Deep Borehole Disposal
Research and Development Program

Timothy C. Gunter
Program Manager, Disposal R&D
Office of Used Nuclear Fuel Disposition R&D

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on Deep Borehole Disposal of Radioactive Waste
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Deep Borehole (DBH) Disposal R&D Program

- DBH Disposal Concept
- DBH Reference Design
- DBH Field Test
- Conclusions
- 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
Deep borehole disposal of high-level radioactive waste has been considered in the U.S. and elsewhere since the 1950s and has been periodically studied since the 1970s.

- Disposal concept consists of drilling a borehole or array of boreholes into crystalline basement rock to about 5,000 m depth.
- Waste canisters would be emplaced in the lower 2,000 meters of the borehole.
- Upper borehole would be sealed with compacted bentonite clay, cement plugs, and cemented backfill.
Deep Borehole Disposal Concept

- 5,000 m deep borehole(s) in crystalline basement rock, well below fresh groundwater resources
- Waste canisters in lower 2,000 m
**Deep Borehole Disposal Concept**

- **Seals in upper 3,000 m**
Several factors suggest that the disposal concept may provide a technically feasible and cost-effective alternative for safe disposal of some DOE-managed waste forms:

- Crystalline basement rocks are common in many stable continental regions
- Existing drilling technology should permit dependable construction at acceptable cost
- Low permeability and long residence time of high-salinity groundwater in deep continental crystalline basement at many locations suggests very limited interaction with shallow fresh groundwater resources
- Geochemically reducing conditions at depth limit the solubility and enhance the sorption of many radionuclides in the waste
- Density stratification of saline groundwater underlying fresh groundwater would oppose thermally induced groundwater convection
Deep Borehole Disposal Concept

Why Deep Borehole Disposal?

- Potential for robust isolation:
- Gives DOE the flexibility to consider options for disposal of smaller waste forms in deep boreholes
  - Potentially earlier disposal of some wastes than might be possible in a mined repository
  - Possible reduced costs associated with projected treatments of some wastes
Site selection guidelines indicate that large areas with favorable geological characteristics exist in the U.S.

Undesirable Features

- Young meteoric groundwater
- Low-salinity, oxidizing groundwater
- Economic natural resources
- Upward hydraulic gradients
- Overpressuring
- High geothermal heat flow
- High permeability hydraulic connections to the subsurface

Depth to Crystalline Basement

Deep Borehole Disposal Concept
Aspects of Borehole Siting

Heat Flow

Oil and Gas

Volcanoes and recent faults
Deep Borehole Disposal Concept
Potential Wastes for Deep Borehole Disposal

- Waste could consist of DOE-managed waste forms, including some DOE spent nuclear fuel, high-level radioactive waste, or other specialized waste types

- Several DOE-managed small waste forms are potential candidates for deep borehole disposal (SNL 2014)
  - Cesium and strontium capsules. 1,936 cesium and strontium capsules stored at the Hanford Site
  - Untreated calcine HLW currently stored at INL in sets of stainless steel bins within concrete vaults
  - Salt wastes from electrometallurgical treatment of sodium-bonded fuels could be packaged in small canisters as they are produced
  - Some DOE-managed SNF currently stored in pools at INL and SRS
Overarching objective: A simple and achievable, internally consistent system for waste disposal that meets regulatory requirements for operational and public safety

Update and refine the conceptual design presented in Brady et al. (2009)

Consider preliminary design alternatives

Provide a reference design for performance assessment and risk analysis

Provide a reference design for more accurate cost estimates

Numerous viable design alternatives exist – this reference design is one choice that provides a basis for the objectives stated above

Arnold et al. (2011)
Borehole casing or liner would assure unrestricted emplacement of waste canisters.

A liner casing would be in place for the emplacement of waste canisters and facilitate potential retrieval (until the liner is pulled and seals set).

The perforated liner would be left in place in the disposal zone, but will be removed in the seal zone, along with most of the intermediate casing.
Waste canisters consist of carbon steel tubing with welded plugs and threaded connections.

Canisters are designed to withstand projected hydrostatic pressure and mechanical load of overlying canisters.

Waste canisters would retain their integrity until after the borehole is loaded and sealed.
Engeneering feasibility has been demonstrated for surface handling and borehole emplacement of waste canisters with the Spent Fuel Test – Climax (SFT-C) at the Nevada Test Site (NTS) (Patrick, 1986)

Spent fuel assemblies were transported to NTS, packaged in canisters, lowered down a 420-m borehole, emplaced in the underground granite thermal test facility for 3 years, and removed to the surface via the borehole

Waste handling and emplacement operations were conducted within operational safety requirements and without incident
Loaded waste canisters would be transported to the site by tractor trailer using shipping casks.

Surface handling would rotate the shipping cask to a vertical position, move the cask by a short rail system over the borehole, attach the canister to the canister string and lower it into the borehole by remote operation.

Strings of 40 canisters (about 200 m) would be attached to the pipe string and lowered to the disposal zone.

Each canister string would be separated from overlying canister strings by a bridge plug and cement plug.

From Woodward-Clyde Consultants (1983)
Deep Borehole Field Test

Additional research and development is necessary in several important areas for further consideration of deep borehole disposal of radioactive waste, including:

- Evaluation of drilling technology and borehole construction to 5 km depth with sufficient diameter for cost effective waste disposal
- Verification of deep geological, geochemical, and hydrological conditions at a representative location
- Evaluation of canister, waste, and seals materials at representative temperature, pressure, salinity, and geochemical conditions
- Development and testing of engineering methods for waste canister loading, shielded surface operations, waste canister emplacement, and borehole seals deployment
The R&D objectives for deep borehole disposal are being met with a borehole field test that is conducted to a depth of 5 km in a representative location (without emplacement of radioactive wastes)

- Obtain a suitable test site
- Design, drill and construct the Characterization Borehole to requirements
- Collect data in the Characterization Borehole to characterize crystalline basement conditions and confirm expected hydrogeochemical conditions
- Design, drill and construct the Field Test borehole to requirements
- Design and develop surface handling and emplacement equipment systems and operational methods for safe canister/waste package handling and emplacement
Conducting a Deep Borehole Field Test:

- Allows further evaluation of the feasibility of the deep borehole disposal concept
- Is consistent with the UFD Mission
- Implements a recommended near-term action of the *Blue Ribbon Commission on America’s Nuclear Future* (BRC 2012)
- Is consistent with the Administration’s *Strategy for the Management and Disposal of used Nuclear Fuel and High-Level Radioactive Waste* (DOE 2013)
- Economic and scientific benefits of a deep borehole field test are of interest and could be valuable to local, state, and regional stakeholders
DBFT Project Organization

Used Nuclear Fuel Disposition
William Boyle, DOE/NE-53
Tim Gunter, DOE/NE-53
Peter Swift, NTD

Deep Borehole Field Test
Project Lead Lab, SNL
Supporting National Labs and University Partners

Procurement Support
DOE-ID

Site Evaluation and Data Integration
Characterization Borehole Design and Testing
Project Management and Concept Evaluation
Site Management and Drilling Integration Services for Characterization Borehole
Test Package and Emplacement System Engineering
Emplacement System Demonstration
Engineering Services
Drilling Integration Services for Field Test Borehole

Technical Advisor/Execution Support
Contracts
Deep Borehole Field Test Participants

- Six National Laboratories
- AREVA Federal Services, LLC
- Site Services and Drilling Contractor
- Universities and other consultants
International and Other Projects

International
- KAERI – Borehole tracer test in granite
- U. of Sheffield - R&D to Support the DBFT (FTBH Design, BH Seal Design and Performance Criteria)

Nuclear Energy University Program
- MIT – Optimization of Deep Borehole Systems for HLW Disposal

Small Business Innovative Research
- RESPEC - Rock Melt Borehole Sealing System (Electric Heater)
- OLYMPIC RESEARCH - Development of thermally formed plugs for deep borehole waste disposal applications (Thermite formula Heat Source and Sealant)
- IMPACT TECHNOLOGIES / Massachusetts Institute of Technology / DoD AFRL- Deep Bore Storage of Nuclear Waste using MMW (Millimeter Wave) Technology  {Microwave heat source}
- CIMENTUM - Unique Cimentum Cement for Cementing & Grout in Deep Boreholes for Radioactive Waste Disposal
- Kapteyn-Murnane Labs - Laser technologies for ultrasensitive groundwater dating using long-lived isotopes

Subsurface Technology and Engineering RD&D (SubTER)
- SNL/LBNL/UNM - Fit-for-Purpose Cement for Rock-Cement Interfaces in SubTER Applications
Deep Borehole Field Test

Major components of deep borehole field test include:

- Field Test Site Selection
- Borehole Drilling and Construction
- Science Thrust
- Engineering Thrust

Science thrust includes hydrogeological, geophysical, and geochemical investigations of deep borehole environment and engineered materials behavior.

Engineering thrust includes drilling, canister testing, simulated waste handling, simulated waste emplacement operations, seals design and closure, and operational retrievability.

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<thead>
<tr>
<th>Activity</th>
<th>FY-1</th>
<th>FY-2</th>
<th>FY-3</th>
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<td>Full-diameter Field Test Borehole Construction</td>
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<td>Canister Emplacement Test</td>
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<td>Finalize Documentation</td>
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The projected cost for the deep borehole field test is approximately $80 million over the five-year life of the test.
Site selection guidelines include depth to crystalline basement, lithology, basement structural complexity, horizontal stress, geothermal heat flux, topographic relief, Quaternary faulting and volcanism, and logistical considerations.

Field Test site selection guidelines indicate that large areas with favorable geological characteristics exist in the U.S.
## Deep Borehole Field Test Schedule

<table>
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<tr>
<th>Event</th>
<th>FY15</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
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Request for Information solicited input and interest from States, local communities, individuals, private groups, academia, or any other stakeholders who were willing to host a DBH Field Test
- Responses received on December 8, 2014 (45 days)

Sources Sought and Draft Request For Proposal (RFP)
- Posted on FedBizOps on April 7, 2015
- Feedback received on May 5, 2015

Final RFP (Solicitation Number DE-SOL-0008071)
- Pre-solicitation notice posted on June 22, 2015
- Final RFP posted on FedBizOps on July 9, 2015
- Proposals due September 23, 2015
- Contract award anticipated in early 2016
Multiple factors have indicated that the deep borehole disposal concept could provide an alternative to safe disposal of radioactive waste for widely available locations with favorable geological and hydrological characteristics.

Implementation of deep borehole disposal with a simple reference design and operations could be feasible, cost effective, and have sufficient capacity to accommodate smaller DOE owned wastes.

A deep borehole field test (without emplacement of radioactive wastes) is the next logical step in evaluating this waste disposal option.

Economic and scientific benefits of a deep borehole field test for local, state, and regional stakeholders could be valuable.

DOE is moving forward with the deep borehole field test.
References

- **BRC 2012**, *Blue Ribbon Commission on America’s Nuclear Future*, January 2012