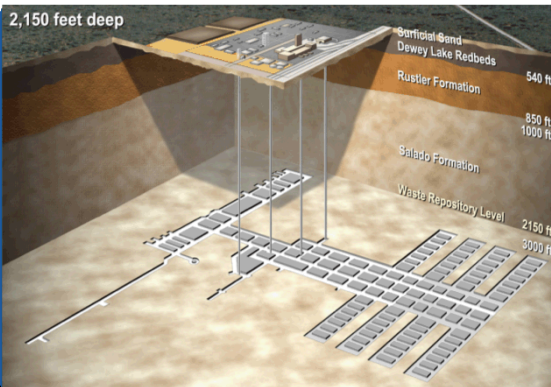




U.S. DEPARTMENT OF
ENERGY

Nuclear Energy

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Update of Radioactive Waste Management Programs in the U.S.

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TECRO-AIT JSC Meeting on Civil Nuclear Cooperation

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106/12/12

Kaohsiung, Taiwan



Presentation Outline

Update of Radioactive Waste Management Programs in the US

■ Geologic disposal

- The goal
- The reality
- WIPP

■ Spent Nuclear Fuel (SNF) storage

■ Current Storage and Transportation R&D

- Canister performance
- Multi-modal transportation tests

■ Current Disposal Research R&D

- Tools for performance assessment – PFLOTRAN
- International collaboration activities



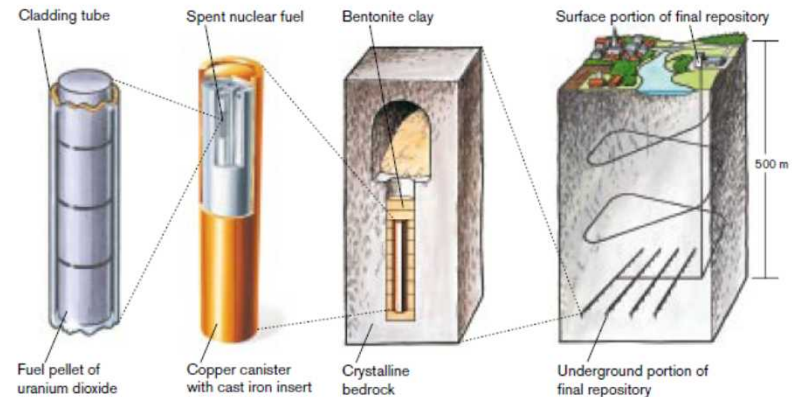
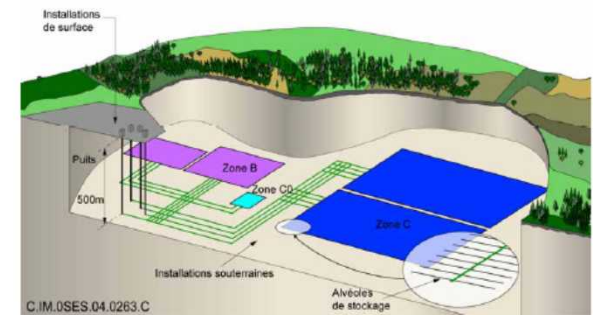
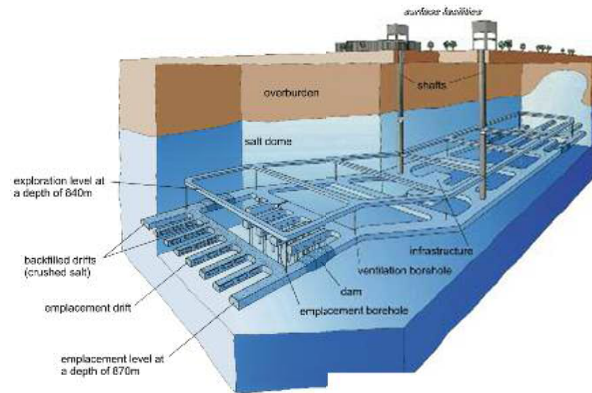
Spent Nuclear Fuel and High-Level Radioactive Waste Disposal: The Goal

“There has been, for decades, a worldwide consensus in the nuclear technical community for disposal through geological isolation of high-level waste (HLW), including spent nuclear fuel (SNF).”

“Geological disposal remains the only long-term solution available.”

National Research Council, 2001

Deep geologic disposal has been planned since the 1950s

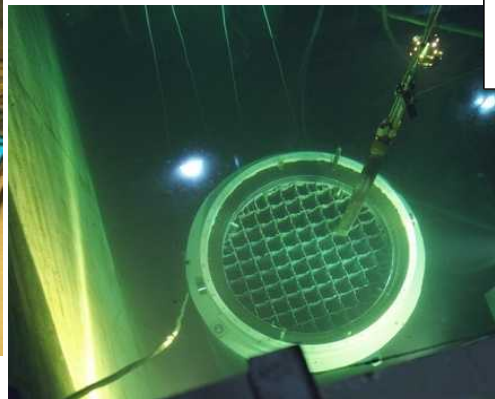
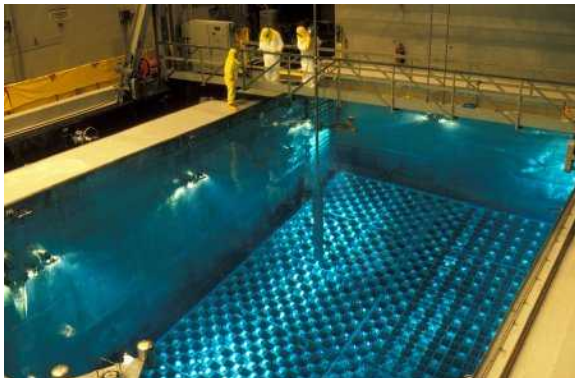
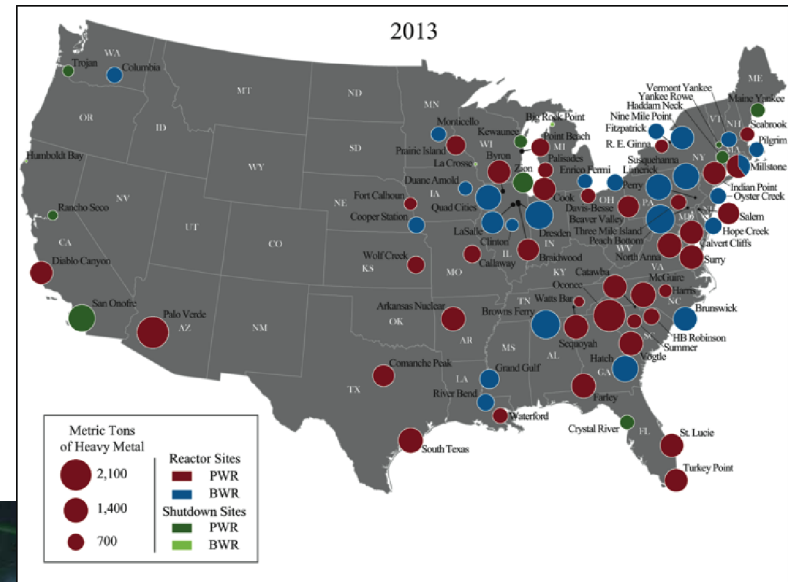




Geologic Disposal in the US: The Reality

Commercial Spent Nuclear Fuel (SNF) is in Temporary Storage at 75 Reactor Sites in 33 States

- Pool storage provides cooling and shielding of radiation
 - Primary risks for spent fuel pools are associated with loss of the cooling and shielding water
- US pools have reached capacity limits and utilities have implemented dry storage
- Some facilities have shutdown and all that remains is “stranded” fuel at an independent spent fuel storage installation (ISFSI)





The Waste Isolation Pilot Plant (WIPP)

April 2017: Resumed Disposal of Transuranic Waste

- Ten primary sites ship waste to WIPP all by truck
- >100 shipments since April



Derived from defense-related activities

- Laboratory and industrial trash contaminated with transuranic radionuclides
- Primarily alpha-emitting radionuclides, relatively little gamma emission and low thermal power
- Fewer fission products than SNF/HLW



Dry Storage Systems for Spent Nuclear Fuel

■ Dual purpose canister (DPC)

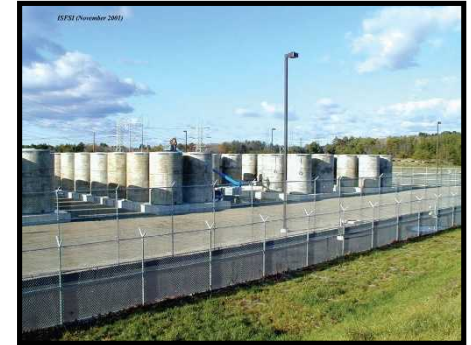
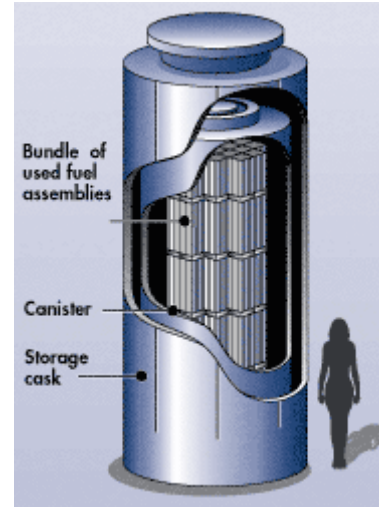
- A canister that is certified for both storage and transportation of spent nuclear fuel

■ Dry cask/canister storage systems

- The most common type of dry storage cask system is the vertical cask/canister system shown above, in which the inner stainless steel canister is removed from the storage overpack before being placed in a shielded transportation cask for transport
 - *Can be constructed both above and below grade*
- Horizontal bunker-type systems and vaults are also in use

■ Some older fuel is also stored as “bare fuel” in casks with bolted lids; few sites continue to load these systems

■ Multiple vendors provide NRC-certified dry storage systems to utilities





Current Storage and Transportation R&D

Spent fuel integrity

- Current tests and analyses indicate that spent fuel is *more robust* than was previously thought
- The *DOE/EPRI High Burnup Confirmatory Data Project* will obtain data after 10 years of dry storage to confirm current test and analysis results from parallel hot cell testing of “sister rods”

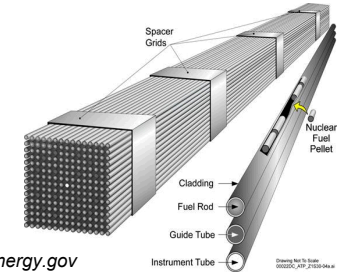


Photo: energy.gov

Storage system integrity

- Stress corrosion cracking of canisters may be a concern in some parts of the country, and more work is needed in analysis and detection*
- Monitoring and Aging Management practices at storage sites will be important to confirm storage system performance during extended service*

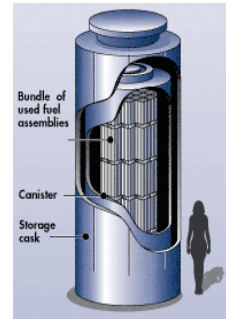
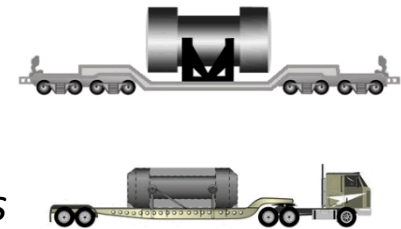


Photo: nrc.gov

Spent fuel transportability following extended storage

- The realistic stresses fuel experiences due to vibration and shock during normal transportation are far below yield and fatigue limits for cladding*



Energy.gov/pictures



Understanding Canister Performance: Primary Concern – Stress Corrosion Cracking (SCC) Requiring 3 Concurrent Conditions



Dust on canister surface at Calvert Cliffs (EPRI 2014)



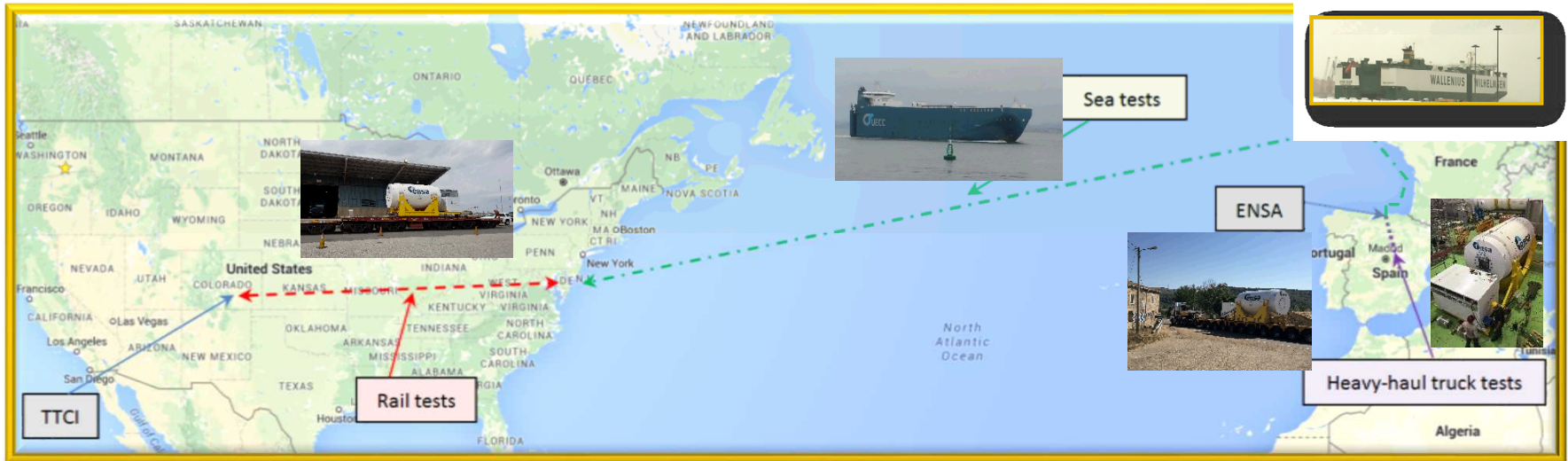
Photo of dry canister weld. Photo: SNL

Mock-up Canister
Photo: Enos, SNL





Routing of Instrumented Cask and Assemblies



Photos provided by Steve Ross, PNNL

- 1) Heavy-haul truck from within Spain ~ June 14, 2017
- 2) Coastal sea shipment from Santander to large northern European port ~ June 27, 2017
- 3) Ocean transport from Europe to Baltimore
- 4) Commercial rail shipment from Baltimore to Pueblo, Colorado ~ Aug 3, 2017
- 5) Testing completed at the Transportation Technology Center, Inc.
- 6) Return trip to ENSA, September 5, 2017

Data was collected throughout all legs of the transport as well as the transfers between legs.



Current Disposal R&D

Provide Sound Basis for Disposal Options in the US

- *Investigate multiple aspects of nuclear waste geologic disposal in*
 1. *Argillaceous (clay-bearing) host rock*
 2. *Crystalline (granitic, metamorphic) host rock*
 3. *Salt (bedded or domal salt formations)*
 4. *Engineered barrier system R&D*
 5. *Dual Purpose Canister (DPC) research*

Develop the Science and Engineering Tools to Support Disposal Concepts

- *Upgrade, integrate, and coordinate the development of subsystem models into the Geologic Disposal Safety Assessment (GDSA) system model architecture*
- *Perform integrated GDSA performance assessment (PA) simulations of detailed coupled processes in the EBS*

Continue to Participate in International Disposal R&D

Disposal R&D at 9 US Labs and multiple universities

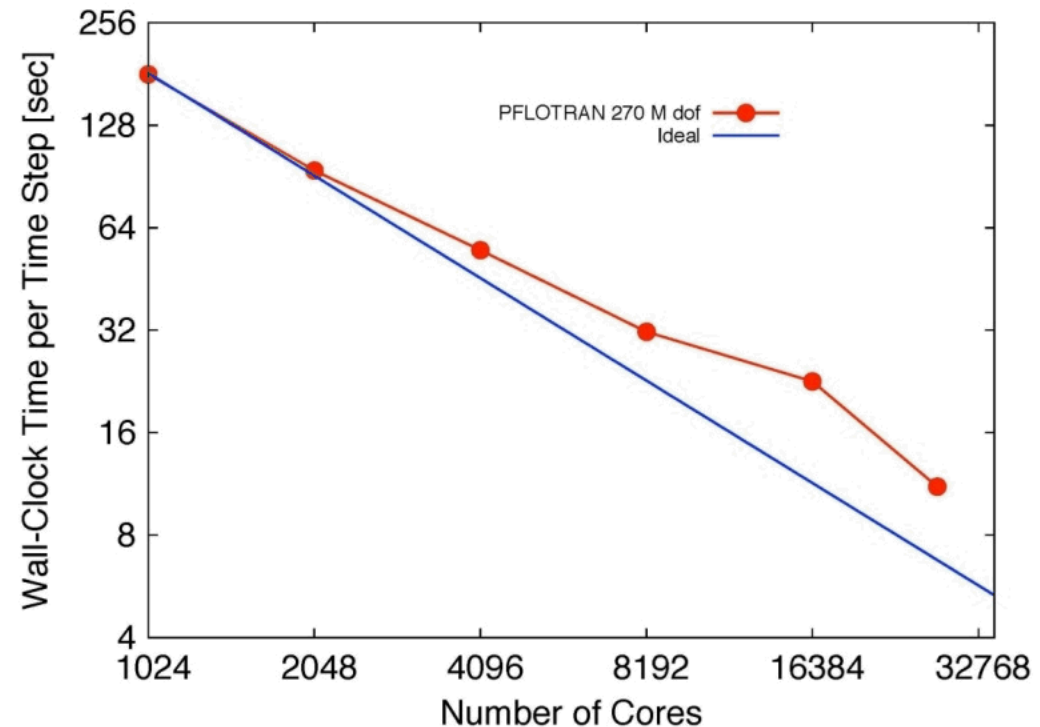




PFLOTRAN: state-of-the-art massively parallel subsurface flow and reactive transport

- *Petascale* reactive multiphase flow and transport code
- *Open source* license (GNU LGPL 2.0)
- *Object-oriented Fortran 2003/2008*
 - Pointers to procedures
 - Classes (extendable derived types with member procedures)
- *Founded upon well-known (supported) open source libraries*
 - MPI, PETSc, HDF5,
 - METIS/ParMETIS/CMAKE
- *Demonstrated performance*
 - Maximum # processes: 262,144 (Jaguar supercomputer)
 - Maximum problem size: 3.34 billion degrees of freedom
 - Scales well to over 10K cores*

code





Nuclear Energy

■ Nuclear waste disposal

- Waste Isolation Pilot Plant (WIPP)
- DOE Used Fuel Disposition Program
- SKB Forsmark Spent Fuel Nuclear Waste Repository (Sweden, Amphos²¹)

■ Climate: coupled overland/groundwater flow; CLM

- Next Generation Ecosystem Experiments (NGEE) Arctic
- DOE Earth System Modeling (ESM) Program

■ Biogeochemical transport modeling

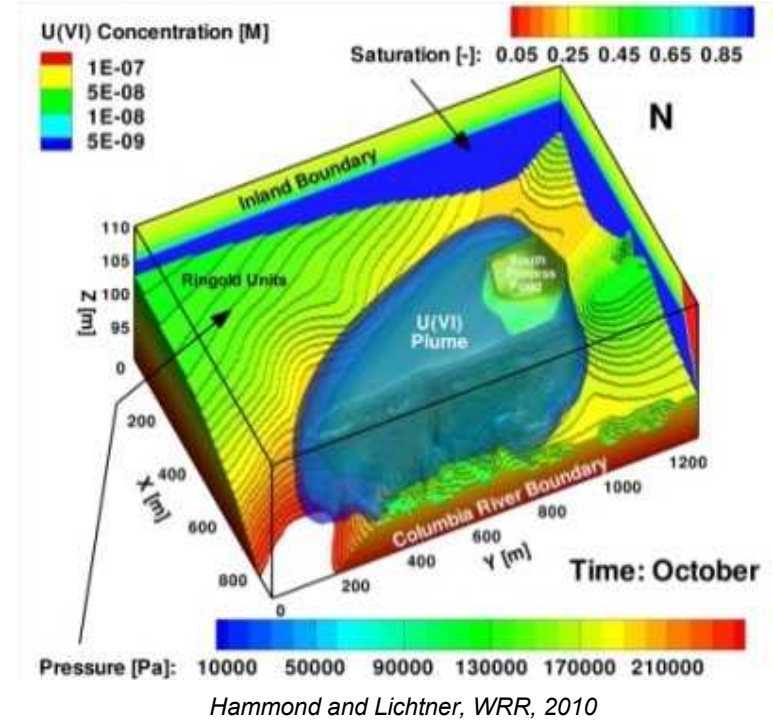
- U(VI) fate and transport at Hanford 300 Area
- Hyporheic zone biogeochemical cycling
 - *Columbia River, WA, USA*
 - *East River, CO, USA*

■ CO₂ sequestration

■ Enhanced geothermal energy

■ Radioisotope tracers

■ Colloid-facilitated transport



NOTE: A PFLOTRAN short-course is planned to be given by Glenn Hammond of Sandia in Taiwan during March of 2018. TECRO will have the details as they become available.



Disposal Collaboration in International Partnerships/Activities

Office of Used Nuclear Fuel Disposition International Program

Strategic Plan
April 2012



Current Portfolio of International Partnerships

*Leveraging global knowledge for domestic goals
Building a foundation for collaboration, trust, and joint action*

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 (ended in 2015)
- ❑ **SKB Task Forces**
 - Participate in crystalline rock research centered around Äspö HRL in Sweden
- ❑ **FEBEX DP**
 - Participate in FEBEX dismantling project, which evaluates bentonite-rock behavior after 17 years of heating
- ❑ **Nuclear Energy Agency (NEA)**
 - Thermochemical Database Project
 - Salt Club
 - Clay Club
 - RepMet (repository metadata initiative)

Bilateral Agreements

- ❑ **US-China**
 - Bilateral Civil Nuclear Energy Cooperative Action Plan (BCNECAP) with working group in Spent Fuel Storage and Repository Science
- ❑ **US-Germany Benchmarking Study for Salt**
 - Participate in model comparison for TM behavior of domal and bedded salt
- ❑ **US-Republic of Korea (ROK)**
 - KAERI Underground Research Tunnel (KURT), experiments in crystalline rock
 - High Level Bi-Lateral Commission (HLBC) information exchange in used fuel disposal
- ❑ **US-Taiwan**
 - Joint Standing Committee on Commercial Nuclear Cooperation (JSCCNC) – Radwaste Management
- ❑ **Other Potential Opportunities**
 - Explore use of existing Memorandum of Understanding (MoU) between DOE and Spain (ENRESA), France (ANDRA), Japan (JNEAP) and Belgium

Planned collaboration in HotBENT project



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Thank you 谢谢

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