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Fuel Cycle Technologies

Current Status of the US Radioactive Waste Disposal Program

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Presented to:
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First Workshop and Steering Committee Meeting
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Outline

- **Current events**
  - Recommendations of the Blue Ribbon Commission
  - Near-term DOE actions
  - Legal and legislative uncertainties
- **The Used Fuel Disposition Campaign: Disposal R&D within the DOE Office of Nuclear Energy**
  - Campaign history and mission
  - Campaign organization
  - Disposal R&D

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The Blue Ribbon Commission

- **Recommendations from the BRC's Report to the Secretary of Energy, January 2012 (http://brc.gov/)**
  - A new, consent-based approach to siting future nuclear waste management facilities.
  - A new organization dedicated solely to implementing the waste management program and empowered with the authority and resources to succeed.
  - Access to the funds nuclear utility ratepayers are providing for the purpose of nuclear waste management.
  - Prompt efforts to develop one or more geologic disposal facilities.
  - Prompt efforts to develop one or more consolidated storage facilities.
  - Prompt efforts to prepare for the eventual large-scale transport of spent nuclear fuel and high-level waste to consolidated storage and disposal facilities when such facilities become available.
  - Support for continued U.S. innovation in nuclear energy technology and for workforce development.
  - Active U.S. leadership in international efforts to address safety, waste management, non-proliferation, and security concerns.

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Looking Ahead for the US Disposal Program

- **The DOE's Response to the BRC**
  - Secretary Steven Chu, February 15, 2012
    - *"Today, I am announcing an internal working group to assess the Blue Ribbon Commission recommendations and develop a strategy that builds on its excellent work."*

      (http://energy.gov/articles/secretary-chus-remarks-vogtle-nuclear-power-plant-prepared-delivery)
  - DOE plans to release its strategic plan for addressing BRC recommendations July 26, 2012
- **Yucca Mountain licensing process**
  - Oral arguments scheduled for May 2, 2012 in the US Court of Appeals for the District of Columbia
  - Key question is whether the Nuclear Regulatory Commission's decision to terminate their review of the Yucca Mountain License Application violates the Nuclear Waste Policy Act
- **Legislative action?**
  - The Nuclear Waste Policy Act precludes site-specific repository investigations at locations other than Yucca Mountain without authorization and appropriation by Congress

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DOE Office of Nuclear Energy Mission Statement

- **The primary mission of the Office of Nuclear Energy is to advance nuclear power as a resource capable of meeting the Nation's energy, environmental, and national security needs by resolving technical, cost, safety, proliferation resistance, and security barriers through research, development, and demonstration as appropriate.**

- **In addition to its primary mission, the Office of Nuclear Energy performs several mission-related functions including providing:**
  - International engagement in support of the safe, secure, and peaceful use of nuclear energy as well as support to other Department offices and other federal agencies on issues related to the international use of civilian nuclear energy
  - The capability to develop and furnish nuclear power systems for use in national security and space exploration missions
  - Oversight for specifically assigned front-end fuel cycle responsibilities
  - Stewardship of the DOE Idaho Site

Source: http://www.ne.doe.gov/neMission.html

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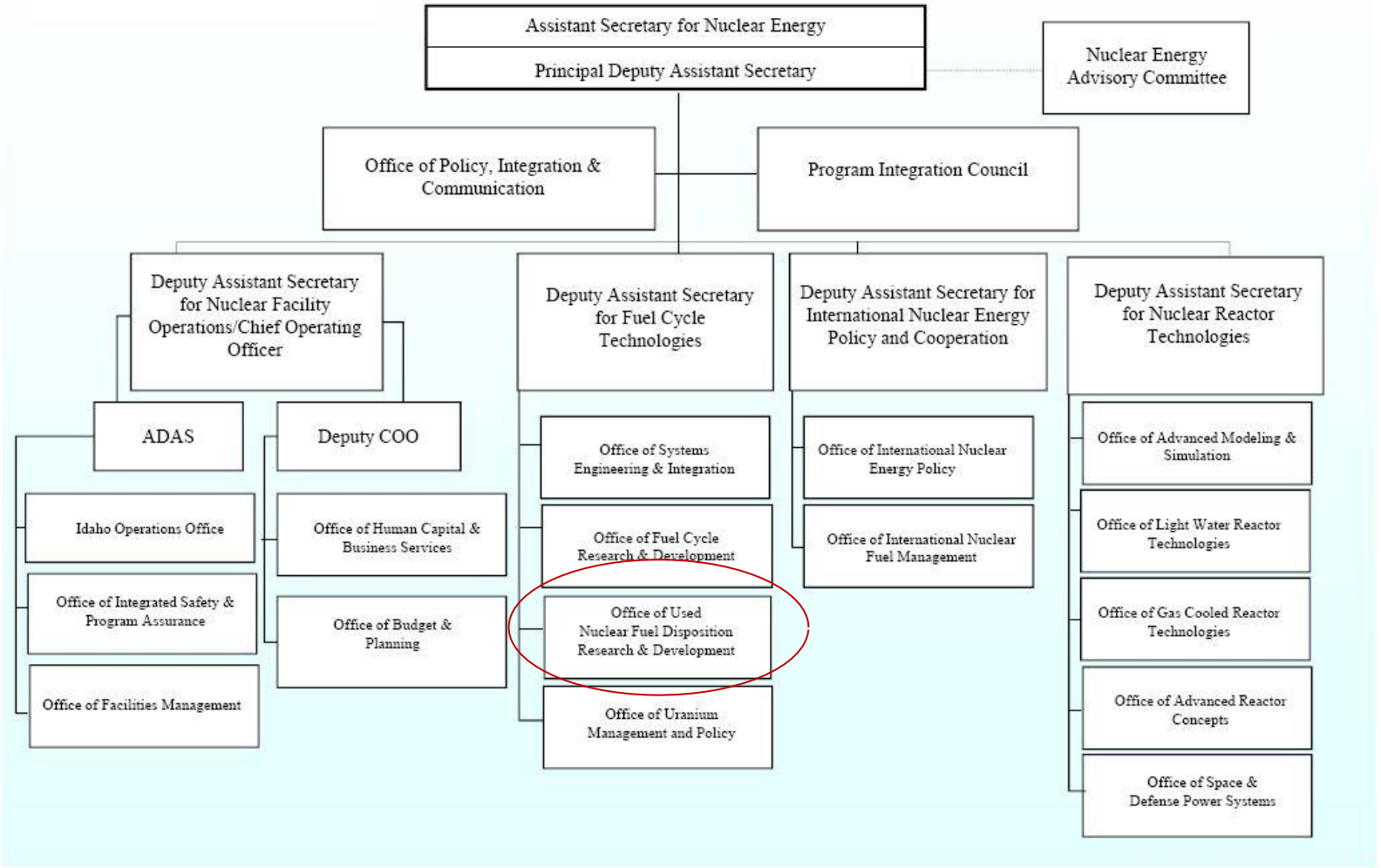
DOE-NE Organization Chart



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The Used Fuel Disposition Campaign

The mission of the Used Fuel Disposition Campaign is 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.

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UFD Campaign 2009-Present

FY09

- Planning meeting at Argonne National Laboratory, June 2009

FY10 R&D

- Disposal R&D, modest level of effort on Storage R&D, no Transportation R&D

FY11 R&D

- Nine national laboratories participating in UFD
- Significant R&D program in Storage, including Transportation
- Disposal R&D not site specific
- Substantive commitment to international collaborations

FY12 R&D

- Uncertainties remain regarding national policy, Yucca Mountain litigation, and budget

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Used Fuel Disposition Campaign

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Role of Disposal R&D after Yucca Mountain

- **The Disposal R&D Program is not starting over**
  - There is an international consensus that deep geologic disposal is a robust and necessary solution for permanent isolation of high-level radioactive waste and used nuclear fuel
  - Internationally, mature safety assessments indicate that granite and clay sites are viable
  - DOE concluded in 2008 that the technical basis for Yucca Mountain was sufficient to submit a license application
- **We have an opportunity to rethink disposal concepts: nearly all options are back on the table**
- **We are limited to generic disposal concepts**
  - No site specific investigations
- **Goals of disposal R&D at this stage**
  - Provide a sound technical basis for the assertion that the US has multiple viable disposal options that will be available when national policy is ready
  - Identify and research the generic sources of uncertainty that will challenge the viability of disposal concepts
  - Increase confidence in the robustness of generic disposal concepts to reduce the impact of unavoidable site-specific complexity
  - Develop the science and engineering tools required to address the goals above, through collaborations within NE and DOE, and with universities, industry and international programs

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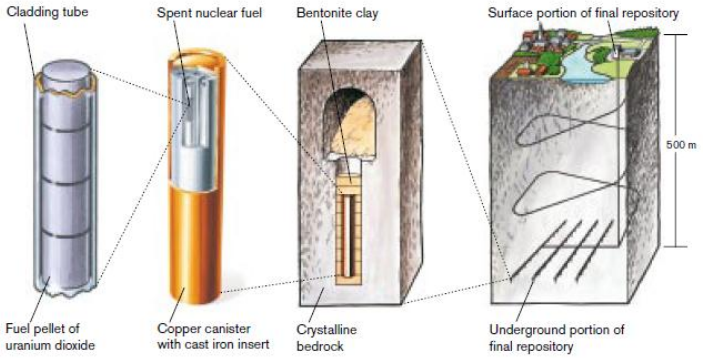
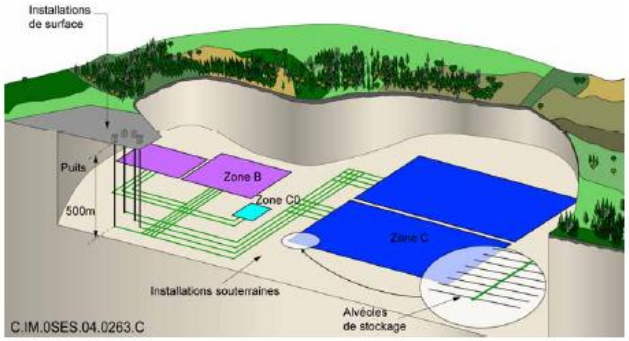
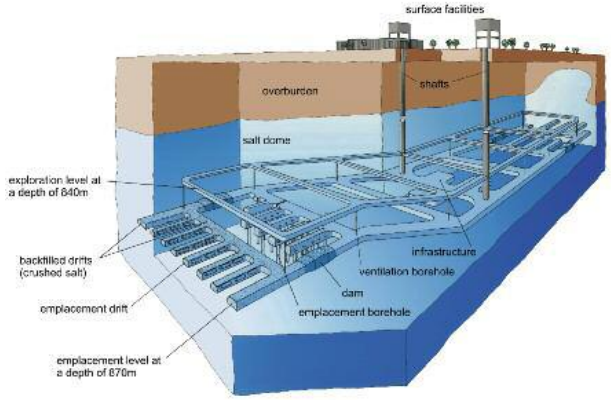
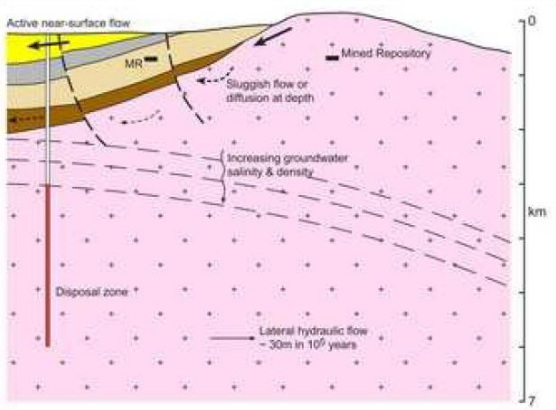
Disposal Options Included for R&D

- **Disposal R&D is focusing on four basic disposal options**
  - Three mined repository options (granitic rocks, clay/shale, and salt)
  - One geologic disposal alternative: deep boreholes in crystalline rocks









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Disposal Options Included for R&D (cont.)

- **A longer list of disposal options: 48 combinations of environments and waste forms**
  - Eight Preliminary Repository Environmental Settings
    - Surface Storage
    - Near Surface Disposal
    - Mined Geologic Disposal (Hard Rock, Unsaturated)
    - Mined Geologic Disposal (Hard Rock, Saturated)
    - Mined Geologic Disposal (Clay/Shale, Saturated)
    - Mined Geologic Disposal (Salt, Saturated)
    - Deep Borehole Disposal
    - Other (sub-seabed, carbonate, …)
  - Six Preliminary Waste Form / Inventory Categories
    - Used Fuel
    - Glass
    - Ceramic / Glass Ceramic
    - Metal Alloy
    - Lower than HLW
    - Other (molten salt, future WFs, ….)
- **Not all of these are the subject of active R&D; some are listed for completeness**
- **Total set of combinations of potential interest is very large because of potential design alternatives, thermal loading strategies, and alternative fuel cycle options**

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How Did UFD Identify These Options?

- **Disposal options have been proposed and evaluated for 50+ years**
- **Consensus for at least thirty years, both in US and internationally, that deep geologic disposal is the preferred option,**
  - Multiple in-depth reviews from the late 1950s to the present have noted the need for geologic disposal
    - "**Geological disposal remains the only-long-term solution available**", National Research Council Board on Radioactive Waste Management, 2001, Disposition of High-Level Waste and Spent Nuclear Fuel; the Continuing Social and Technical Challenges", p. 3
    - "**One or more geologic repositories eventually will be needed in the United States**", Nuclear Waste Technical Review Board, June 2011, Technical Advancements and Issues Associated with the Permanent Disposal of High-Activity Wastes, Lessons Learned from Yucca Mountain and Other Programs, p.1.
    - "**Every nation that is developing permanent disposal capacity plans to use a deep, mined geologic repository for this purpose. Other disposal options (i.e., deep boreholes) have been considered and may hold promise in the long-term but are at a much earlier stage of development.**" Blue Ribbon Commission on America's Nuclear Future Draft Report to the Secretary of Energy, July 29, 2011, page 12.
  - Definitive US work on disposal options dates from the 1970s, summarized in the 1980 *Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste*, DOE/EIS-0046F.

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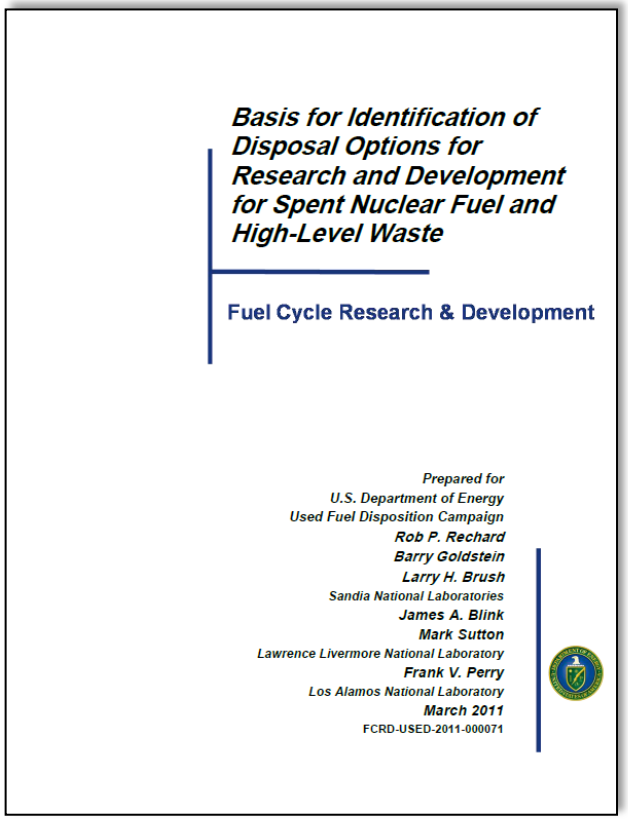
How Did UFD Identify These Options? (cont.)

- **Alternatives summarized by Rechard et al., 2011**
  - Potential media for mined geologic disposal
    - *Salt*
    - *Clay/shale*
    - *Carbonate rocks and chalk*
    - *Granitic rocks*
    - *Basalt*
    - *Volcanic Tuff*
  - Alternative settings for geologic disposal
    - *Saturated zone versus unsaturated zone*
    - *Continent interior*
    - *Coastal areas*
    - *Islands*
  - Alternatives to mined disposal
    - *Deep boreholes in igneous/metamorphic basement rock*
    - *Shallow boreholes in alluvium*
    - *Sub-seabed*
    - *Well injection*
    - *Rock Melt*
  - Alternatives to geologic disposal
    - *Engineered Mountain/Mausoleum*
    - *Ice-Sheet Disposal*
    - *Space Disposal*



http://www.ne.doe.gov/FuelCycle/neFuelCycle_UsedNuclearFuelDispositionReports.html

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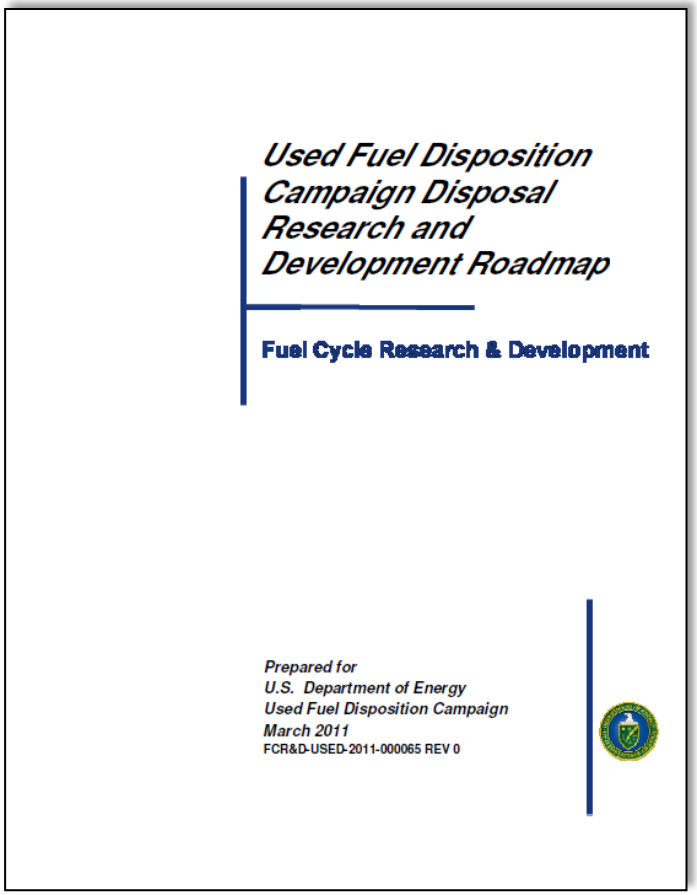
How Did the UFD Identify Disposal R&D Needs?



- ***Used Fuel Disposition Campaign Disposal Research and Development Roadmap***
  - "an initial evaluation of prioritization of R&D opportunities that could be pursued by the campaign"
  - Completed March 2011
  - Used to inform prioritization decisions for disposal research in FY12 and beyond
- **Update planned for Sept. 2012**

http://www.ne.doe.gov/FuelCycle/neFuelCycle_UsedNuclearFuelDispositionReports.html

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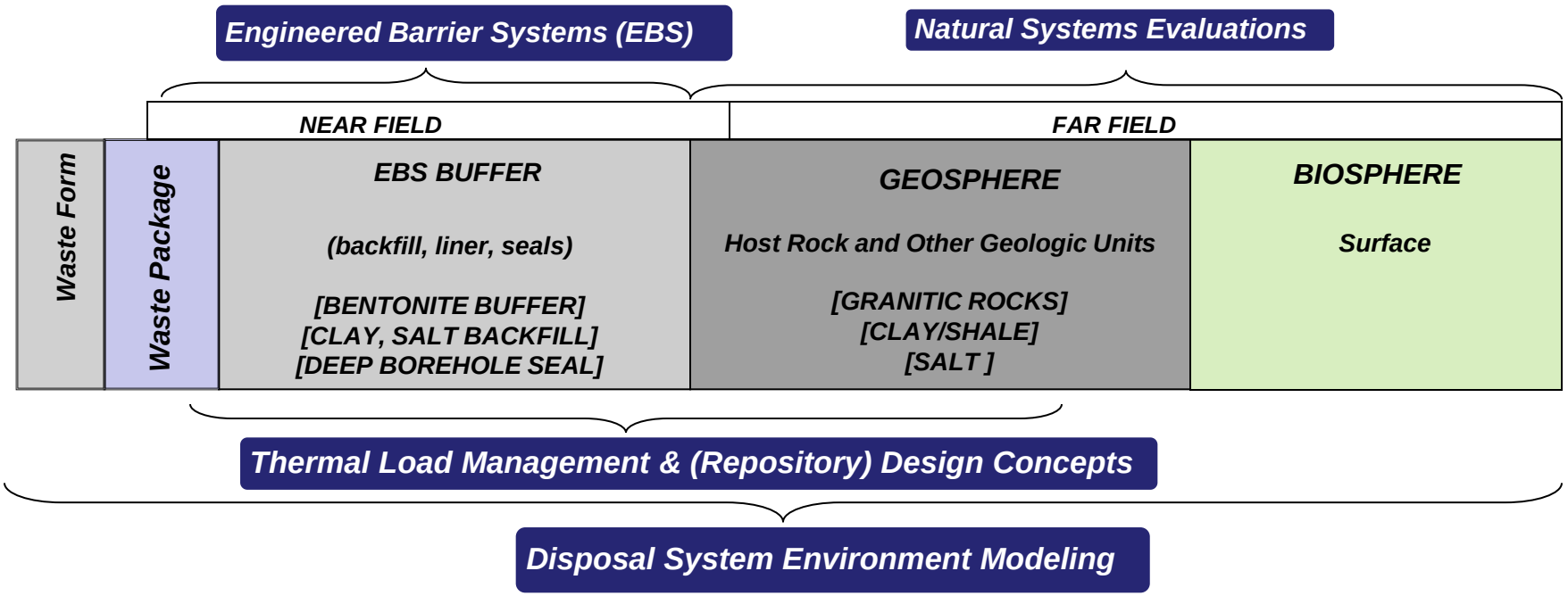
UFD Disposal Research Activities



SUPPORT, ANALYSIS & EXPERIMENTAL ACTIVITIES

Engineered Materials Performance	*(corrosion, degradation studies)*
Features, Events & Processes	*(how R&D is organized and prioritized)*
Low Level Waste Disposition Issues	*(part of total nuclear waste consideration)*
Inventory Projections	*(LLW/HLW, used fuel, open → closed fuel cycles)*

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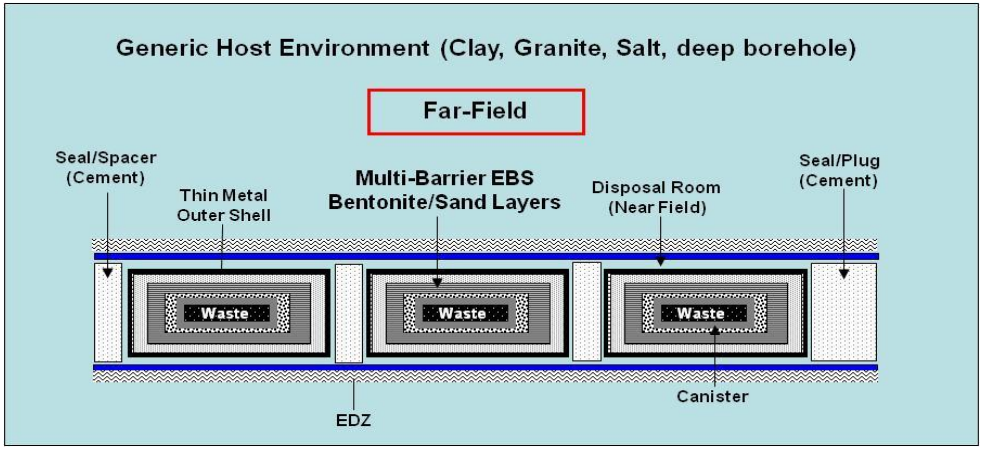
Generic Engineered Barrier Systems R&D

EBS and materials evaluation for multiple disposal environments (clay/shale, granitic rocks, salt, deep borehole)



Representative activities

- Evaluation of EBS configurations and material properties: backfill and sealing material (clay and cement)
- Evaluation of clay / metal interactions at elevated temperatures and pressures: literature review, clay phase characterization, and experiments
- Expand THM constitutive and reactive diffusive transport modeling in bentonite
- Laboratory-scale crushed-salt consolidation experiments and modeling

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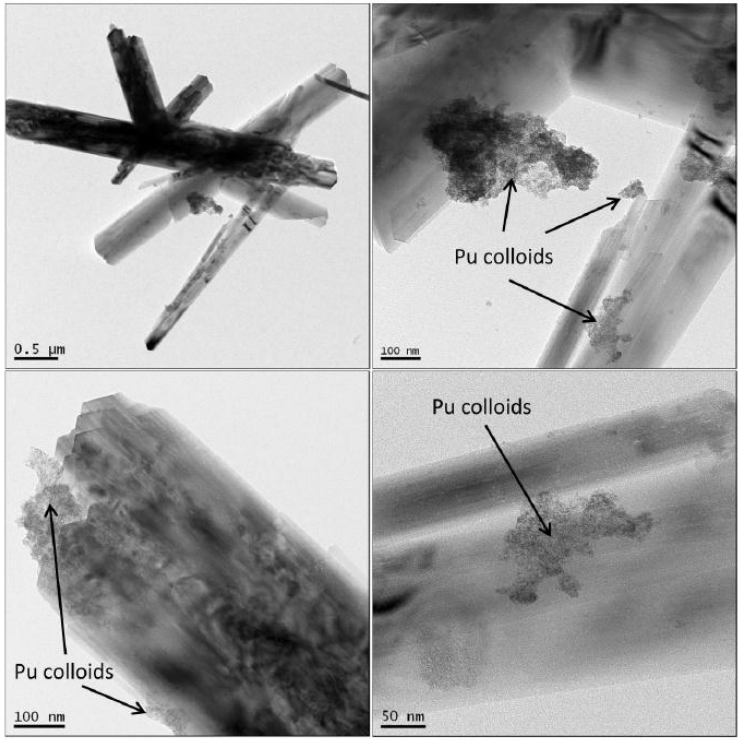
Generic Natural Systems Evaluation R&D

Evaluation of key natural system attributes of multiple disposal system concepts to evaluate impacts on waste immobilization and isolation.

Representative activities

- Discrete fracture network simulation
- Effects of spatial heterogeneity in Kd on radionuclide transport
- Experimental work on Pu colloid behavior in the presence of goethite
- Geomechanical modeling of excavation damage zone in clay/shale
- Experimental work on saturated and unsaturated flow through clay
- Experimental work related to direct disposal of e-chem salt in a salt repository



•TEM of intrinsic Pu(IV) nano-colloids sorbed to goethite at 25° C for 103 days (Wang et al., 2011; Natural System Evaluation and Tool Development—FY11 Progress Report, FCRD-USED-2011-000223)

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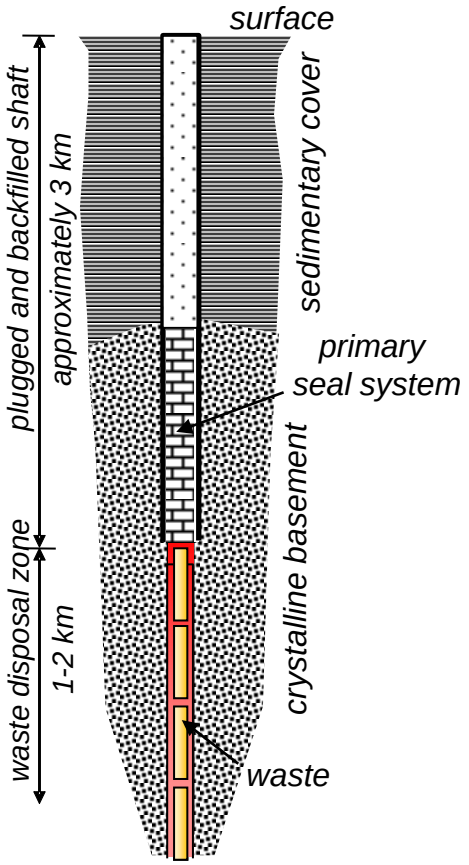
Generic Disposal System-Level Modeling R&D

Develop models to evaluate performance of multiple generic disposal systems

Representative activities

- Implement configuration management for the generic performance assessment (PA) models
- Document technical basis for treatment of Features, Events, and Processes for each generic PA model
- Develop preliminary generic PA models for repositories in clay/shale, granitic rock, salt, and deep borehole settings
  - Highly simplified geometries
  - Isothermal behavior except for deep borehole



(not to scale)

Source: modified from Brady et al., 2009, Deep Borehole Disposal of High-Level Radioactive Waste, SAND2009-4401

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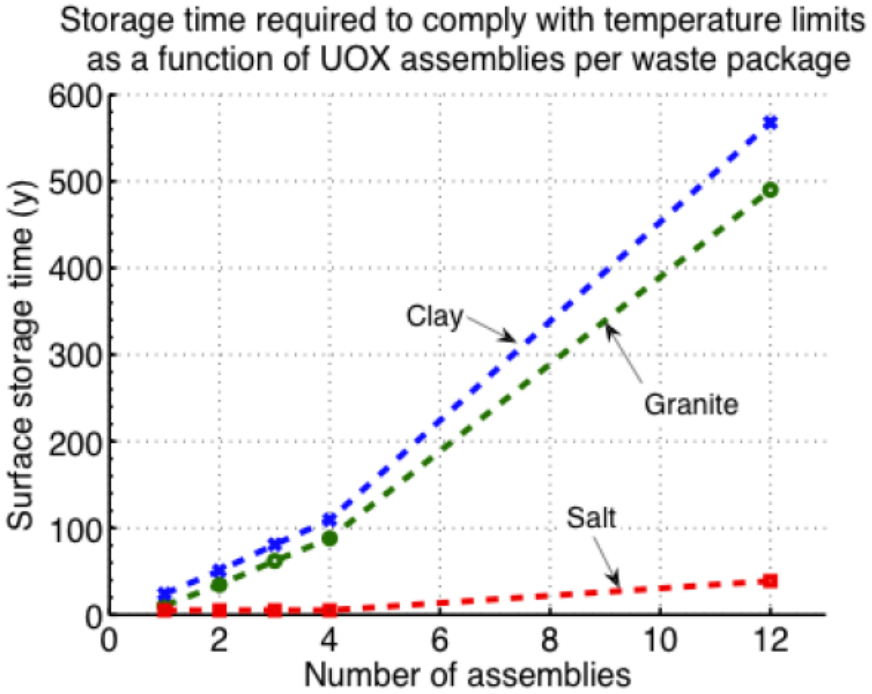
Thermal Load Management & Design Concepts R&D

Thermal modeling and testing to evaluate thermal loading options for multiple disposal concepts and alternative waste forms

Representative activities

- Develop representative design concepts for repositories in clay/shale, granite, salt, and deep borehole settings.
- Identify waste streams for thermal analysis
- Complete thermal loading analyses in representative design concepts for selected waste streams



Minimum decay storage durations to limit peak PWR waste package surface temperature to 100˚ C (granite, clay) or 200˚ C (salt). (Hardin et al., 2011, Generic Repository Design Concepts and Thermal Analysis (FY11), FCRD-USED-2011-000143)

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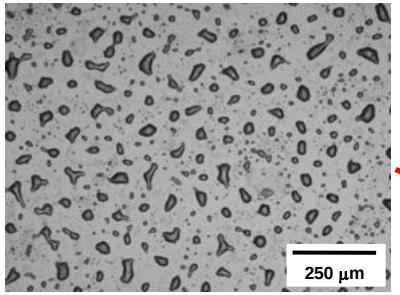
Engineered Materials Performance R&D

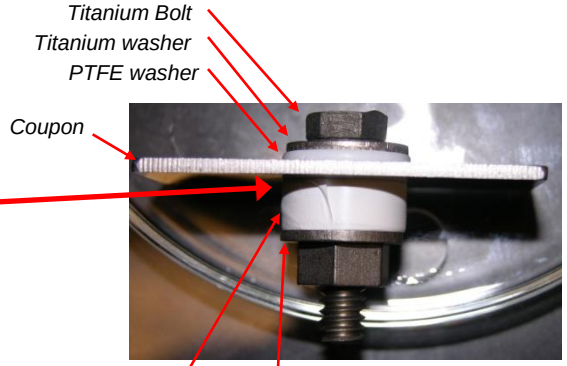
Experiments and model development for long-term performance of engineered materials in storage and repository environments

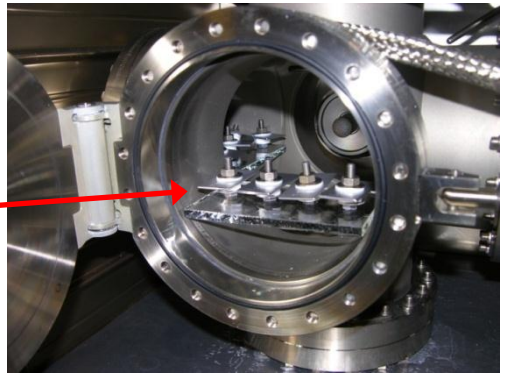
Representative activities (limited to repository environments in FY11, expanded to inlcude storage in FY12)

- Ongoing experiments (YMP initiated, continuing):
  - Immersion: Sampled after 9 months of exposure (12/10). Analysis of samples underway
  - Deliquescence: Corrosion initiation experiments with 2-,3-, and 4-salt assemblages completed
  - Dependence of extent of corrosion on quantity of salt present is now being investigated
- Literature survey/gap analysis for material performance in repository environments has been initiated



Salt mixture on an Alloy 22 Coupon




T, RH-Controlled Environmental Chamber

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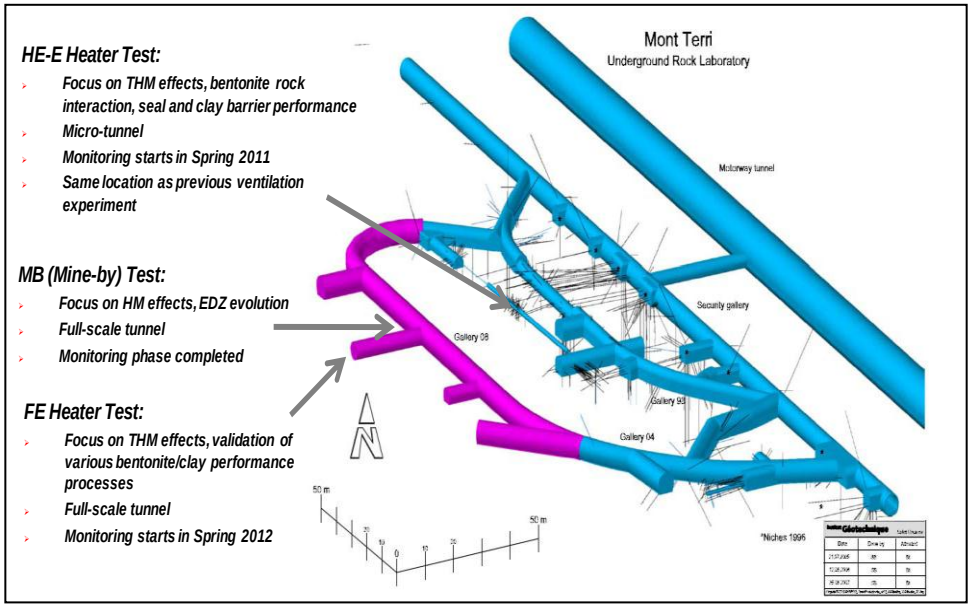
UFD Campaign International Activities

Collaboration continues in multiple areas, including storage, transportation, and disposal

Primary new goal for Disposal R&D in FY12: Establish formal collaborative R&D arrangements with three ongoing European programs

Major current or soon-to-be started experiments



Mont Terri: International underground research laboratory (URL) in clay in Switzerland

Joining the URL will give DOE access to data from all Mont Terri R&D, also the opportunity to conduct new experiments

Colloid Formation and Migration Project

Colloid research at Grimsel granite URL in Switzerland

DECOVALEX: (Development of Coupled Models and their Validation against Experiments)

DOE has participated in the past, new phase of project begins Spring 2012

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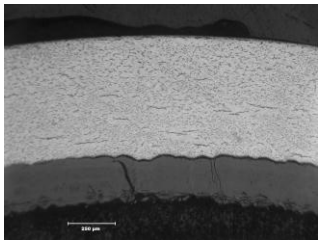
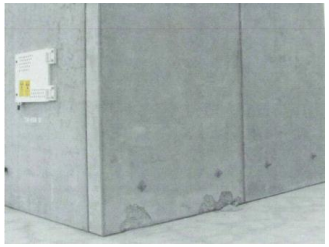
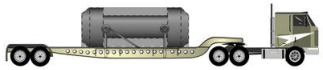
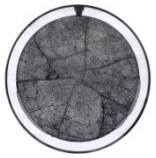
Storage and Transportation Work Package Structure

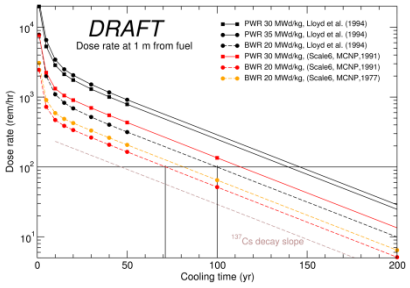
- **Storage R&D Investigations**
  - Data gap analyses
  - Plan to address gaps
  - Development of technical basis
- **Conceptual Evaluation**
  - Evaluate scenarios for accomplishing development of technical basis
  - Develop a systems framework for decision-making
- **Transportation**
  - High burnup fuels
  - Transportation of all fuels after storage
- **Security**
  - Regulatory assessment
  - Identify issues for long-term storage and subsequent transportation
  - Evaluate methods for security assessment for long-term storage











Questions?