USDOE Deep Borehole Proposal
Oregon Hanford Cleanup Board
January 26, 2016
Dirk Dunning, P.E.
Basic idea

- Drill one or more boreholes into crystalline basement rock to about 5,000 m depth
- Emplace waste canisters in the lower 2,000 meters of the borehole
- Seal the upper borehole
  - compacted bentonite clay, cement plugs, and cemented backfill
- Deep borehole disposal of high-level radioactive waste has been considered since the 1950s and periodically studied since the 1970s
- One of several possible disposal options
- Develop the science and engineering tools to support implementation
Possible wastes considered

Some DOE-managed small waste forms are potential candidates for deep borehole disposal (SNL 2014)

- Specialized waste types
  - Cesium and strontium capsules. 1,936 cesium and strontium capsules stored at the Hanford Site

- Small dimension DOE spent nuclear fuel
  - Some DOE-managed SNF currently stored in pools at INL and SRS

- Some high-level radioactive wastes
  - Untreated calcined HLW currently stored at INL
  - Salt wastes from electrometallurgical treatment of sodium-bonded fuels
Proposed attributes

- Lots of possible sites (crystalline basement rocks are common)
- Can use existing drilling technology
  -> may permit construction at acceptable cost
- Disposal flexibility (option for disposal of smaller waste forms)
- Potential for earlier disposal (of some wastes)
Proposed attributes

- Possibly reduced costs (for some wastes)
- Potential for robust isolation (presumed conditions)
  - Low permeability and long residence time of high-salinity groundwater
    - Limited interaction with shallow fresh water
  - Geochemically reducing conditions at depth
    - Limit solubility & enhance sorption
    - But not for all radionuclides
  - Dense salty groundwater underlying fresh groundwater
    - Would oppose heat induced groundwater convection
Site selection criteria

Desirable features present:

- Crystalline rock with 2,000 meters of the surface
- Absence of commercial mineral resources and hazards
  - Oil, natural gas, commercial minerals
- Absence of volcanoes or recent faults
- Low seismic risk potential (< 0.16 g in 50 years)
- Low heat flow and moderate temperatures (~ less than boiling)
Site deselection guidelines

Undesirable features present:

- Absence of crystalline rock within 2,000 meters of the surface
- Volcanoes or recent faults
- Over-pressuring (e.g. natural gas or high formation pressures)
- High permeability hydraulic connections to the subsurface
  - Presence of young surface water at depth (indicating movement)
  - Low-salinity, oxidizing groundwater (indication of surface water)
- Upward hydraulic gradients
Site deselection guidelines

Undesirable features present:

- High geothermal heat flow (driving movement)
- High permeability hydraulic connections to the subsurface
- Presence of economic natural resources (gas, oil or minerals)
- Significant nearby populations
Depth and Faults

Depth and Seismic Risk

Depth to Basement (meters)
- Contour for 2000 meter Basement Depth
- Exposed Crystalline Rocks
- Structure Type:
  - High-angle fault, based on geologic data
  - High-angle fault, based on magnetic data
  - Ductile shear zone
  - Boundary of major rift zone
  - Thrust fault associated with suture zones
Combined Deep Borehole
Physical Criteria

Magenta – meets all criteria
Brick – salinity deeper
Combined Deep Borehole with Metropolitan Criteria

Magenta – meets all criteria
Brick – salinity deeper
Methods

• DOE Proposed two means of putting waste into the borehole:
  – Drill string emplacement
    Connecting all of the packages together and lowering them as a single 600,000 pound package
  – Wireline emplacement
    Lowering each waste container one at a time

• Experts suggested a third means
  – Coiled tube
    Lowering each waste container one at a time
Deep Borehole Field Test Engineering Design Selection Study Drill-String Emplacement Operations

Sandia National Laboratories
Albuquerque, NM
Approved for Unclassified, Unlimited Release (SAND2015-8334V)

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
October 20-21, 2015
Board Deep Borehole Workshop
Washington, DC

- International Panel of experts
- Two days of presentations and discussions with the Board
- Wide array of expertise
- Lots of hands on experience drilling deep wells.
  - Identified a very large array of severe problems, issues, challenges and concerns with every aspect of the proposal
  - Identified several technologies DOE/Sandia had not considered
Key Observations

- Seven Panels
  - Panel 1 – Experience in Deep Drilling in Crystalline Rocks
  - Panel 2 – Emplacement
  - Panel 3 – Seals
  - Panel 4 – Hydrogeology
  - Panel 5 – Geochemistry
  - Panel 6 – Barriers
  - Panel 7 – Efficacy
- Long litany of issues that make potential success of deep boreholes extremely challenging
Panel 1 – Deep Drilling Experience

## Deep Crystalline Drilling

### Nuclear Energy

<table>
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<tr>
<th>Site</th>
<th>Bores</th>
<th>Location</th>
<th>Years</th>
<th>Depth [km]</th>
<th>Diam* [in]</th>
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*borehole diameter at total depth

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D. Sassani and E. Hardin, NWTRB 20 Oct 2015; SAND2015-8753 PE
Panel 2 – Emplacement

http://www.oshatrain.org/courses/images/901/901_2_1_fire2_bsee.jpg

Panel 3 – Seals

Figure 3. Borehole Sealing, Plugging, and Backfilling Reference Design Schematic.

http://decarboni.se/sites/default/files/imagecache/620xH/publications/16676/advanced/fig-010.jpg

Panel 4 – Hydrogeology

Panel 5 – Geochemistry

http://water.usgs.gov/edu/graphics/gwflowlagtimetowell.gif
Panel 6 – Barriers

[Image of a diagram showing layers at different depths, including a Waste Disposal Zone at 4,000 m and a Canister and Bentonite barrier system.]
Panel 7 – Efficacy
Field Test Site

- DOE issued a Request for Proposal for a field test borehole in April 2015
  - One characterization well,
  - One field test borehole, and
  - Emplacement of surrogates for actual waste test packages.

- DOE did not solicit public comment on site selection criteria – or – actual test site selection
- No radioactive or hazardous waste will ever be disposed at the test site.

- DOE received five proposals
- Jan 5, 2016 - DOE selected a Battelle Memorial Institute-led team
  - test borehole of over 16,000 feet into a crystalline basement rock
  - near Rugby, North Dakota
  - $35 million, 5 year contract
  - 20 acres of a state-owned land outside of Balta, about 15 miles south of Rugby in Pierce County, North Dakota
State Response

• January 15, 2016 – State of North Dakota Land Board
  -> Wants a hearing on any application
  -> On the board’s Jan. 29, 2016 agenda

• “It is not certain whether there will be an application on the table, or whether team members, including the Energy and Environmental Research Center at Grand Forks, will simply provide information.”

• “The board heard some preliminary information in September and made it clear that anything about this project must be brought to them”
  - board administrator Lance Gaebe

• North Dakota State Land Board members:
  Jack Dalrymple: Governor
  Alvin A. Jaeger: Secretary of State
  Kirsten Baesler: Superintendent of Public Instruction
  Kelly Schmidt: State Treasurer
  Wayne Stenehjem: Attorney General

USDOE Consent Based Siting

- Views the voluntary nature of the teams submitting proposals as a test of the Blue Ribbon Commission on America’s Nuclear Future “consent based siting” process.
- Refuses to release any details about the precise location selected
- Refuses to release any details at all about the other four teams or sites claiming legal procurement limitations.
  - “Unfortunately, the Federal Acquisition Regulation (FAR) 15.506.(e) prevents the Department from providing information on the unsuccessful applicants to the Borehole Funding Opportunity Announcement.” – Alison Kennedy, DOE/HQ
  - “Additionally, this also prevents the Department from releasing the evaluation of the winning proposal.” – Alison Kennedy, DOE/HQ
  - “The drilling site itself is located on 20 acres of Department of North Dakota Trust land in Pierce County, North Dakota. It is about thirty miles south of Rugby on the west side of Highway 3. We cannot provide exact coordinates at this time, as Battelle is still working to finalize the land lease.” – Alison Kennedy, DOE/HQ
Field Test Schedule

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<thead>
<tr>
<th></th>
<th>FY15</th>
<th>FY16</th>
<th>FY17</th>
<th>FY18</th>
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Field Test
Borehole site
Field Test
Borehole site

Williston Basin
Sleeping Giant Gas Project
Denver Basin
Analogue-Beecher Island

Image: Strata-x
SLEEPING GIANT SHALLOW NIobRARA GAS PLAY

http://www.strata-x.com/images/sleeping-giant-01.png
Summary - *Potential* advantages

- Alternate path for small diameter waste forms
- Earlier disposal than a large deep repository
- Cost advantages depending on waste pretreatment required
Summary - **Potential** Disadvantages

- No protection to the environment from the hole
- Claimed passive safety appears unlikely
- No full site characterization or safety assessment
- Calculated doses mean little
Summary - Risks

- Sudden failures possible
  - with loss of control and little ability to recover
- Single point failures during operation
  - e.g. package drop, well collapse, ...
- Costs will push toward single barrier -> increasing risks
- Large suite of unknowns
Summary - Expected uncertainties

- Operational risks likely to dominate
- Post-closure risks may pop up as we better understand conditions and scenarios
  - Geotechnical
  - Microbial
  - Hydrogeologic
- High temperatures may impact waste forms and needs consideration
- Lack of international experience: No benchmark available
Questions
Backup
Credits:

Deep Borehole Disposal Research and Development Program

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

DOE Deep Borehole Field Test: Site Characterization and Design Requirements

David Sassani, Principal Member of Technical Staff, Sandia National Laboratories
Ernest Hardin, Distinguished Member of Technical Staff, Sandia National Laboratories

International Technical Workshop on Deep Borehole Disposal of Radioactive Waste
Washington, D.C. October 20-21, 2015

http://www.nwtrb.gov/meetings/2015/oct/15oct.html
Scale comparison

- Burj Khalifa Tower, Dubai: 830 m
- Onkalo: 500 m
- WIPP: 650 m
- Waste Disposal Zone: 4,000 m

Depth:
- 1,000 m
- 2,000 m
- 3,000 m
- 4,000 m
- 5,000 m
Objectives of the Deep Borehole Field Test

- Synthesize field test activities, test results, and analyses into a comprehensive evaluation of concept feasibility.

- Design and construct characterization borehole then field test borehole
- Develop and test systems for handling, emplacing, and retrieving WPs
- Design and test WPs
- Evaluate site
- Characterize overlying sediments, fluids, and hydrologic conditions
- Characterize the borehole disturbed rock zone (DRZ)
- Characterize crystalline basement, fluids, and hydrologic conditions
- Emplacement hazard analysis
- Design seal system
- Evaluate WP, WF, casing, cement, and seal materials
- In situ thermal test
- Assess post-closure safety

In no case will the US Government place or otherwise have nuclear material, waste, or other waste disposal material on the property (RFP 2015).
Dark Teel – Meets physical criteria

White – Crystalline rock >2 km deep
Salmon – Exceeds seismic criteria 0.15g
Black – Oil, gas and minerals
Light Green – Exceeds boiling at depth
# Deep Borehole Field Test Schedule

<table>
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<tr>
<th>Activity</th>
<th>FY15</th>
<th>FY16</th>
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<th>FY18</th>
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