Overview of Disposal R&D Activities

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SAND2024-06184PE
Overview of Presentation Materials

- Overview of Program
  - Program technical coverage
  - Disposal concepts – research, development, demonstration
  - Disposal program conceptual schedule

- Capability Development and Demonstrations

- Processes to Assess SFWST Disposal Research (DR) Activity Progress
  - DR Program Planning
    - 2012 Roadmap and assessment
    - 2019 Roadmap reevaluation/gap analysis
    - DR Five-year Plan
  - Geologic Disposal Safety Assessment (GDSA) Framework
  - Roadmap reimagination and Features, Events, and Processes (FEP) Tool

- Summary
FY 24 SFWST R&D Campaign Structure (EVOLVING)

SFWST Campaign Leadership

Storage and Transportation Research
- Fuel Integrity Testing and Analysis
- External Load Testing and Analysis
- Thermal and Drying
- Security
- (Rail Car Optimization)
- Dry Storage Canister Stress Corrosion Cracking
- Canister Deposition Field Demonstration

Disposal Research
- Argillite Disposal R&D
- Crystalline Disposal R&D
- Salt Disposal R&D
- Geologic Disposal Safety Assessment
- Direct Disposal of Dual Purpose Canisters
- International Collaborations Disposal Research
- Engineered Barrier System R&D
- Inventory and Waste Form Characteristics and Performance
- Technical Support for Underground Research Laboratory Activities

Knowledge Management

Advanced Reactors SNF and Waste Streams

Host-rock Investigations

Cross-cutting Investigations

High-burnup Confirmatory Data Project (industry-led, managed directly by DOE)

5/21/2024 D. Sassani, SNL; SFWST Overview NWTRB Spring 2024
Provide a **sound technical basis for multiple** viable disposal options in the US

- Spent nuclear fuel (SNF)
  - Commercial
  - DOE-managed
- High-level nuclear waste (HLW)

**Increase confidence** in the robustness of generic disposal concepts

**Develop the science and engineering tools** needed to support disposal concept implementation

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**Salt Repository Example**
Gorleben, Germany (BMWi 2008)

**Argillite Repository Example**
Meuse/Haute Marne, France (ANDRA 2005)

**Crystalline Repository Example**
Forsmark, Sweden (SKB 2011)

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**Wide range of geologic disposal concepts**
- Prioritize the **generic R&D for each**
- Define complete enough for generic R&D
- Utilize & contribute to vast **international experience**
- Integrate cross-cutting aspects clearly
- **Poise Program to Leap** into Next Stage

https://www.posiva.fi/en/index/finaldisposal
Disposal Research (DR) Program Conceptual Timeline

- Concept Evaluation
  - Evaluate Disposal Concepts; FEPS; Develop and Demonstrate Technologies; Generic RD&D

- Site Selection/Characterization
  - Development of Siting Guidelines/Criteria
  - Identification of Potential Sites
  - Progressive Site Down-Selection
  - Site Characterization

- Repository Development
  - Repository Design
  - Construction & Monitoring
  - Operations & Monitoring
  - Closure

- Research, Development, and Demonstration (RD&D):
  - Demonstrations initially focus on analytical capabilities
  - Characterization/operational demonstrations increase later in a program

- Leads to License Application (LA) to Construct

We (Used Fuel Disposition/Spent Fuel and Waste Science and Technology Campaign(s)) are HERE…

- LA for construction reviewed and granted

- Generic Assessment Bases Final
Isolation mechanisms may differ for different radionuclides in different disposal concepts.

Overall performance relies on multiple components; different disposal concepts emphasize different barriers.
Features, Events, and Processes (FEP)

- **Features** are physical components of the repository system.
- **Processes** are phenomena that act continually over a long time scale.
- **Events** are phenomena that occur over a short time scale.
- FEP are evaluated and screened for either being
  - Included into, or
  - Excluded from
- The Geologic Disposal Safety Assessment Model (GDSA) of the System Performance
The Geologic Disposal Safety Assessment (GDSA) Model

Next Gen Workflow

Input Parameters

- Parameter database

Uncertainty Sampling and Sensitivity Analysis

Computational Support

- Processing
  - VoroCrust
  - Python
  - fenWorks
- Visualization
  - ParaView

Multi-Physics Simulation and Integration

PFLOTRAN

- Source Term and EBS Evolution Model
  - Inventory
  - Decay, ingrowth
  - WF degradation
  - WP degradation
  - Radionuclide release
  - Thermal, mechanical
  - Gas generation

- Flow and Transport Model
  - Advection, diffusion, dispersion
  - Discrete fracture networks
  - Multiphase flow
  - Sorption, solubility, colloids
  - Isotope partitioning
  - Decay, ingrowth
  - Thermal effects
  - Chemical reactions

- Biosphere Model
  - Exposure pathways
  - Uptake/transfer
  - Dose calculations

Results

https://www.nwtrb.gov/meetings/past-meetings/fall-2021-virtual-board-meeting---november-3-4-2021

https://pa.sandia.gov/
• Demonstrations Build Capabilities/Process Understanding
  • Huge Dinner Party (not just family)
    • Practice meal preparation (until enjoyable or servable?)
    • Iterate cooking and refine ingredients, timing, thermal, technique…
  • Sports or Arts Performances (Paint/Music/Dance)
    • Practice, practice, practice…build skills/know-how/strengths, refine technique…
  • Good Fortune: Develop New Home Plans
    • Where, how big, # floors/levels, plumbing, heating/cooling, roof type…
    • Prelim/draft/final Floor Plans are NOT your New Home
• Features, Events, and Processes (FEP) Evaluations
• GDSA Capabilities Demonstrations
Wide range of geologic disposal concepts: challenges:
- Prioritize the generic R&D for each
- Define complete enough for generic R&D
Plan/Prioritize/Status DR Activities – Program Scale

• Used Fuel Disposition (UFD) Campaign 2012 Roadmap
  • Features, Events, and Processes (FEP) gap assessment synthesis
  • Synthesize into High Priority Topics for UFD Campaign work planning
  • 2012 Roadmap Report (Rev. 01; 2012)

• 2019 Roadmap Update
  • Review/prioritize DR Activities for progress, gaps, and recent Program Direction
    • Begin assessment of DR R&D Program in FY2017
    • 2019 Roadmap Update Report (Rev. 01; 2019)

• Development of SFWST Disposal Research Five-year Plan (2020)
  • Incorporate/address updated priorities
  • Identify short-term primary objectives (1-2 years; relatively certain)
  • Provide longer-term vision (3-5 years; general guide)
Disposal R&D Strategic 5-Year Plan (2023)

• Builds Upon
  - 2012 Roadmap Report (Rev. 01, 2012)
  - 2019 Roadmap Update Report (Rev. 01, 2019)
  - DR 5-Year Plan (2020; 2021)

• Short-term Primary Objectives (1-2 years; relatively certain)

• Longer-term Vision (3-5 years; general guide)

• Progress Updates

https://www.nwtrb.gov/meetings/past-meetings/fall-2020-board-virtual-meeting----december-2-3-2020
GDSA Framework Summary

- GDSA Framework Development Guided by
  - Roadmap
  - FEP analyses
  - DR 5-yr plan
  - International influences
- Model Capability Development Decisions Rely on
  - Readiness considerations
  - Prioritization considerations
- Framework Provides Status of GDSA Model Capabilities
GDSA Status of Generic FEP screening (from Vaughn et al. 2012)

Source (Inventory and Waste Form)
- Radionuclide inventory (heat generation, decay and ingrowth)
- Waste form degradation (dissolution processes)
- Gas generation
- Radionuclide release and transport (mobilization, early release [e.g., from gap and grain boundaries], precipitation/dissolution)

Near Field (Waste Package, Buffer, Backfill, Seals/Liner, and DRZ)
- Waste package degradation (corrosion processes, mechanical damage, early failures)
- Evolution/degradation of EBS components and DRZ
- Effects from rockfall, drift collapse (e.g., salt creep)
- Fluid flow and radionuclide transport (advection, dispersion, diffusion, sorption, decay and ingrowth)
- Chemical interactions (aqueous speciation, mineral precipitation/dissolution, reaction with degraded materials, surface complexation, radiolysis)
- Thermal effects on flow and chemistry
- Effects from disruptive events (seismicity, human intrusion)

Far Field (Host Rock and Other Units)
- Fluid flow and radionuclide transport (advection, dispersion, diffusion, sorption, decay and ingrowth)
- Effects of fracture flow (e.g., dual porosity/permeability, discrete fracture)
- Groundwater chemistry

Receptor (Biosphere)
- Dilution due to mixing of contaminated and uncontaminated waters
- Receptor characteristics (basis for converting radionuclide concentrations in groundwater to dose)

Key
Red = FEP included, at least to some degree
Black = FEP capability lacking or excluded so far

DRZ – Damaged Rock Zone
EBS – Engineered Barrier System

Features, Events, and Processes (FEP)
- Many excluded FEP (or yet-to-be-implemented FEP) are chemical, mechanical, and disruptive FEP
Geologic Disposal Safety Assessment (GDSA) is Applicable to Multiple Generic Disposal Concepts

For example:
- France
- Switzerland

Considered by:
- Germany
- Netherlands

https://www.nwtrb.gov/meetings/past-meetings/board-meeting---september-13-14-2022
https://www.sandia.gov/salt/home/bats-field-heater-test/
DR Progress Will Poise Program to Enter the Next Stage

Concept Evaluation
Evaluate Disposal Concepts; FEPPs; Develop and Demonstrate Technologies; Generic RD&D

Site Selection/Characterization
Development of Siting Guidelines/Criteria | Identification of Potential Sites | Progressive Site Down-Selection | Site Characterization

Repository Development
Repository Design | Construction & Monitoring | Operations & Monitoring | Closure

We (Used Fuel Disposition/Spent Fuel and Waste Science and Technology Campaign(s)) are HERE...

LA for construction reviewed and granted
Features, Events, and Processes (FEP) Database Overview

- **Historical Information**
  - Generic FEP Defined in 2010
  - YMP & WIPP FEP
  - 2012 Generic FEP Prioritization Results
  - 2010-12 FEP Screening Results for Shale, Crystalline, and Salt
  - 2019 Roadmap Update Activities
  - Reference Cases for Shale, Crystalline, and Salt Defined in Earlier Reports (possibly others in the future)

- **General Integration Information – Program Management Team**
  - Tied to Thrusts Defined in 5-Year Plan
  - Reports **Support Decision Making** by Management
  - Database Will Provide **Documentation of Progress**
FEP Database/Tool Objectives

• Use FEP Tool to **Organize, Integrate, and Status** Activities
  • Online database as planning tool
  • Ties work activities to program thrusts/priorities
  • Each work activity maps to detailed FEP being addressed
  • Documents
    • Activity screening approach for GDSA (in/exclude)
    • Approach for intended inclusion into GDSA
    • Time/effort to complete and extent complete

• **Demonstrate Progress** Toward Program Objectives - Status

• Use for **Continuous Program Improvement**
  • Updates to DR 5-year Plan
  • DR Program Roadmap revisions
FEP Database Inputs

Focused on Work Activities

• Principle Investigators (PI) Define Annual Work Activities
  • Control Account
  • Activity Name and Description
  • Implementation (% Complete)
  • Level of Effort
  • FY to Complete
• PI Map Work Activities to Thrusts (*DR 5-yr Plan*)
• PI Map Work Activities to *Roadmap* Update Activities
• *PI Map Work Activities to FEP or subFEP*
  • Results May Support Inclusion in GDSA
  • Results May Provide Justification for Exclusion from GDSA
FEP Database System Architecture

Integration Library

Integration.xlsx
Reports
Tables (FEPs, Reference Cases, FEP-RefCase)

PI-RoadAct-Thrust_Int.xlsx
Tables (for reference; appended from PI Libraries)
Tables (historical information; sent to Integration.xlsx)

Integration Area

PI Area

GDSA Library
GDSA.xlsx

Argillite Library
Argillite.xlsx

EBS Library
EBS.xlsx

...Other PI Libraries

PI Excel files have tables for Activities, Gaps, mapping Activities to Thrusts, mapping Activities to 2019 Roadmap Activities, and mapping FEP-RefCase to Activities and/or Gaps.
### Example Input Table (1 of 2)

<table>
<thead>
<tr>
<th>Activity ID</th>
<th>Control Account</th>
<th>Work Package</th>
<th>Activity Name</th>
<th>Activity Description</th>
<th>ISC</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT-GDSA-101</td>
<td>GDSA</td>
<td>PFLOTRAN</td>
<td>Agile/Jira system</td>
<td>Software configuration and management</td>
<td></td>
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<tr>
<td>ACT-GDSA-102</td>
<td>GDSA</td>
<td>Biosphere</td>
<td>Biosphere modeling</td>
<td>Multi-path radionuclide biosphere model for PFLOTRAN repository PA</td>
<td></td>
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<tr>
<td>ACT-GDSA-103</td>
<td>GDSA</td>
<td>Framework &amp; PFLOTRAN</td>
<td>Buffer erosion</td>
<td>Add Neretnieks et al. (2017) crystalline repository buffer erosion model to PFLOTRAN</td>
<td></td>
</tr>
<tr>
<td>ACT-GDSA-104</td>
<td>GDSA</td>
<td>PFLOTRAN</td>
<td>Buffer evolution</td>
<td>Add smectite-illite transition model to PFLOTRAN</td>
<td></td>
</tr>
<tr>
<td>ACT-GDSA-105</td>
<td>GDSA</td>
<td>RSA &amp; Framework</td>
<td>DECOVALEX-2023 Task F:</td>
<td>Lead repository PA modeling comparisons</td>
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<tr>
<td></td>
<td>Activity Description</td>
<td>ISC</td>
<td>ISC Rationale</td>
<td>Implementation (%)</td>
<td>Implementation Notes</td>
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<tr>
<td>---</td>
<td>--------------------------------------------------------------------------------------</td>
<td>-----</td>
<td>------------------------------------------------------------</td>
<td>--------------------</td>
<td>---------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Software configuration and management</td>
<td></td>
<td></td>
<td>100%</td>
<td>Running well. Annual maintenance required</td>
</tr>
<tr>
<td>2</td>
<td>Multi-path radionuclide biosphere model for PFLOTRAN repository PA</td>
<td></td>
<td></td>
<td>50%</td>
<td>Pathways largely incorporated for several radionuclides. More to do for certain radionuclides.</td>
</tr>
<tr>
<td></td>
<td>Add Neretnieks et al. (2017) crystalline repository buffer erosion model to PFLOTRAN</td>
<td></td>
<td></td>
<td>20%</td>
<td>1) Conceptual and mathematical models developed and documented; 2) coding in mapDFN and PFLOTRAN underway</td>
</tr>
<tr>
<td></td>
<td>Add smectite-illite transition model to PFLOTRAN</td>
<td></td>
<td></td>
<td>100%</td>
<td>Model added to PFLOTRAN. Additional features being considered.</td>
</tr>
<tr>
<td>3</td>
<td>Lead repository PA modeling comparisons</td>
<td></td>
<td></td>
<td>85%</td>
<td>Completed models and analyses. Writing final</td>
</tr>
</tbody>
</table>
FEP Database Is in Initial Stage of Development. In the Future, It Will…

• Become an *Integral* Part of *Annual Planning*
• Support Future *Roadmap Update* Activities/Long-Term Planning
• *Document* the *Status* of the GDSA Model, FEP Screening
  • For all generic repository concepts
• *Identify Gaps* and *Overlaps* To Be Addressed
• Identify/Improve PI *Integration* – All Activities Apparent
• *Make Efficient Use of Resources*
Summary

• Program Shift to Disposal Research and Development Focus
  • Currently within generic conceptual disposal system stage
• Capability Development and Demonstrations for Generic Concepts
  • Poise the program to move to the next stage in ~ 2 years
  • Conceptual schedule for disposal programs covers multiple decades
  • Use U.S. and International experience to efficiently progress through stages
• Processes to Assess SFWST Disposal Research (DR) Activity Progress
  • Program-scale Roadmap (~every 7 years) of detailed R&D
  • Disposal Research Five-year plan with 2-year focus and 3- to 5-year outlook
  • Geologic Disposal Safety Assessment (GDSA) Framework
    • Status of what is in the GDSA Capability
• Move to Roadmap Reimagination: Prepare for Next Stage
  • FEP Database Tool for activity status, prioritization, integration, and Program efficiency
Questions?
References


