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Fuel Cycle Technologies

DOE-NE Used Fuel Disposition Campaign R&D on Storage, Transportation and Disposal

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DOE-NE Used Fuel Disposition Campaign

Presented to:
The 10th Joint Workshop Between Korea and China on Nuclear Waste Management and Fast Reactor Technologies
9-11 October, 2012, Busan, Korea

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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 R&D Activities**
  - Campaign Mission
  - Storage R&D
  - Storage, Transportation, Disposal System Interface R&D
  - Disposal R&D

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 Used Nuclear Fuel Management 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)
  - Congress has requested DOE's strategy for addressing BRC recommendations within 6 months of the release of the BRC's report
- **Yucca Mountain licensing process**
  - Oral arguments heard 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
  - The Nuclear Waste Policy Act precludes the operation of a Federal storage facility with a construction authorization for a repository at Yucca Mountain
  - Senator Bingaman's bill: "Nuclear Waste Administration Act of 2012"

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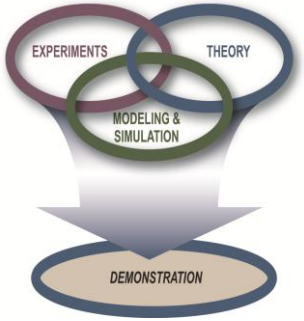
The Used Fuel Disposition Campaign

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.

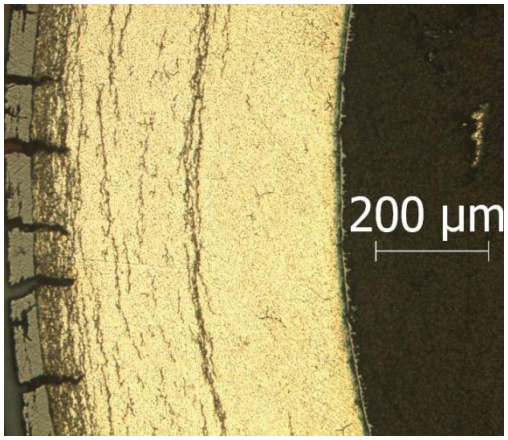
Storage and Transportation Objectives

Overall Objectives:

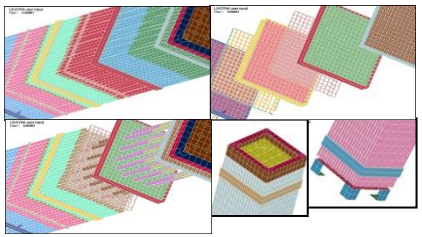
- Develop the technical bases to demonstrate used fuel integrity for extended storage periods.
- Develop technical bases for fuel retrievability and transportation after long term storage.
- Develop the technical basis for transportation of high burnup fuel.

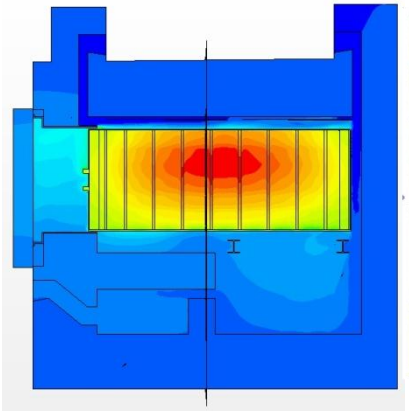


Science based, Engineering driven



UFD Telecon, April 12, 2012
Billone, Liu; Argonne





UFD Telecon, April 12, 2012
Wagner, Adkins; ORNL

'Jones 2010.ppt',
Calvert Cliffs Dry Fuel Storage and Industry Lessons Learned

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Storage and Transportation Major Work Areas

- **Five major work activities are designed to define the work to address the objectives**
  - Engineered Materials – Experimental
  - Engineering Analysis
  - Field Testing
  - Transportation
  - Security

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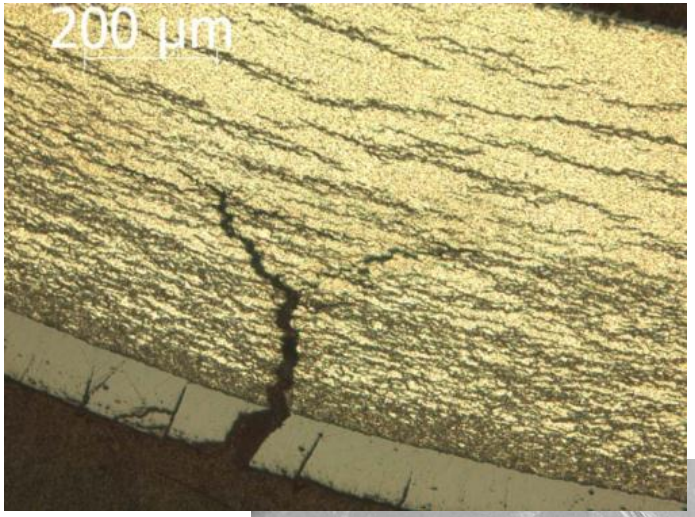
Engineered Materials - Experimental

Scope & Status

- Conduct ring compression tests on used fuel cladding at ANL
- HFIR cladding tests at ORNL
- Conduct SS canister corrosion tests at SNL



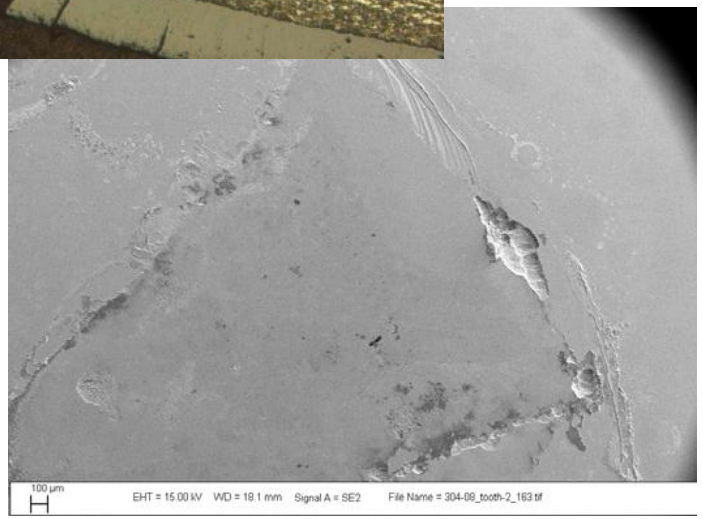
UFD Telecon, April 12, 2012
Ring compression test on HB Zry-4
Billone, Liu; ANL

Impact

- This testing addresses high priority gaps identified for cladding and canisters

FY13

- Continue cladding and canister testing



UFD Telecon, April 12, 2012
304 SS 100µg/cm^2 corrosion test
Bryan, Enos; SNL

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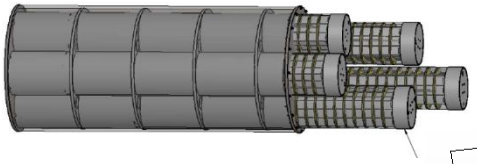
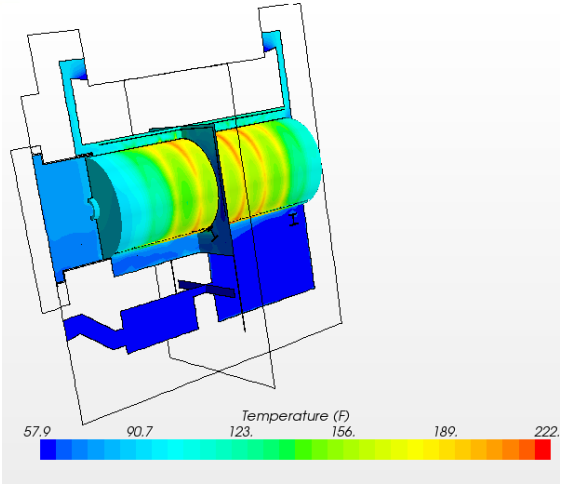
Engineering Analysis

Scope & Status

- Develop Can-in-Can concept: ORNL
- Conduct thermal analysis on Calvert Cliffs Canister: PNNL
- Hydride re-orientation: SNL
- Support mechanical analysis of transport testing: INL/PNNL



UFD Telecon, April 12, 2012
Can-in-can analysis
Wagner, ORNL



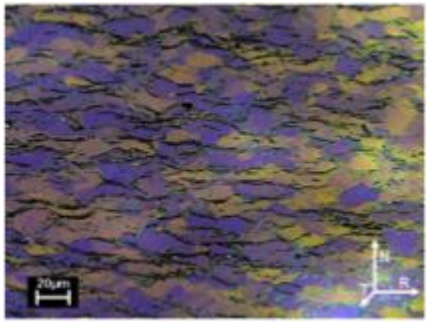
UFD Telecon, April 12, 2012
NuHOMS thermal analysis
Adkins; PNNL

Impact

- This testing addresses identified high priority gaps
  - Thermal profiles
  - Cladding integrity

FY13

- Continue cladding and canister analysis
- Support transportation loading tests



Email/Tikare to Wagner; May 10, 2012
Preliminary Hydride analysis
Tikare; SNL

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Field Testing

Scope & Status

- Write Storage/Transportation RD&D Plan: Lead by INL
- Revise facility functional requirements based on up-dated data gap report: SRNL
- Develop collaborative test plan with EPRI to assess on-site canister corrosion: SNL
- Collaborate with field canister corrosion tests: INL

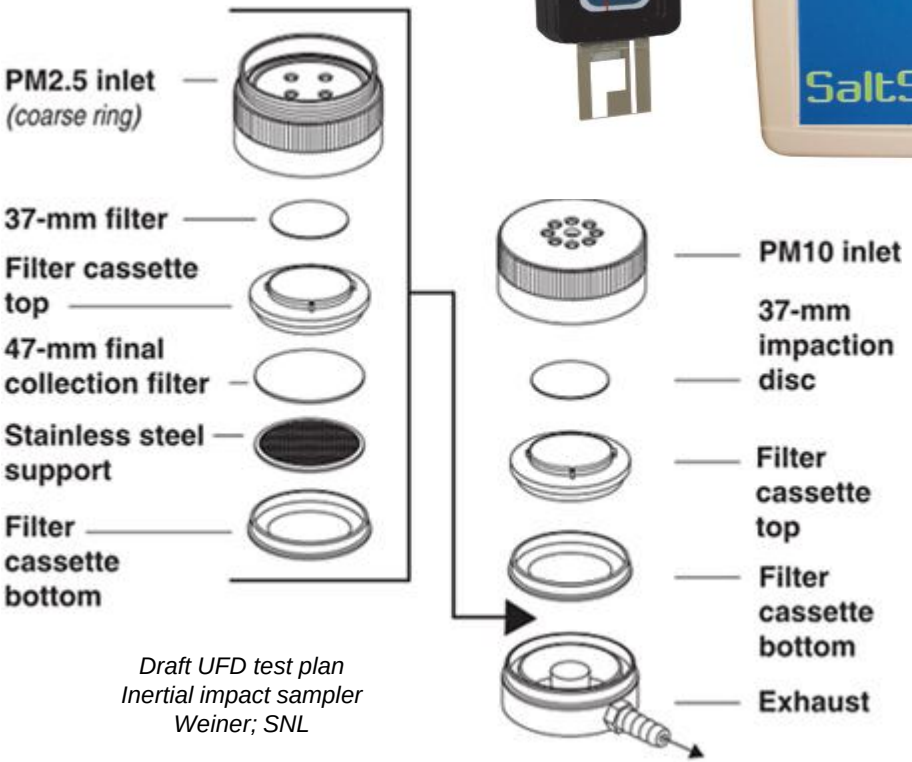
Impact

- The RD&D report supports readiness for the BRC recommendations.
- This testing addresses identified high priority gaps
  - Thermal profiles
  - Cladding integrity

FY13

- Expand canister corrosion testing to multiple sites

Draft UFD test plan
Salt content sampler
Weiner; SNL



Draft UFD test plan
Inertial impact sampler
Weiner; SNL

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Transportation

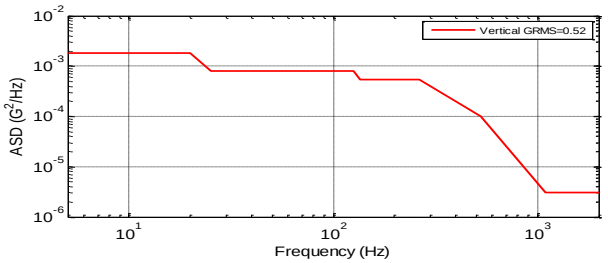
Scope & Status

- Criticality analysis: ORNL
- Moderator exclusion: INL
- Data base work: SRNL
- Transportation test: SNL

CASK VENDOR	CANISTER Type	NUMBER OF CANISTERS (12/2011)	TRANSPORT CASK(S)	NUMBER OF FABRICATED TRANSPORT CASKS
FUEL SOLUTIONS	W150	8	TS-125	0
	VSC-24	58	None-Storage Only	-
TN (NUHOMS)	24PT1, 24PT4 24PT	68	MP-187/MP-197HB	1 / 0
	7P, 12T, 24P **24PHB[1], 32P[1],** 52B	258	None-Storage Only	-
	24PTH, 32PT, 32PTH 61BT, 61BTH	263	MP-197/MP-197HB	0 / 0
NAC	MPC-26, MPC-36	59	NAC-STC	2[2]
	UMS-24	204	NAC-UMS	0
	TSC-37	0	NAC-MAGNATRAN	0
HOLTEC	MPC-24[3], MPC-32 MPC-68, MPC-80	439	HISTAR 100	12

[1] Still being loaded as of 12/2011. All others "Storage Only" canisters have not been loaded in at least the last five years
[2] NAC-STC Casks Fabricated for Offshore Use Only
[3] Includes Trojan 24UT

UFD Mid-yr, May 17: SRNL



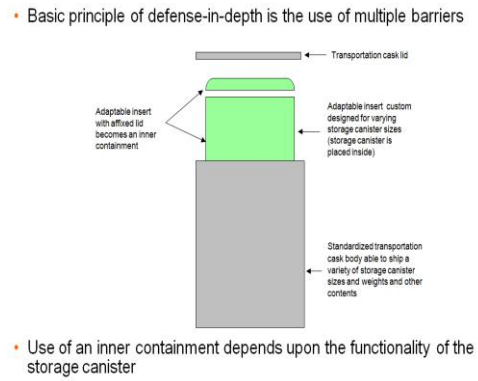
Assembly vibration analysis SNL

Impact

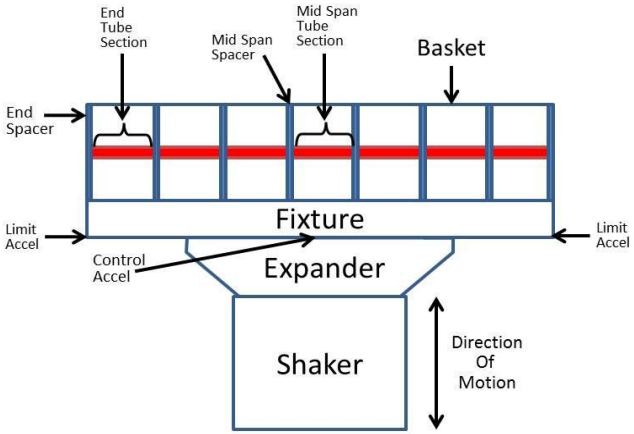
- Supports BRC recommendations to conduct transportation studies early and to de-inventory orphan sites
- Addresses alternate path to transporting used fuel without the full suite of cladding data

FY13

- Continue analyses and testing to support transport of HB used fuel
- Continue data analysis to support planning for transport of fuel



Moderator exclusion concept: INL



Vibration test frame concept: SNL

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Storage, Transportation, Disposal Interface Analyses

- **Recognized need for and initiated integrated system-level evaluations of the used nuclear fuel management system**
  - Future repositories likely to have thermal constraints that limit waste package size
  - Require packaging/re-packaging – where, when?

- **Direct disposal of dual-purpose canisters (DPCs)**
  - Feasibility would have to be demonstrated and suitable site identified/selected
  - Multi-year feasibility evaluation required; initiated in FY12
    - *Complex problem (YM did not accept DPCs for direct disposal)*

- **Implementation of standardized canisters**
  - Could have system-level benefit, depending on when deployed
  - Uncertainty regarding standard canister size; repository media unknown
  - Still would have to manage DPCs
  - Multi-year evaluation/implementation required; initiated in FY12

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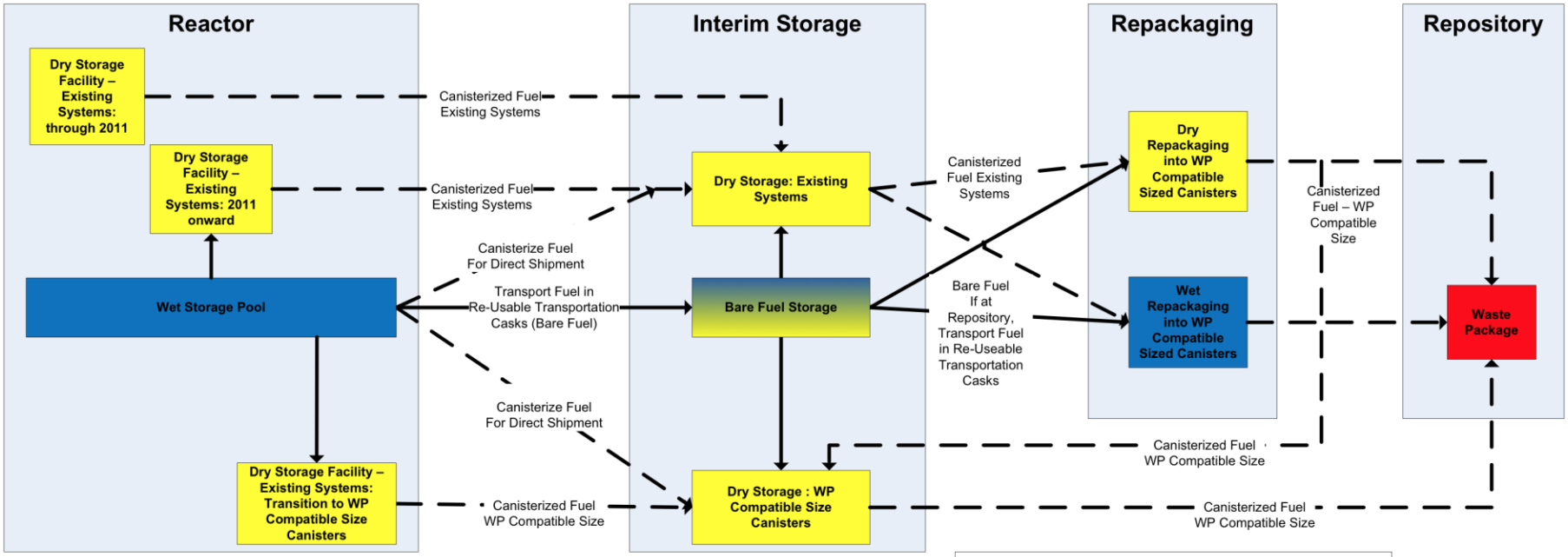
Storage, Transportation, Disposal Interface Analyses



At-Reactor Fuel Management: Options

1. Wet Storage Fuel Management
   - 1a. Transfer to dry-storage to maintain full core off-load capability
   - 1b. Accelerate transfer to dry storage (age ≥ 5 yr)
2. Continue off-loading of fuel in wet storage pools into existing sized dry storage systems
3. Initial off-loading of fuel in wet storage pools into existing sized dry storage systems – transition to WP compatible sized dry storage system at T = 20xx.
4. Transport all fuel in wet storage pool to CIS (when operational and has bare fuel storage capacity) in re-useable transportation casks
5. Canisterize fuel in wet pool for direct shipment to CIS (when operational and does not have bare fuel handling capability)
   - 5a. Existing dry storage systems
   - 5b. WP compatible sized dry storage systems

CIS Fuel Management: Options

1. Wet storage capability at CIS
   - 1a. Maintain fuel in wet storage
   - 1b. Transfer to existing dry storage systems
   - 1c. Transfer to WP sized canisters
2. Re-packaging locations
   - 2a. At CIS
   - 2b. At repository
3. Re-packaging technology alternatives
   - 3a. Wet
   - 3b. Dry
4. Received fuel at CIS in existing dry storage system sized canisters
   - 4a. Store as-is
   - 4b. Repackage into WP compatible size canisters and store

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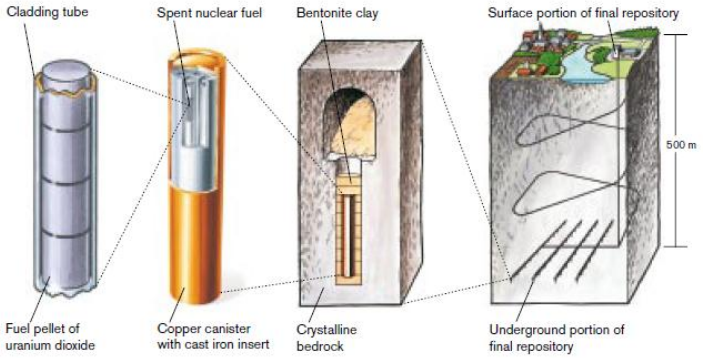
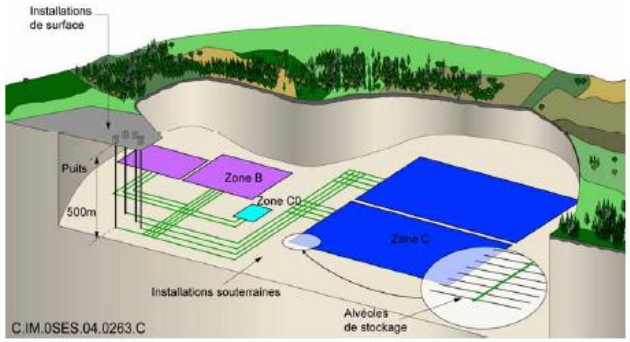
Role of Disposal R&D after Yucca Mountain

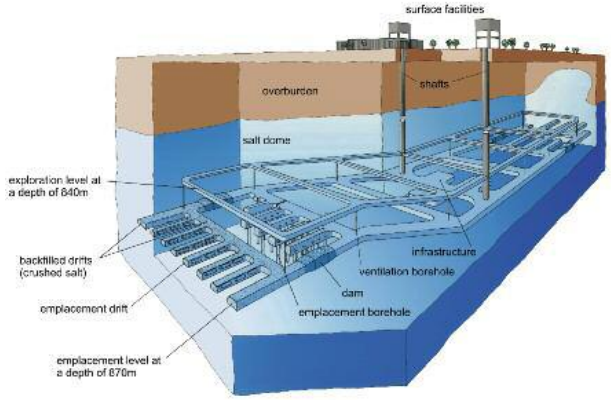
- **The Disposal R&D Program is not starting over**
  - There is an international consensus that deep geologic disposal is a robust and necessary solution for permanent isolation of high-level radioactive waste and used nuclear fuel
  - Internationally, mature safety assessments indicate that granite 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

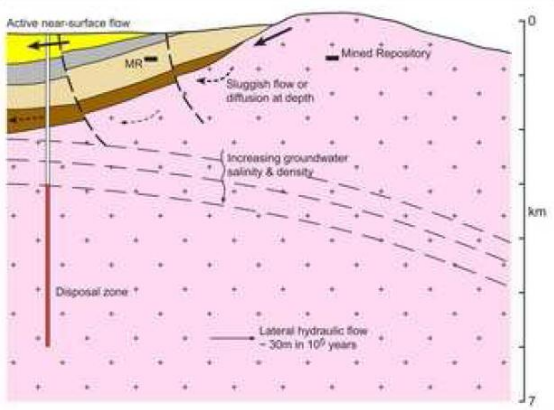
Disposal Options Included for R&D

- **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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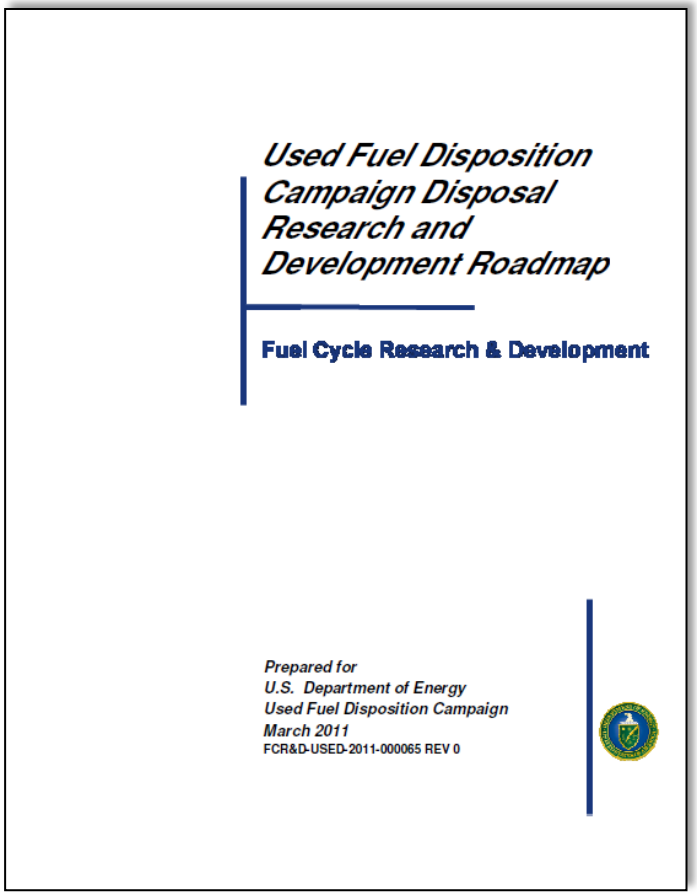
How Did the UFD Identify Disposal R&D Needs?



- ***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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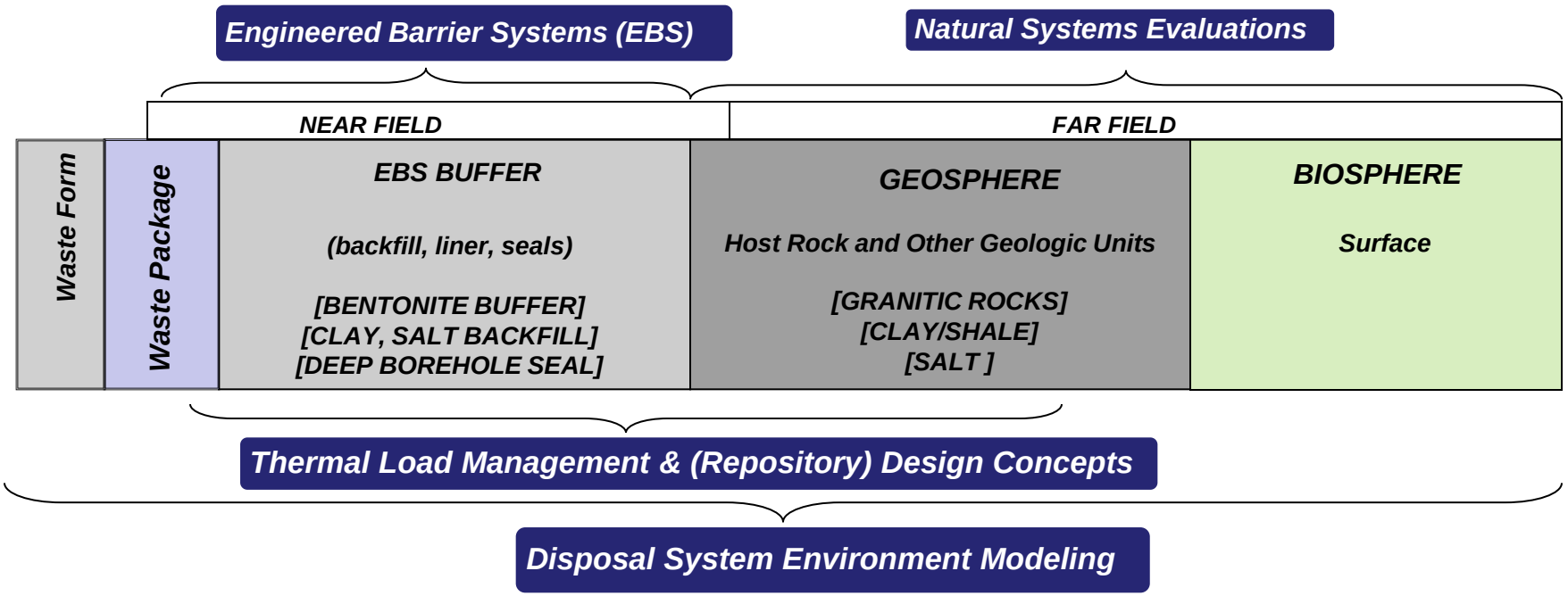
UFD Disposal Research Activities



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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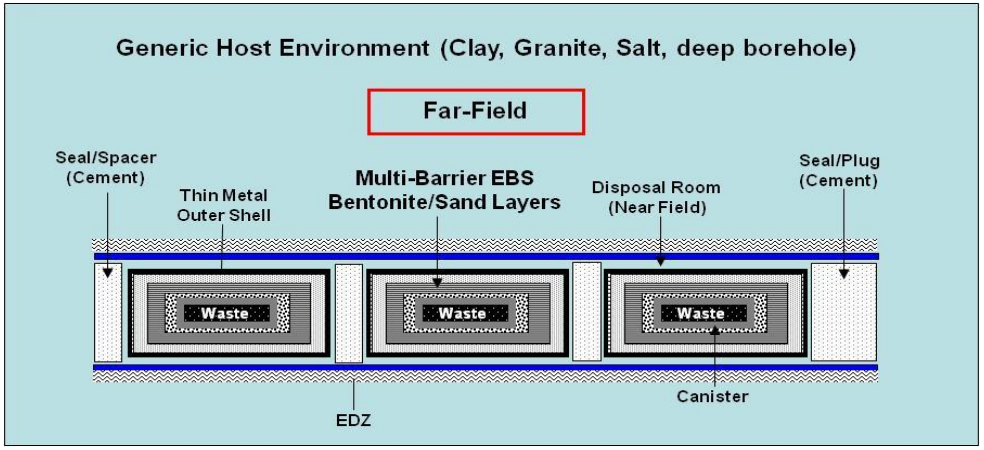
Generic Engineered Barrier Systems R&D

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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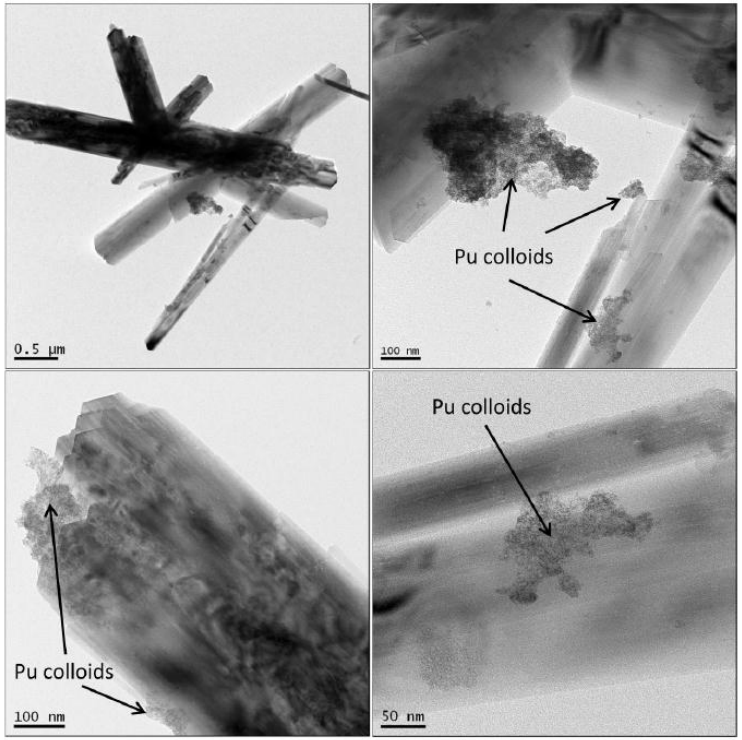
Generic Natural Systems Evaluation R&D

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



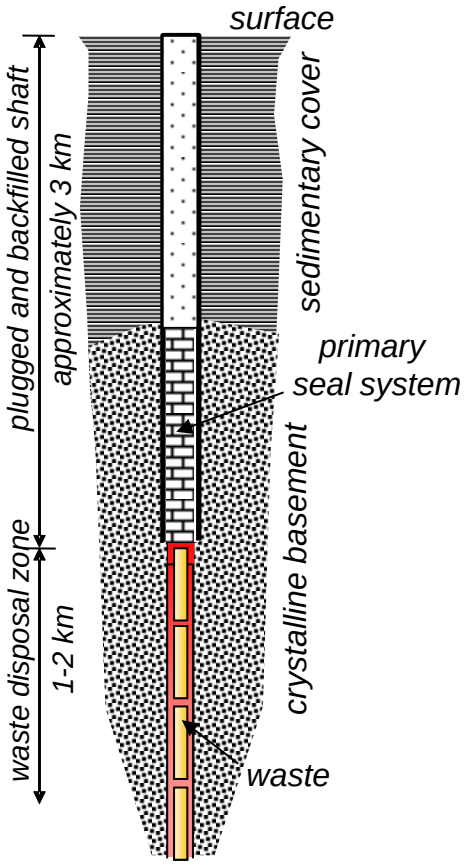
•TEM of intrinsic Pu(IV) nano-colloids sorbed to goethite at 25° C for 103 days

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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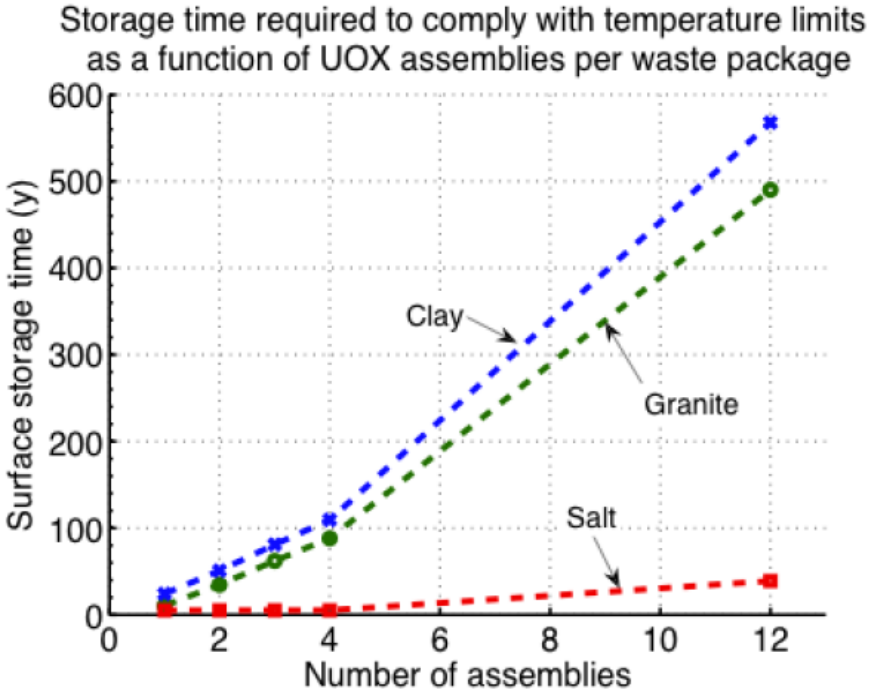
Thermal Load Management & Design Concepts R&D

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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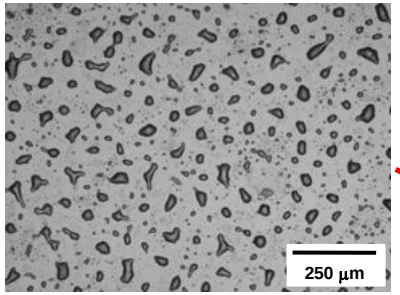
Engineered Materials Performance R&D

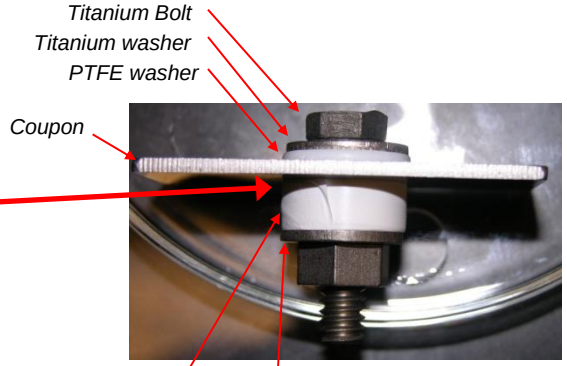
Experiments and model development for long-term performance of engineered materials in storage and repository environments

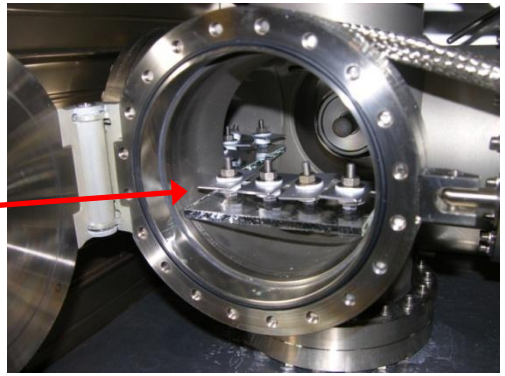
Representative activities (limited to repository environments in FY11, expanded to inlcude storage in FY12)

- 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





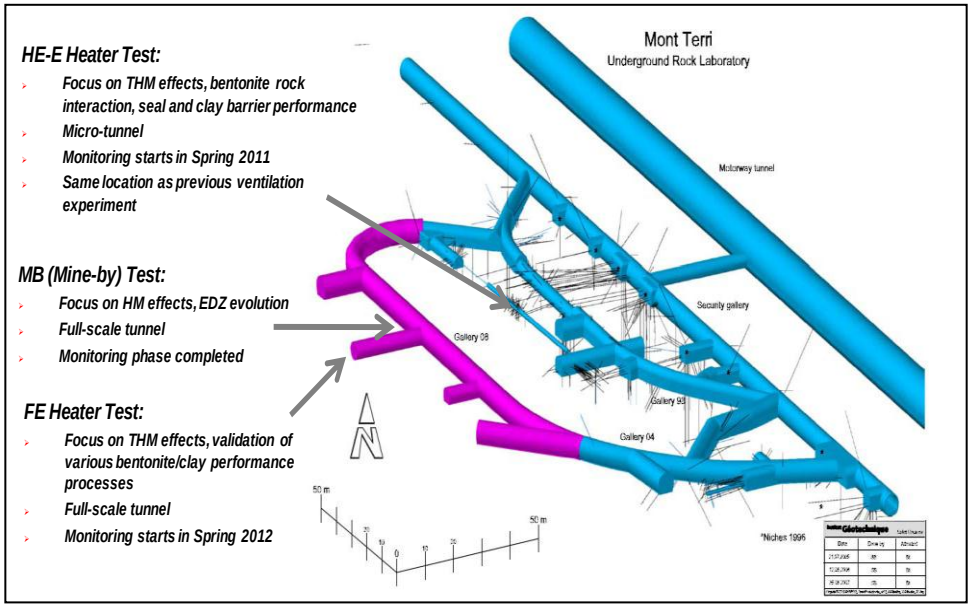
T, RH-Controlled Environmental Chamber

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 ongoing international 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

KAERI Underground Research Tunnel (KURT)

R&D plan for experiments beginning in FY13

Questions?