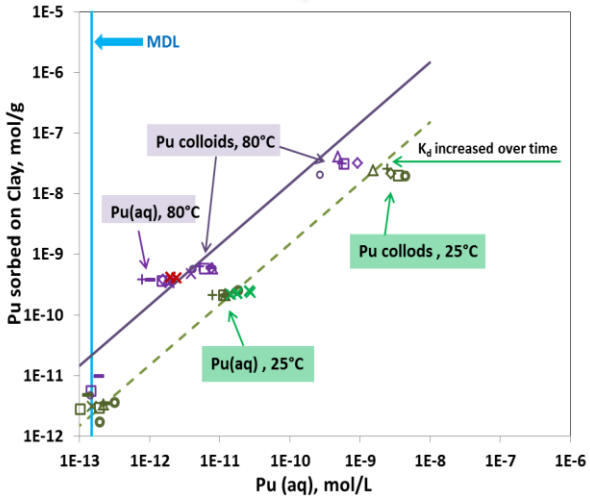
Example FY14 Accomplishments: Crystalline Disposal Research

- Generic reference case established for crystalline disposal media
- Capability of a discrete fracture network model demonstrated using fracture parameters from Swedish Forsmark site.
- Thermo-hydrologic-mechanical (THM) model has been applied to an engineered barrier system. ~3000 year delay of water saturation in bentonite is predicted.
- Significant progress has made in understanding radionuclide (e.g., Pu colloid) interactions with buffer and granitic materials. Thermal treatment of clay materials may enhance radionuclide retention.
- International collaborations in progress (e.g., DECOVALEX, KAERI, Sweden URL).







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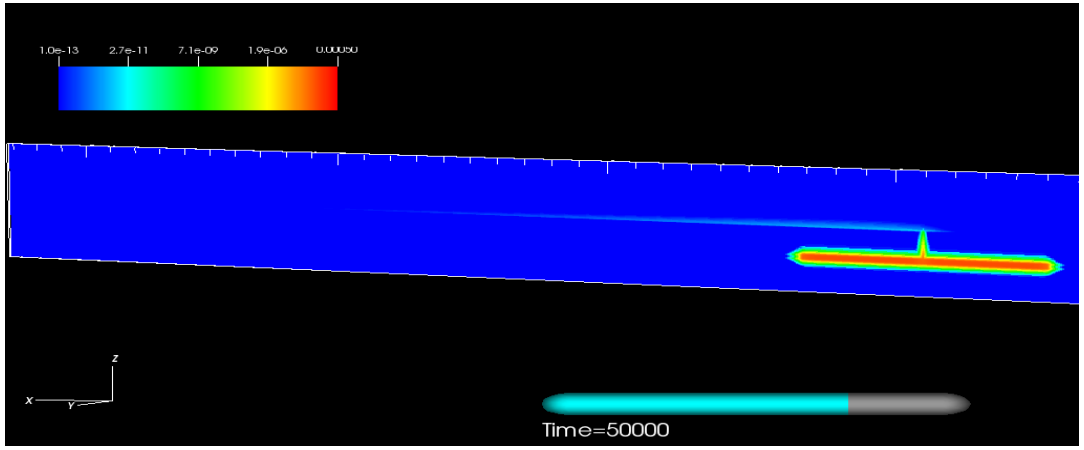
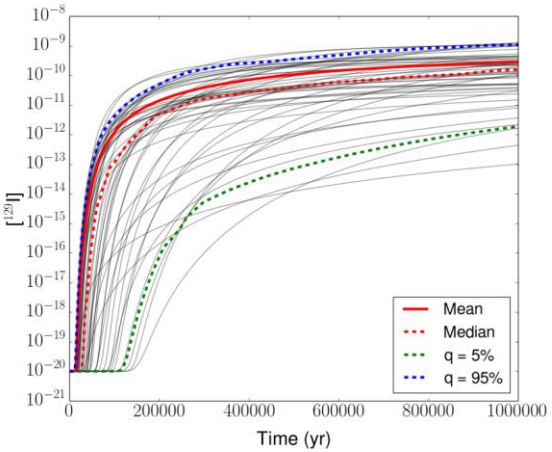
Example FY14 Accomplishments: Generic Disposal System Analysis

Probabilistic THC Simulations and Sensitivity Analyses

- Generic salt repository reference case with
  - spatially-varying waste degradation (160 individual waste packages)
  - decay heat and thermal effects
  - fluid flow, radionuclide mobilization and transport, and a coupled biosphere



- Sensitivity analyses from 100 realizations with 10 varying parameters



G. Hammond (SNL), G. Freeze (SNL), W.P. Gardner (SNL), P. Mariner (SNL), S.D. Sevougian (SNL)

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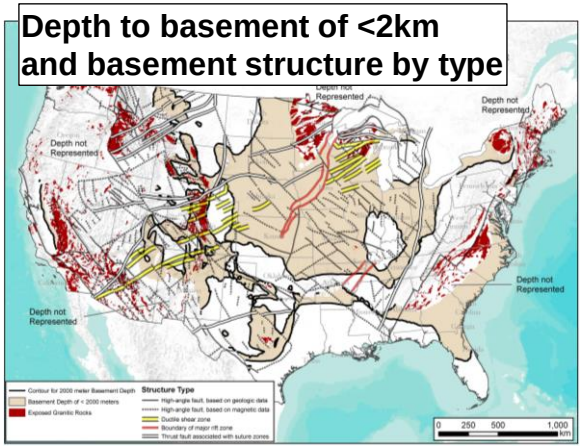
Example FY14 Accomplishments: Disposal Research: Regional Geology

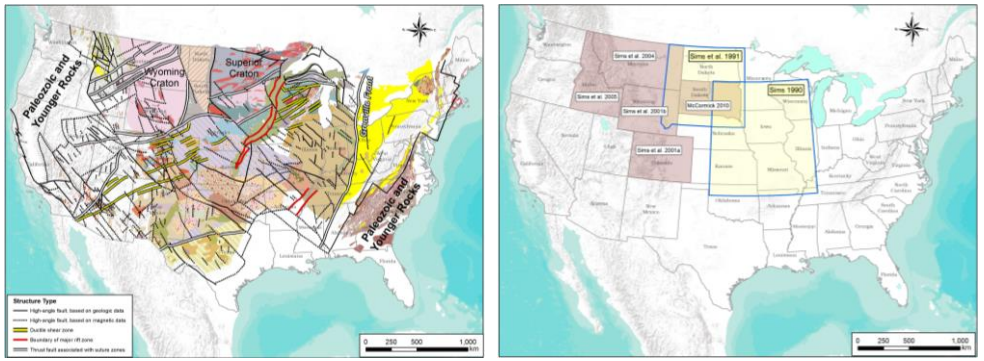
GIS database to support understanding of siting alternatives for the four UFD disposal options

- Created a national framework for broad consideration of siting alternatives for a deep borehole field test
  - Data at the national scale provide the overall framework to evaluate data at the sub-regional to local scale
  - Provides information on major terrane boundaries (structures) and alternative lithologies that would influence siting decisions



Basement structure from Sims et al. (2008); basement depth from SMU Geothermal Laboratory

- Planned and prototyped an interactive web mapping tool for the GIS database in collaboration with INL for implementation in FY15
- Supported other media-specific work packages that are developing the granite and argillite reference cases by providing information related to the geology, hydrology and depth or distribution of shale and crystalline rocks



National-scale map of basement terranes and selected areas that include more detailed regional to state coverage

Left: data from Reed et al. (1993)

Frank Perry and Rick Kelley (LANL),
Pat Dobson and Jim Houseworth (LBNL)

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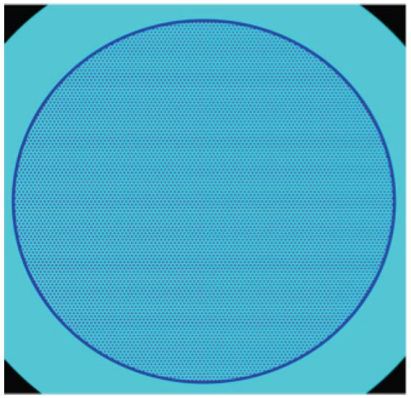
Example FY14 Accomplishments: Disposal Research: Preliminary Study of DPC Direct Disposal Alternatives

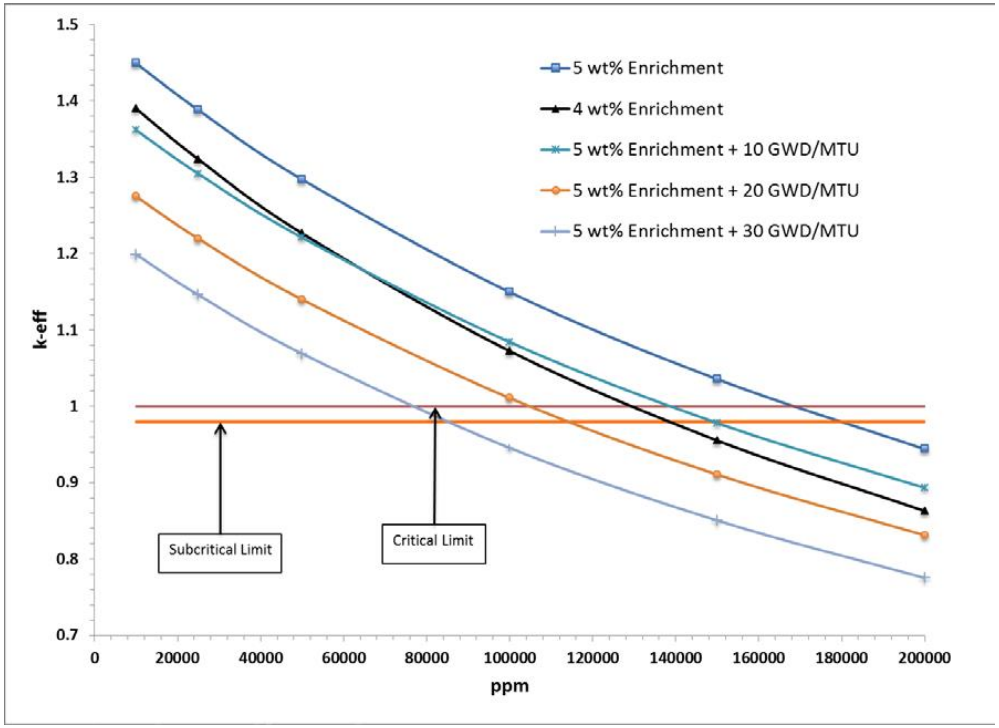
Postclosure Nuclear Criticality of SNF in Dual-Purpose Canisters Flooded with Chloride Brine and Degraded



Bounding-Type Configuration of Fuel Rods in a DPC

Hypothetical Neutron Multiplication Factor (keff) vs. Chloride Concentration

(NaCl saturation at 20℃ gives 158,000 ppm chloride)



Conclusion: Groundwater salinity (^{35}Cl) could allow exclusion of postclosure criticality from performance assessment for direct disposal of most DPCs in a salt repository.

John Scaglione, Justin Clarity and Rob Howard (ORNL); Ernest Hardin (SNL)

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Example FY14 Accomplishments: International Collaborations in Disposal Research

- Promising international opportunities for "active" collaboration were identified, evaluated, and selected
- DOE has joined formal collaborative R&D agreements with multinational collaborative initiatives as well has bilateral agreements with selected international programs in Europe and Asia
- Several UFD funded collaborative R&D projects have been initiated within these R&D agreements

Multinational Initiatives

- **Mont Terri Project**
  - *Participate in experiments at Mont Terri clay URL in Switzerland*
- **DECOVALEX Project**
  - *Participate in model comparison initiative for several URL related tasks in different host rocks*
- **Colloid Formation and Migration Project**
  - *Participate in colloid research at Grimsel granite URL in Switzerland*
- **SKB Task Forces**
  - *Participate in crystalline rock research centered around Äspö HRL in Sweden*
- **FEBEX DP**
  - *Participate in FEBEX dismantling project, which will analyze bentonite-rock behavior after 17 years of heating*

Bilateral Agreements

- **KAERI Underground Research Tunnel (KURT)**
  - *Participate in collaborative US/ROK experiments in crystalline rock*
- **US-German benchmarking study for salt**
  - *Participate in model comparison for TM behavior of domal and bedded salt*
- **Other**
  - *Other opportunities may be pursued, as bilateral agreements exist with France, Japan, Belgium, etc.*

Also NEA Salt Club, Clay Club, Thermochemical Database Project

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Example FY14 Accomplishments: International Collaborations in Disposal Research (cont.)

URL	Relevant Experiments	Cooperation Mode	UFD Participation
Mont Terri, Switzerland	• FE: Full-scale heater test demonstration experiment • HE-E: Half-scale heater test in VE test section • MB: Mine-by experiment • HG-A: Gas path host rock and seals • DR-A: Diffusion, retention and perturbations	• Mont Terri Project • DECOVALEX • Mont Terri Project • Mont Terri Project • Mont Terri Project	• Ongoing, LBNL • Ongoing, LBNL • Completed, LBNL • Ongoing, LBNL • Completed, LBNL
Grimsel Test Site, Switzerland	• CFM: RN tracer test and RN-doped plug test • FEBEX-DP: full-scale heater test dismantling	• CFM • FEBEX-DP	• Ongoing, LANL • Planned, SNL, LANL, LBNL
Äspö Hard Rock Laboratory, Sweden	• BRIE: Bentonite rock interaction experiment • Prototype Repository: full-scale prototype tunnels	• SKB Task Forces • SKB Task Forces	• Ongoing, LANL • Likely
Bedrichov Tunnel, Czech Republic	• Flow patterns and tracer transport in fractured granite	• DECOVALEX	• Ongoing, SNL
Horonobe URL, Japan	• EBS experiment: Vertical heater and buffer test	• DECOVALEX	• Ongoing, LBNL
KURT URL, Korea	• Streaming potential (SP) testing • Technique development for borehole characterization	• MoU KAERI • MoU KAERI	• Ongoing, SNL • Ongoing, SNL

Approximately 15% of the campaign's disposal R&D budget in FY15 will support international collaborations

UFD R&D Campaign FY15 Plans

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Implementing UFD R&D Priorities from FY14 to FY15

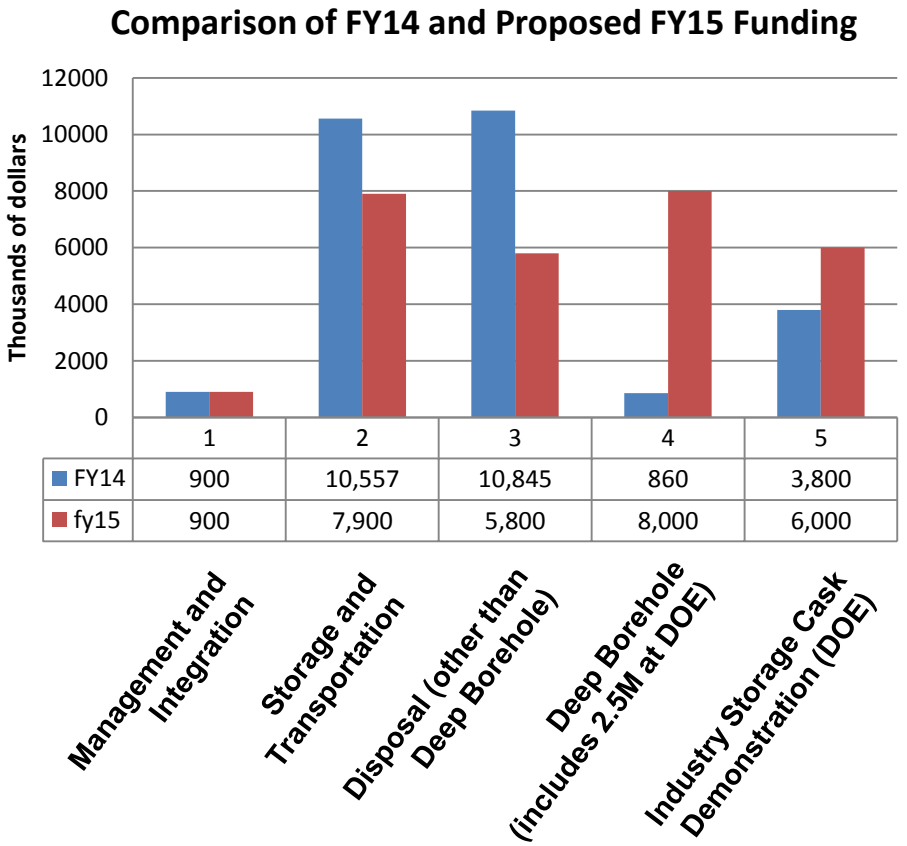
Overall funding for UFD R&D (including campaign and DOE managed activities) increases from ~ $27M to $28.6M

Increase in funding for storage cask demonstration project and proposed deep borehole field test cause changes in other activities

Storage and Transportation R&D outside of cask demonstration project decreases ~ 26%

Disposal Research other than deep borehole decreases ~ 42%

International collaborations remain a high priority within the reduced funding



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FY14 UFD R&D Campaign Structure
(as of July 23, 2014)

Management Group	Control Accounts	Proposed FY15 Funding
Campaign Management and Integration	Management and Integration	900k
Storage and Transportation Research (ST)		7900k
	Experiments	3050k
	Analysis	1550k
	Demonstration Project Support	1800k
	Security	200k
	Transportation Experimental Programs and Analysis	1300k
Disposal Research (DR)		11300k
	Engineered Material Performance	150k
	Argillite Disposal R&D	1290k
	Crystalline Rock Disposal R&D	1250k
	Salt Disposal R&D	750k
	Salt Field Testing	500k
	Generic Disposal System Analysis	700k
	International Research Coordination	600k
	Dual Purpose Canister Disposal R&D	600k
	Deep Borehole Field Test	5500k

Proposed Campaign Total for FY15 $20.1M

15 Control Accounts

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Storage and Transportation R&D FY15 Planned Activities

- **Experiments**
  - Fuel cladding ring compression tests at lower temperatures
  - Fuel cladding bend tests with different alloys
  - Assess non-destructive evaluation methodologies for crack detection in canisters
  - Assess residual stresses seen in a typical dry storage canister
  - Continue stress corrosion cracking R&D on stainless steel canister material
- **Analysis**
  - Support selection and configuration of fuel assemblies and sister rods for the DOE/EPRI high-burnup demonstration project
  - Conduct thermal analyses for two industry dry storage systems
  - Complete the hydride model
  - Develop and apply the Uncertainty Quantification model to further streamline future R&D
- **Transportation**
  - Obtain and analyze data for the shocks and vibrations experienced by fuel rods during normal conditions during transport over rail
- **Field Demonstration**
  - Support fuel selection and development of non-destructive evaluation technologies
- **Security**
  - Refine RIMES (Risk-Informed Management of Enterprise Security) analysis and incorporate a force-on-force modeling tool

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Disposal R&D FY15 Planned Activities

- **Engineered Material Performance**
  - Continued research on radiolysis effects on uranium oxide fuel in reducing environments
- **Argillite Disposal**
  - Evaluate thermal/hydrological/mechanical/chemical (THMC) processes in the far and near fields, including backfilled engineered barrier systems and materials relevant to argillite disposal environment for used nuclear fuel.
  - Develop thermodynamic databases (e.g., cement and clay) and modeling approaches for chemical equilibria and sorption.
- **Crystalline Disposal**
  - Evaluate THMC behaviors in clay-based backfill and buffer materials
  - Experimental investigation of radionuclide interactions with natural and engineered materials in a crystalline disposal environment
- **Salt Disposal**
  - Experimental investigations of radionuclide transport properties of salt
  - Mechanical testing of core samples
  - Benchmark testing of coupled process models
  - Complete test plan for thermal field test
- **Generic Disposal System Analysis**
  - Integrate updated subsystem models into system model architecture; selected reference case simulations
- **International Disposal Collaborations**
  - Support ongoing collaborations
- **Disposal of Dual Purpose Canisters**
  - Continue mapping of criticality potential of existing DPCs to disposal environments, simulate reactivity, identify low-k_{eff} canisters, simulate formation waters, evaluate fillers
  - Prepare summary report with cost estimates for disposal of dual purpose canisters
- **Deep Borehole Field Test**
  - See later presentation

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Used Fuel Disposition R&D Concluding Remarks and Issues

- **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
  - 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, 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

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