

Prioritization of International Activities and Moving Forward: Disposal Research 5-Year Plan

U.S. Nuclear Waste Technical Review Board
Fall 2020 Board Meeting
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Virtual Meeting

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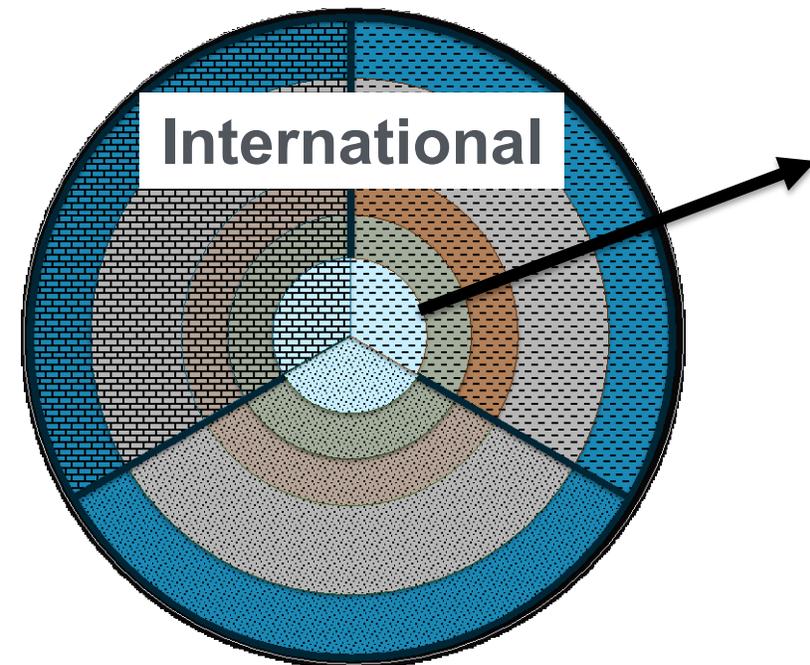
International Disposal Research Activities: Tapping into Multinational Initiatives and Individual Collaborations

Multinational Initiatives

- Cooperative research partnerships, often requiring formal participation agreements
- Examples with active research focus include DECOVALEX Project, Mont Terri Project, SKB Task Forces, FEBEX-DP Project, and HotBENT Project
- Other examples with focus on information exchange are provided by Nuclear Energy Agency (NEA) or certain European Union Projects

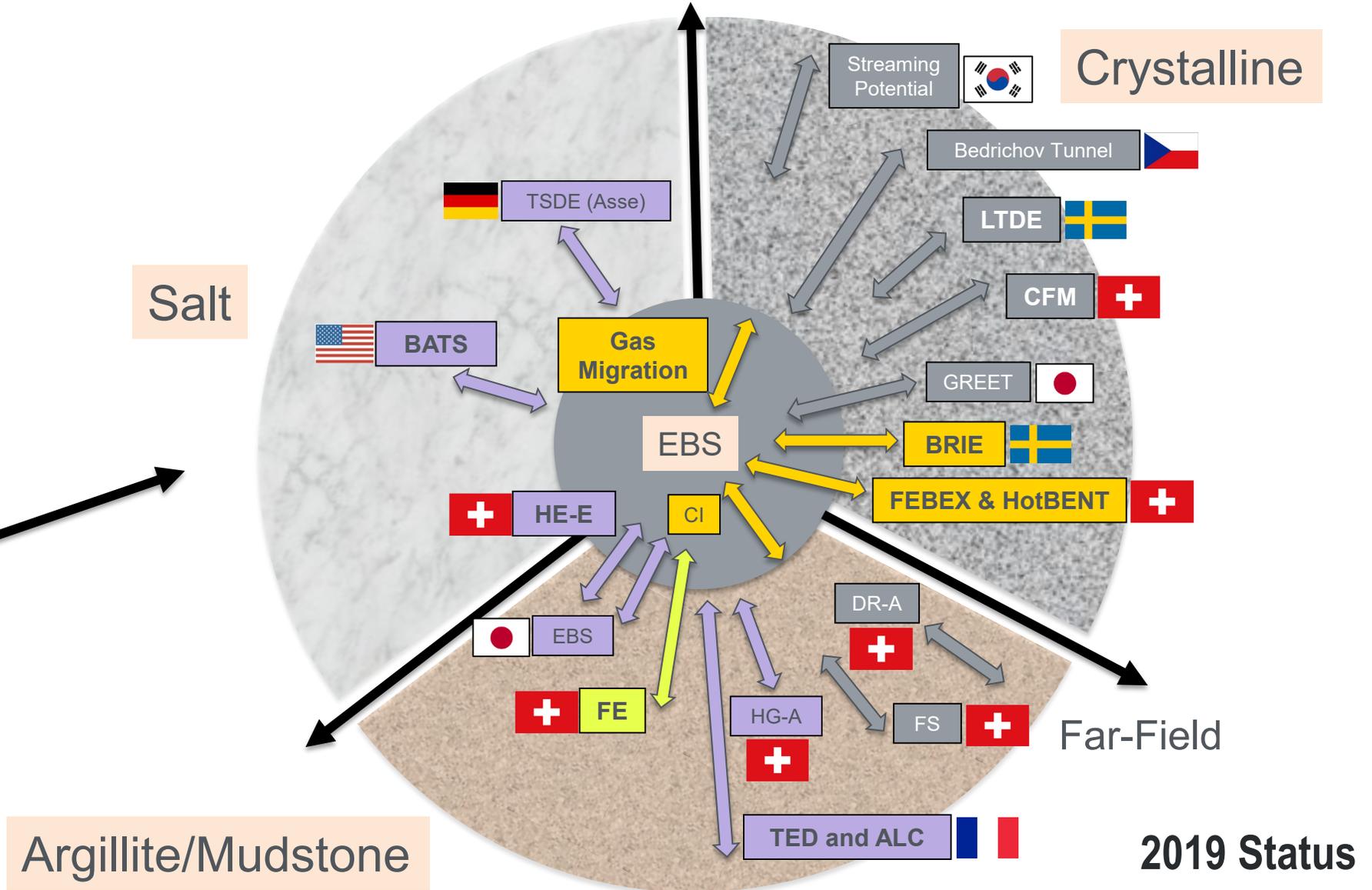
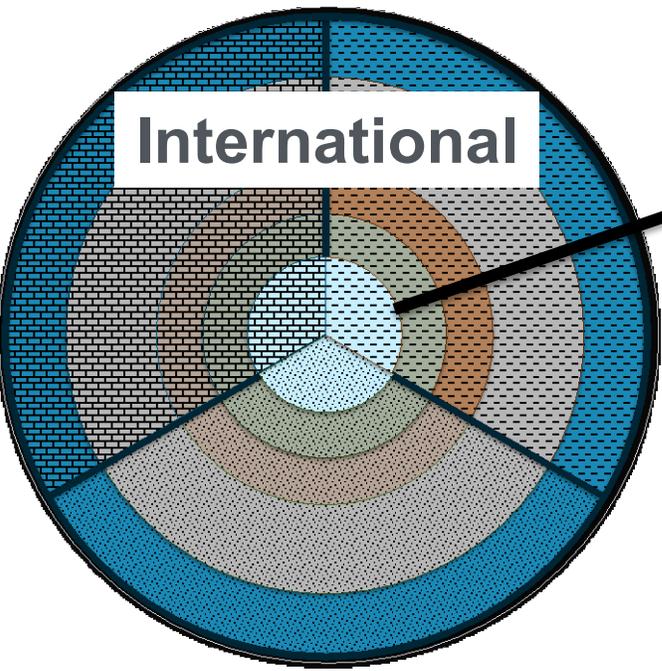
Bilateral Collaborations

- Informal or formal research collaboration with individual organizations
- A prominent current example is the comprehensive collaboration on salt disposal with German organizations



International Collaboration Activities with Experimental Focus

- Key R&D Issues**
- Near-Field Perturbation
 - Engineered Barrier Integrity
 - Flow and Radionuclide Transport
 - Demonstration of Integrated System Behavior



Motivation and Prioritization

Scientific and Technical Benefits

- Tap into global knowledge, stay abreast of science advances, and gain access to international datasets and experiments
- Test and validate advanced process-modeling and experimental tools
- Understand research needs arising from critical (and sometimes surprising) issues related to “real” rocks and sites
- Leverage resources and share cost of science campaigns, in particular large experimental projects

Other Benefits

- Build valuable relationships and re-establish the U.S. disposal research program as a committed international partner
- Work towards a common set of disposal best practices and lessons learned (e.g., risk communication and site selection)
- Attract and build a new generation of “waste disposal” scientists

Prioritization Principles

- Prioritize international R&D activities based on key issues, technical merit, relevance to safety, and cost/benefit
- Emphasize active R&D participation and access to experiments in underground research laboratories (URLs)
- Balance portfolio across host rocks, repository designs, and key R&D areas

Integrated Planning of Priority R&D Topics and International Collaboration Opportunities

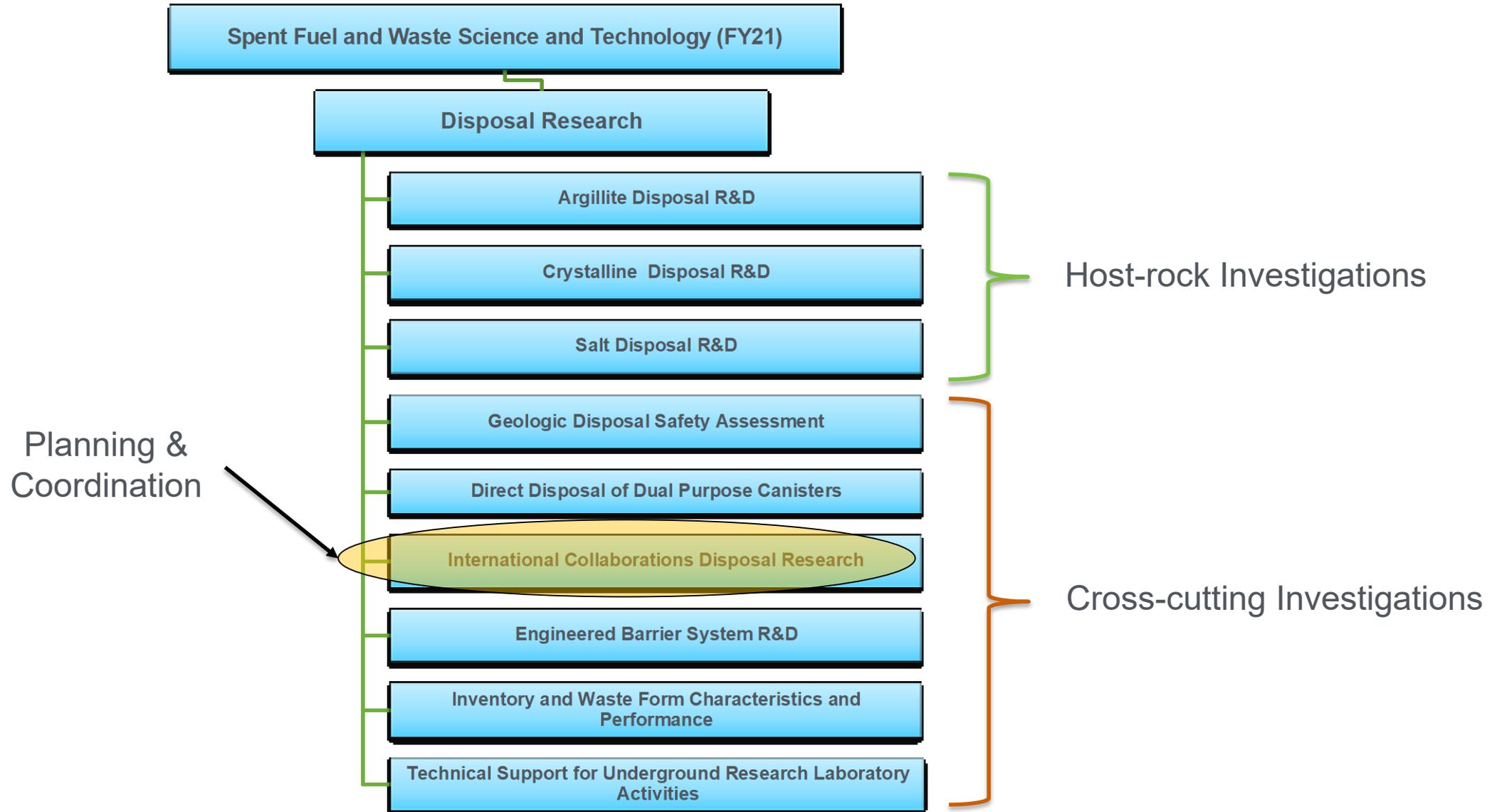
Integration with Campaign Research Roadmapping Exercises

- **2010-2012:** Roadmap Workshops to identify high-priority research needs for campaign
- **2012:** International collaboration workshop to discuss priority research activities related to international URLs
- **2019:** Roadmap Update to review existing R&D activities, assess priority levels, and brainstorm remaining research needs (fully integrated with international activities planning)

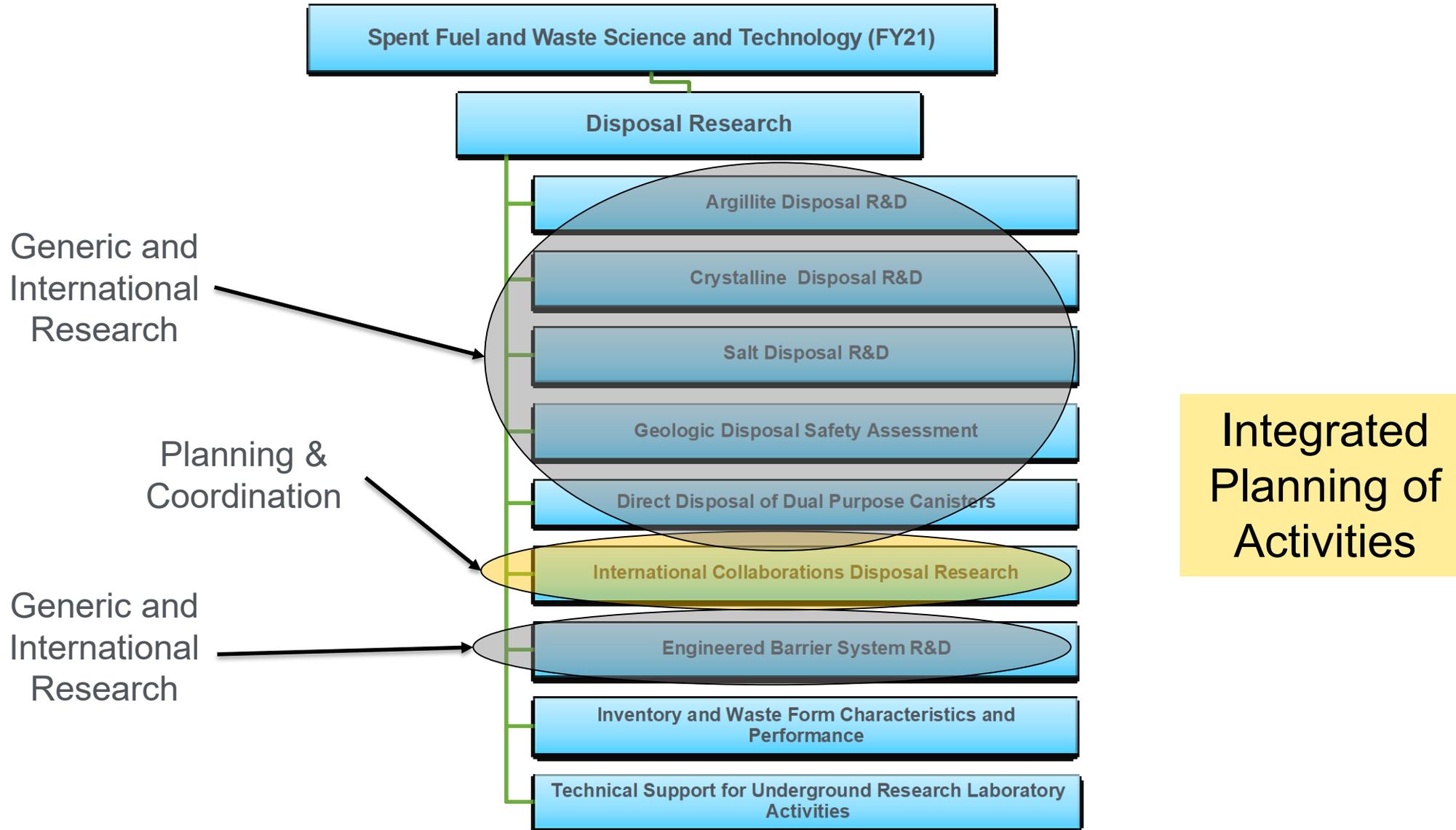
Continuous Re-Evaluation in Annual Campaign Working Group Meetings

- Assess emerging or changing research needs (e.g., gas pressure buildup, seal performance, interfacial processes, etc.)
- Consider changing campaign priorities (e.g., higher thermal limits)
- Assess or create new international opportunities (e.g., DECOVALEX-2023)
- Revise international portfolio

Integration Among Disposal Research Activities



Integration Among Disposal Research Activities



From Opportunistic Participation to Active Engagement

- During the first few years, DOE participated in international R&D efforts that had been planned years earlier
- Since then, DOE has been actively involved in planning of new projects together with the international community, achieving more integration
- Examples of international research leadership and active engagement:
 - Joint planning & execution of HotBENT field test with NAGRA and others
 - Leading the THMC modeling of HotBENT Lab Experiment in SKB EBS Task Force
 - Chairing the international DECOVALEX Project and thus coordinating its research emphasis
 - Coordinating use of the BATS salt heater test at WIPP (Waste Isolation Pilot Plant) as a modeling task in the international DECOVALEX 2023 project
 - Coordinating performance assessment benchmarking exercises (salt, crystalline) as a modeling task in DECOVALEX 2023

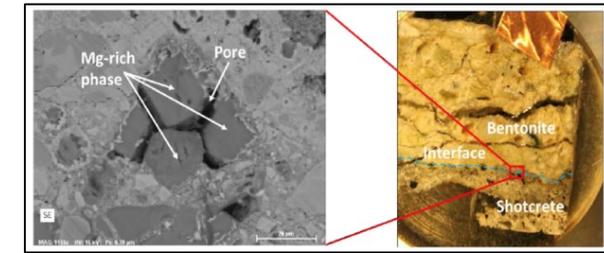
Examples of Prioritization and Integrated Planning: High Temperature Effects

Fundamentals of Physico-Chemical Alterations

- Laboratory imaging/characterization of heated samples
- Detailed coupled processes modeling of individual components



Micro-structural analysis

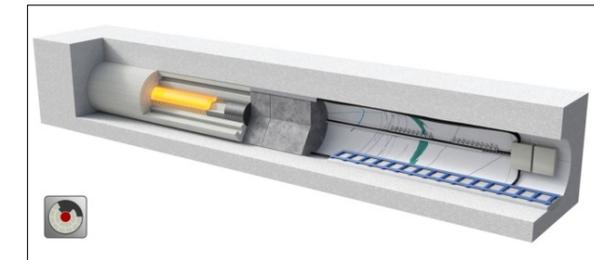


Barrier System Behavior

- Laboratory or *in situ* testing of barrier systems
- Validation of predictive process models for system behavior
- Predictions of engineered and natural barrier perturbations
- Optimization studies (e.g., alternative backfill materials)



Lab and field experiments (HotBENT)

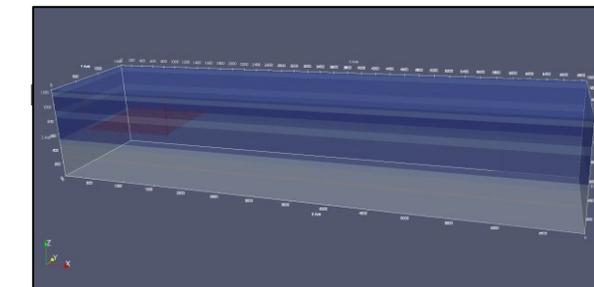


Performance Assessment

- Include high temperature effects in performance assessment models
- Determine scenarios and parameters with significant impact on high-temperature repository performance
- Conduct performance assessment for different thermal designs



Performance assessment modeling



International Experiments: Long-Term Planning & Coalition Building & Execution

Timeline Towards HotBENT:

- **2013:** discussions with international partners about high-temperature research needs
- **2015:** joint paper with NAGRA about research status/needs, including *in situ* test
- **2016:** international coalition building and first HotBENT planning meeting (five partners; NAGRA leadership)
- **2018:** official HotBENT partnership (five full & four associated partners)
- **Since 2019:** preparation and installation of *in situ* test
- **2021:** HotBENT heaters will be turned on and run for 10 to 20 years



ANS 2015 International High-Level Radioactive Waste Management Conference

April 12-16, 2015 • Charleston Marriott • Charleston, SC
“Real World Solutions for Achieving Disposal of Used Fuel and HLW
through Integrated Management”

CALL FOR PAPERS – Abstract deadline: September 2, 2014

THMC behavior of clay-based barriers under high temperature – from laboratory to URL scale

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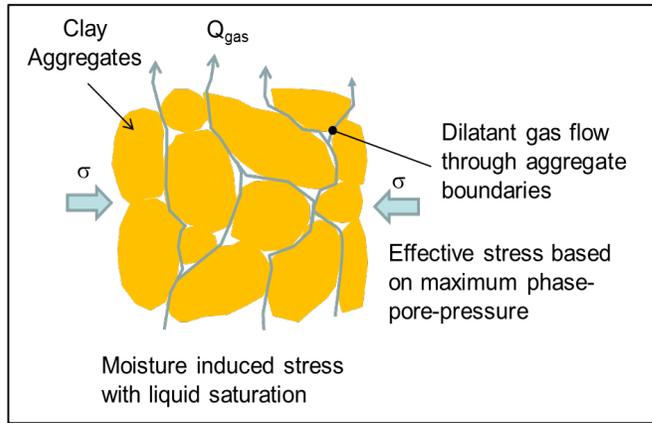
** Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley CA, 94707, USA

ABSTRACT

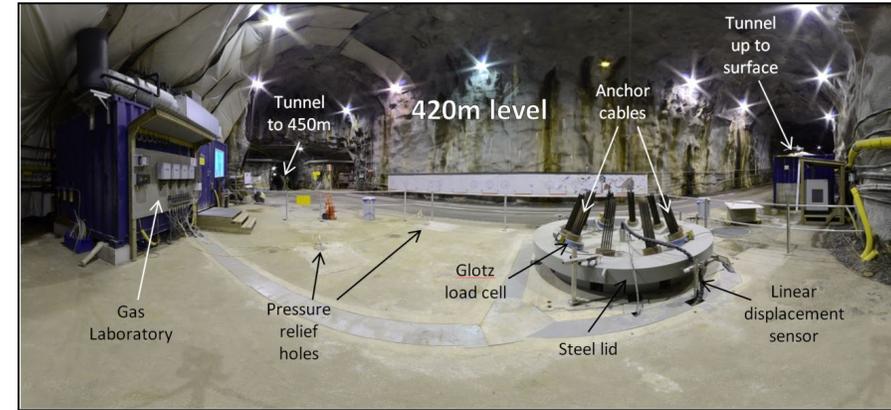
International disposal programs have been investigating if clay-based barriers can withstand temperatures higher than the 100 °C threshold for bentonite performance assumed in some advanced repository designs. For example, the United States disposal program is investigating the feasibility of direct geological disposal of large spent nuclear fuel canisters currently in dry storage.

advanced repository designs. For example, the United States disposal program is investigating the feasibility of direct geological disposal of large spent nuclear fuel canisters currently in dry storage. These canisters typically hold as many as 32 PWR assemblies and recent designs hold even more, meaning that there is significant heat output associated with these canisters. Projections show that, by the year 2025, there will be more than 3,000 such canisters in use and that sometime before 2040 more than half of the spent nuclear fuel in the U.S. will be in

Examples of Prioritization and Integrated Planning: Gas Migration in Clay-Based Materials

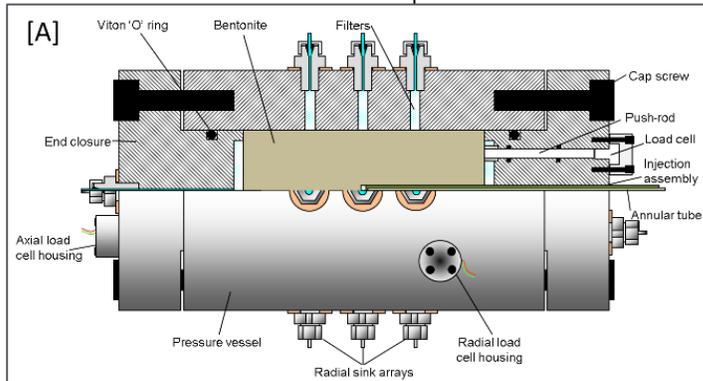
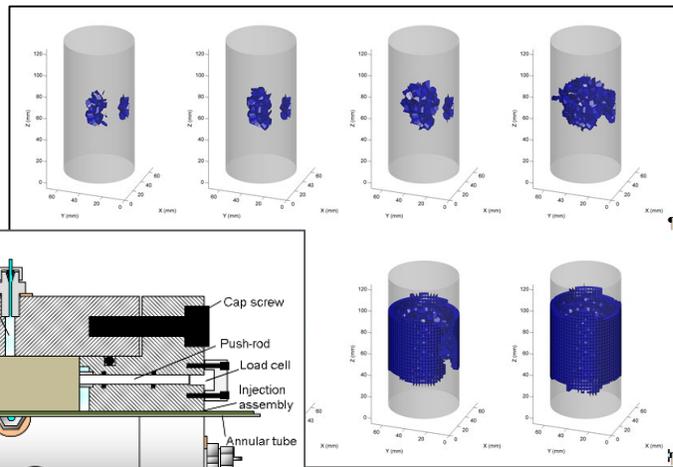


Step 2: Full-scale behavior and predictive modeling



In-Situ LASGIT Experiment at Äspö Hard Rock Lab in DECOVALEX-2023

Step 1: Basic process understanding



Laboratory Experiments in DECOVALEX-2019

Step 3: Testing of a gas permeable seal



In-Situ Gas Permeable Seal Test (GAST) at Grimsel Test Site

Examples of Prioritization and Integrated Planning: Site Selection, Comparison and Characterization

Best Practices and Lessons Learned

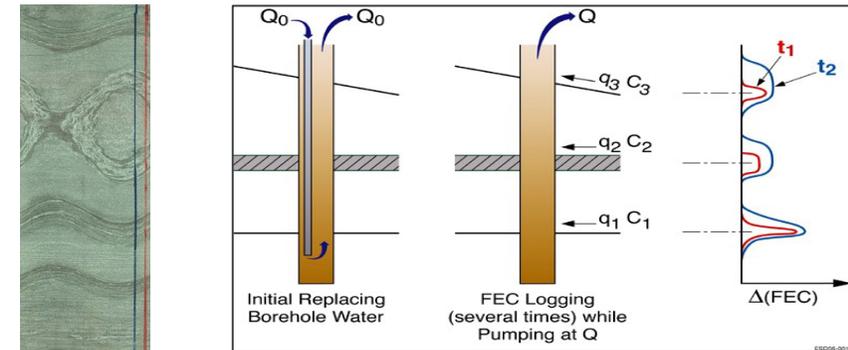
Germany: is currently in early stages of site selection with broad range of host rocks

Switzerland: has narrowed its selection to three regions, which are compared in a formal process. Detailed characterization is ongoing.

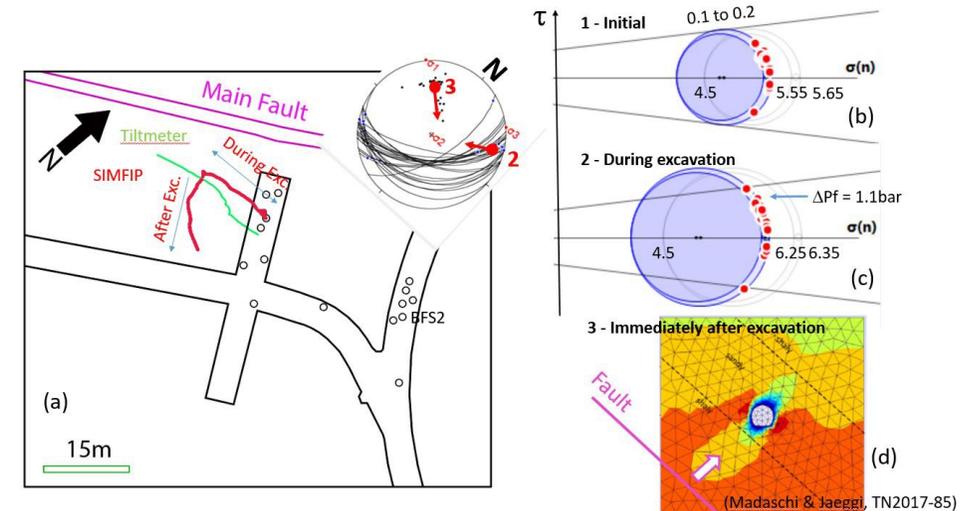
Canada: has narrowed its search from initially 22 areas to two sites. Detailed characterization is ongoing.

Sweden: has finalized its site selection and site characterization process. Waiting for permission to construct.

Site Characterization Methods



Characterization of flowing fractures in deep borehole at COSC Project, Sweden



Fault characterization studies at Mont Terri, Switzerland

Summary

- **Active collaboration with international programs is a central and fully integrated element of DOE's disposal research program**
- **International research activities have been extremely beneficial to the Disposal Research Campaign:**
 - Improving science base, reducing uncertainty, and building confidence in alternative geologic disposal options
 - Testing new advanced process-modeling and monitoring tools
 - Shared cost for large expensive experiments
 - Information and knowledge exchange in terms of best practices, state of the art simulation and monitoring methods, R&D priorities elsewhere
- **Prioritization of international activities is conducted via integrated, open, and frequent planning efforts across the campaign**
- **Various opportunities exist for expansion of international disposal research activities**

Reference: International Collaboration Report FY20

Content of Report (332 pages):

- International Opportunities and Strategic Considerations
- Multinational Cooperative Initiatives
- Bilateral Collaboration Opportunities
- Selection of International Collaboration Activities
- Disposal Research Activities Associated with International Collaborations

International Collaboration Activities in Geologic Disposal Research: FY20 Progress

Spent Fuel and Waste Disposition

*Prepared for
US Department of Energy
Spent Fuel and Waste Science and Technology
Milestone Report M2SF-20LB010307012*

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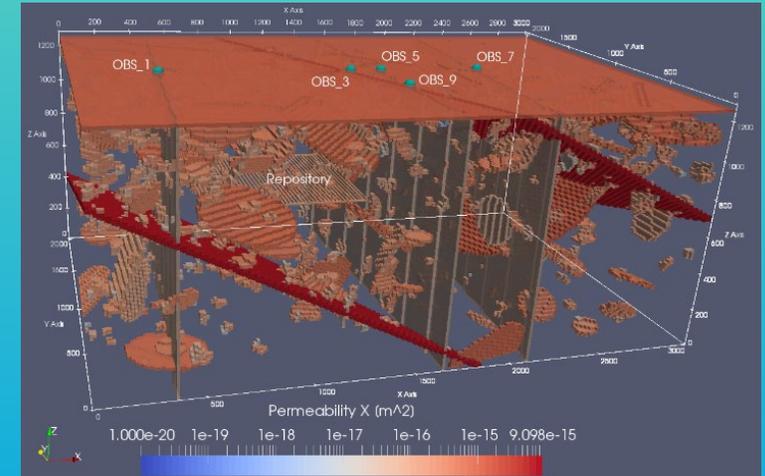
*September 30, 2020
LBNL-2001353
SFWD Working Document: External Release*

International - Acronyms and Abbreviations (1)

ALC	Full-scale Emplacement Experiment
BATS	Brine Availability Test in Salt
BRIE	Bentonite Rock Interaction Experiment
CFM	Colloid Formation and Migration Project
CI	Cement Clay Interaction Experiment
COSC	Collision Orogeny in the Scandinavian Caledonides
DECOVALEX	DEvelopment of COupled Models and their VALidation Against EXperiments
DOE	Department of Energy, USA
DR-A	Diffusion, Retention, and Perturbation Experiment
EB	Engineered Barrier
EBS	Engineered Barrier System
FE	Full-scale Emplacement Experiment
FEBEX	Full-scale Engineered Barrier Experiment
FEBEX-DP	FEBEX Dismantling Project
FS	Faults Slip Hydro-Mechanical Characterization Experiment
FY	Fiscal Year
GAST	Gas-Permeable Seal Test
GREET	Groundwater REcovery Experiment in a Tunnel
HE-E	<i>In Situ</i> Heater Experiment in Micro-tunnel
HG-A	Gas Path through Host Rock Experiment
KURT	KAERI Underground Research Tunnel, Republic of Korea

International - Acronyms and Abbreviations (2)

LASGIT	Large-scale Gas Injection Test
LTDE	Long-Term Sorption Diffusion Experiment
NAGRA	Swiss waste management organization
NEA	Nuclear Energy Agency
SFWST	Spent Fuel and Waste Science & Technology
SKB	Swedish Nuclear Fuel and Waste Management, Sweden
TSDE	Thermal Simulation for Drift Experiment
TED	Thermal Experiment
THMC	Thermo-hydro-mechanical-chemical
URL	Underground Research Laboratory
WIPP	Waste Isolation Pilot Plant, New Mexico, USA



Moving Forward: Disposal Research 5-Year Plan

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(SFWST) Campaign

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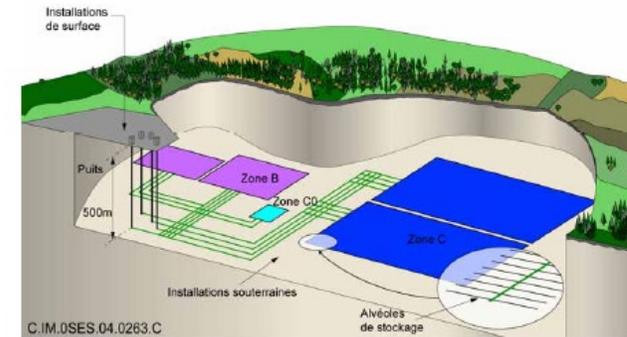
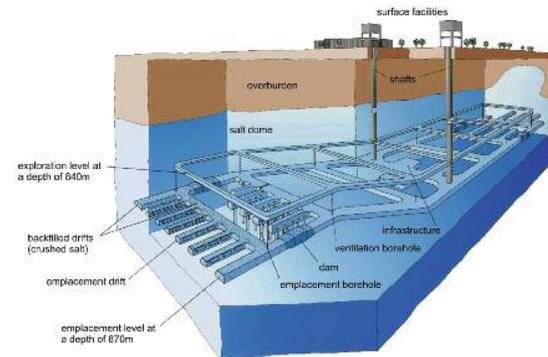
- Program Planning Introduction
 - Overview and challenges
 - Completed prioritization efforts and Disposal Research coverage
- Disposal Research Five-year Plan
 - Purpose and structure
 - R&D priorities
 - Integration example from FY21 planning
- Summary and Conclusions

Generic Disposal Concepts and Program Planning

- 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) glass
- **Increase confidence** in the robustness of generic disposal concepts
- **Develop the science and engineering tools** needed to support disposal concept implementation

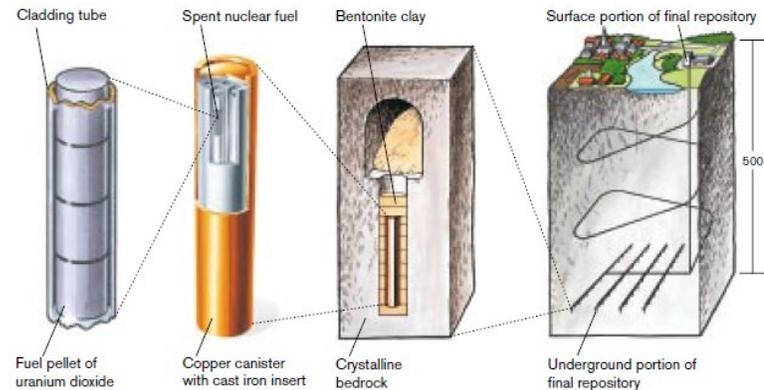
Salt Repository Example

Gorleben, Germany (BMW 2008)



Argillite Repository Example

Meuse/Haute Marne, France (ANDRA 2005)



Crystalline Repository Example

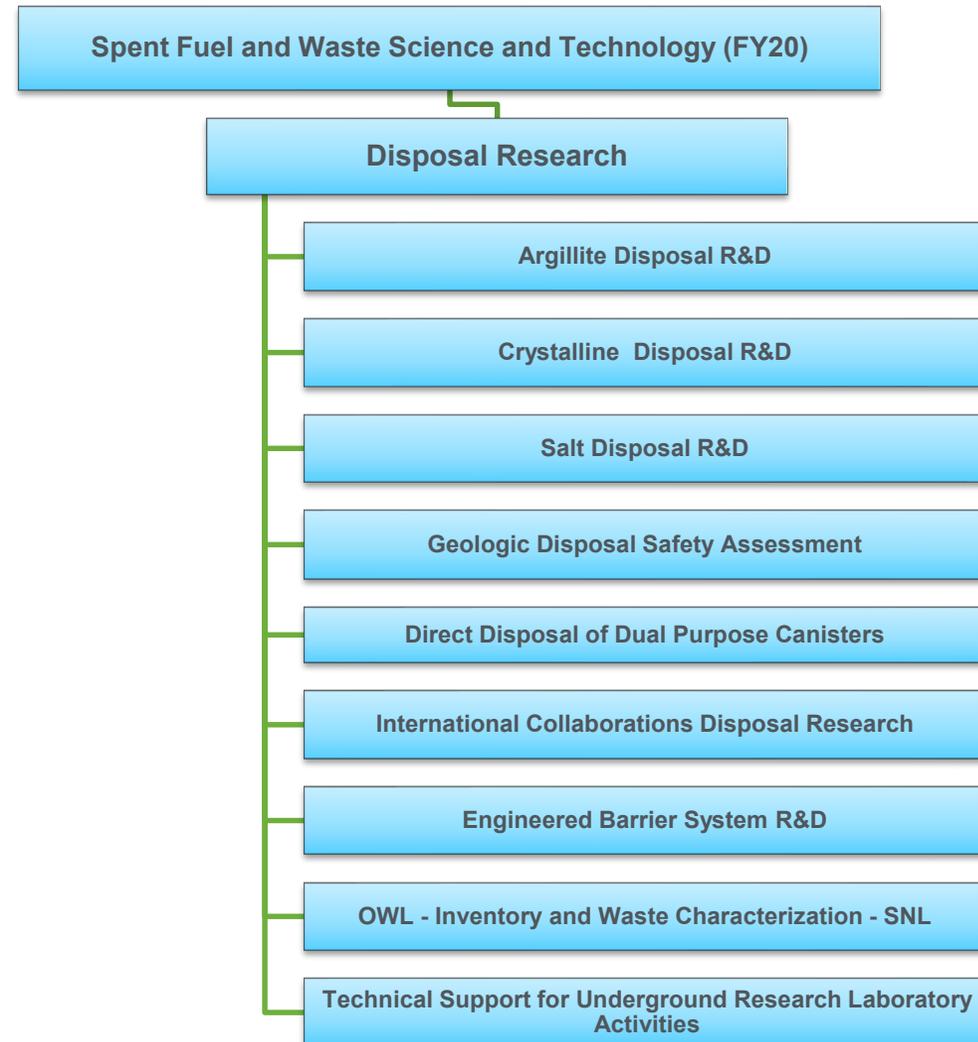
Forsmark, Sweden (SKB 2011)

■ Planning Challenges:

- **Wide range** of geologic disposal concepts
- Constrain the **generic R&D** most important for each
- **Define complete enough** for generic D&D
- Utilize **vast international experience**
- **Integrate** cross-cutting aspects clearly

Planning Prioritization Drivers, Previous Efforts, and Disposal Research Coverage

- Driving Forces
 - Program Direction
 - Generic nature of R&D studies
 - Provide bases and capabilities applicable to broad concepts
 - GDSA capabilities in multiple geologic disposal concepts
 - International investigations including site-specific work
- Completed prioritization efforts
 - Used Fuel Disposition Roadmap (2012)
 - Generated from FY10 through FY12
 - Roadmap Update (2019)
 - Started in FY17 reassessment
- Disposal Research Coverage



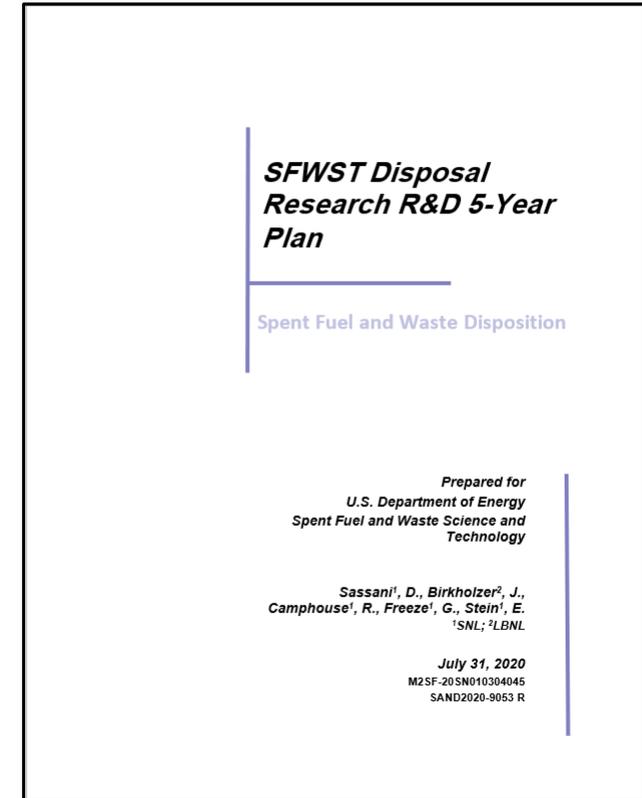
Disposal Research (DR) Five-year Plan Overview

■ Purpose and Utility

- Strategic guide to the work within the DR R&D technical areas (i.e., the control accounts)
 - Concise consolidated plan report for Disposal Research Program
 - Provides thrust topics in each DR technical area
- Living document to be updated annually based on
 - Program Direction
 - Technical progress
 - Enhanced knowledge

■ Plan Structure: Thrust Topics in each DR Technical Area for

- The near term => 1- to 2-year timeframe
 - The present DR R&D portfolio with modest modifications
- The longer term => 3- to 5-year timeframe
 - Vision of where the DR R&D is heading (w/o major Program changes)
- Implemented by executing the work and revising the plan each year
 - First revision will add report on progress for short term thrusts and bases for revised prioritization



Disposal Research (DR) Technical Area Thrust Topics

- Argillite Disposal R&D
 - Near-Term Thrust Topics (Next 1- to 2-year period)
 - Elucidation of the [coupled thermal, hydrologic, mechanical, and chemical \(THMC\) processes](#) affecting repository performance and
 - Development of multi-fidelity approaches for integration of process models into the GDSA Framework
 - Longer-Term Thrust Topics (Next 3- to 5-year period)
 - Simplifying the representations of THMC processes occurring from within the EBS
 - International collaborations with inputs on [field testing and process understanding](#)
- Crystalline Disposal R&D
 - Near-Term Thrust Topics
 - Flow and [transport in fractures, including matrix diffusion](#)
 - Improved representation of coupled THM processes affecting fracture transmissivity
 - Longer-Term Thrust Topics
 - Performance of [candidate buffer materials](#) under a range of disposal conditions

Disposal Research (DR) Technical Area Thrust Topics (Continued)

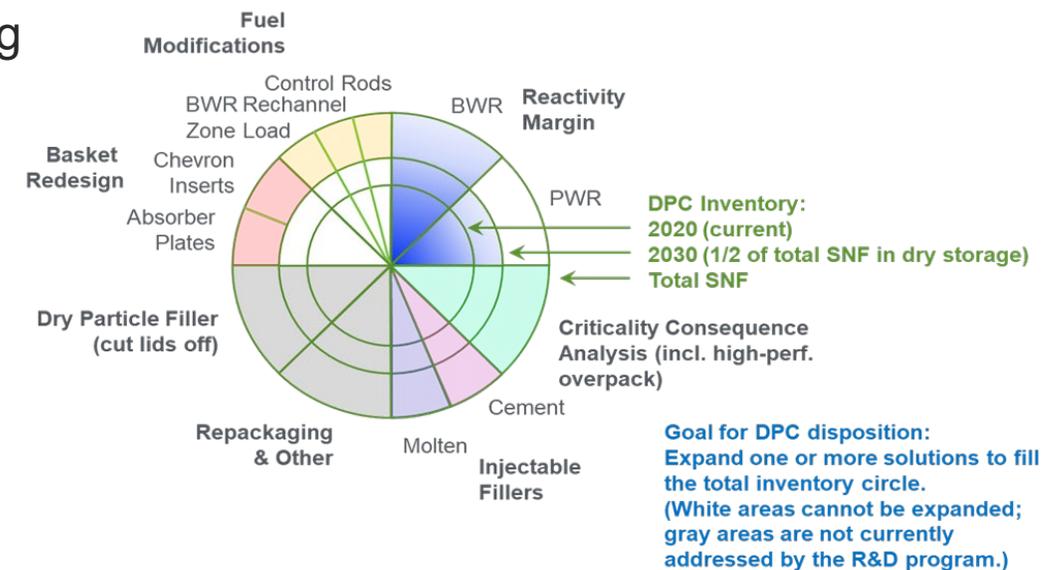
- Salt Disposal R&D
 - Near-Term Thrust Topics
 - Effect of [heat-generating waste](#)
 - Evolution of engineered barriers in salt
 - Model development
 - Longer-Term Thrust Topics
 - Additional heated borehole tests (beyond BATS)
 - [Integration of models into GDSA](#) Framework
- Geologic Disposal Safety Assessment
 - Near-Term Thrust Topics
 - Advanced simulation capability
 - [Uncertainty and sensitivity analysis](#)
 - Workflow
 - [Repository systems analysis](#)
 - Geologic modeling
 - Longer-Term Thrust Topics
 - Incorporation of newer [models from host-rock investigations](#) for additional FEP
 - Refined representations of EBS and geologic features

Disposal Research (DR) Technical Area Thrust Topics (Continued)

■ Direct Disposal of Dual-Purpose Canisters (July 2020)

• Near-Term Thrust Topics

- Probabilistic Post-Closure DPC **Criticality Consequence Analyses**
- As-Loaded DPC Reactivity Margin Modeling
- DPC **Injectable Filler Testing and Analysis**
- Future DPC (Fuel/Basket) Modifications



• Longer-Term Thrust Topics

- Higher-fidelity GDSA Probabilistic Post-Closure DPC Criticality Consequence Model
- Near Full-scale **Demonstration of DPC Injectable Filler Testing and Analysis**
- Develop/Demonstrate Most Promising Future DPC (Fuel/Basket) Modifications

Disposal Research (DR) Technical Area Thrust Topics (Continued)

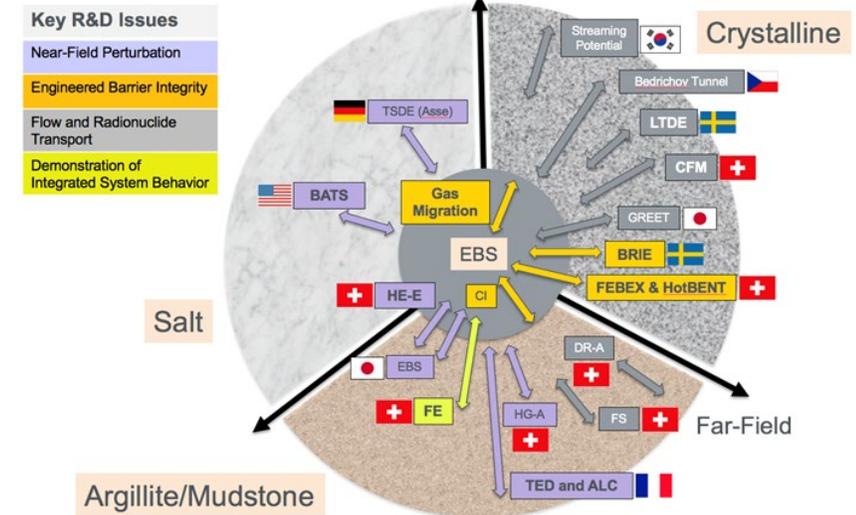
■ International Collaboration in Disposal Research (April 2019)

• Near-Term Thrust Topics

- Continue participation within international R&D in underground research laboratories for a range of geologic systems
- Continue assessment of **new international opportunities**
- Pursue a **more active role in conducting experimental work** in international underground research laboratories
- Contribute to integration and confidence building for Generic Disposal System Analysis

• Longer-Term Thrust Topics

- Develop **best practices and technologies for site selection** and characterization
- Utilize international activities for training/education of junior staff



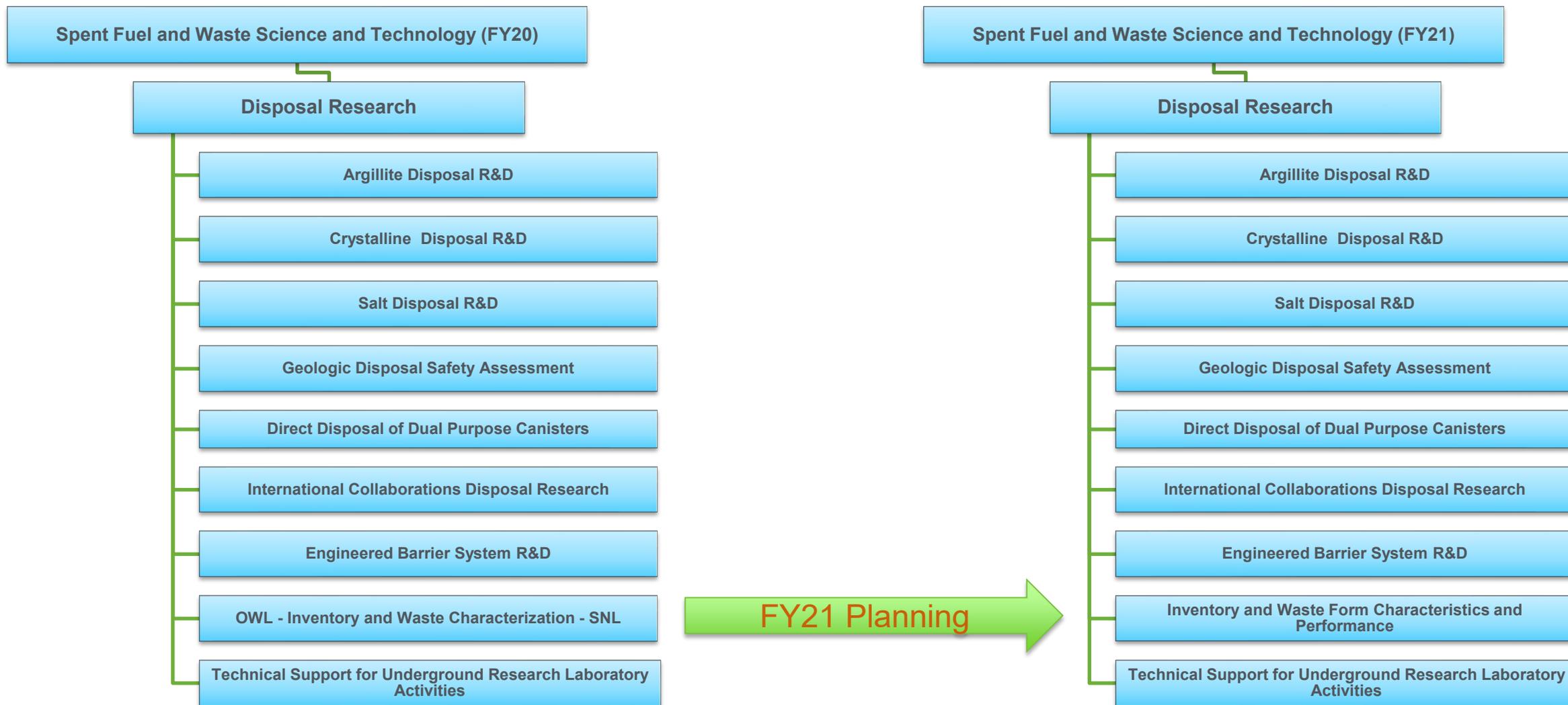
Disposal Research (DR) Technical Area Thrust Topics (Continued)

- Engineered Barrier System (EBS) R&D
 - Near-Term Thrust Topics
 - Analysis of thermal, mechanical, and chemical processes that will influence performance of EBS designs for each host media
 - Understanding of [bentonite buffer drying and re-saturation processes](#) (i.e., thermal-hydrologic behavior)
 - Longer-Term Thrust Topics
 - a) International collaboration and [URL studies for EBS performance and design materials](#) (e.g., cement)
- Online Waste Library (OWL) – Inventory and Waste Characterization
 - Near-Term Thrust Topics
 - Provide [Change Control and Release Control processes](#) for OWL
 - Develop Glass Waste Degradation Expertise
 - Longer-Term Thrust Topics
 - Maintain OWL Inventory Content
 - Consider [Additional Interface Capabilities for the GDSA Framework](#)

Disposal Research (DR) Technical Area Thrust Topics (Continued)

- Technical Support for Underground Research Laboratory Activities
 - Near-Term Thrust Topics
 - Operational
 - [Passive monitoring](#)
 - Cosmic radiation
 - Longer-Term Thrust Topics
 - [Long-term data collection](#) for both passive monitoring and cosmic radiation detection activities
- **Knowledge Management (KM - in Campaign Management Control Account)**
 - Near-Term Thrust Topics
 - Continued maintenance and development on KM Repository
 - [Expand topical coverage](#) for disposal programs and storage & transportation
 - Longer-Term Thrust Topics
 - Expand [KM Repository efficacy](#) to larger portions of the nuclear energy fuel cycle community
 - Consider developing training courses

FY 21 Update SFWST Disposal Research R&D Campaign Structure (from PICS NE 1.08.01)

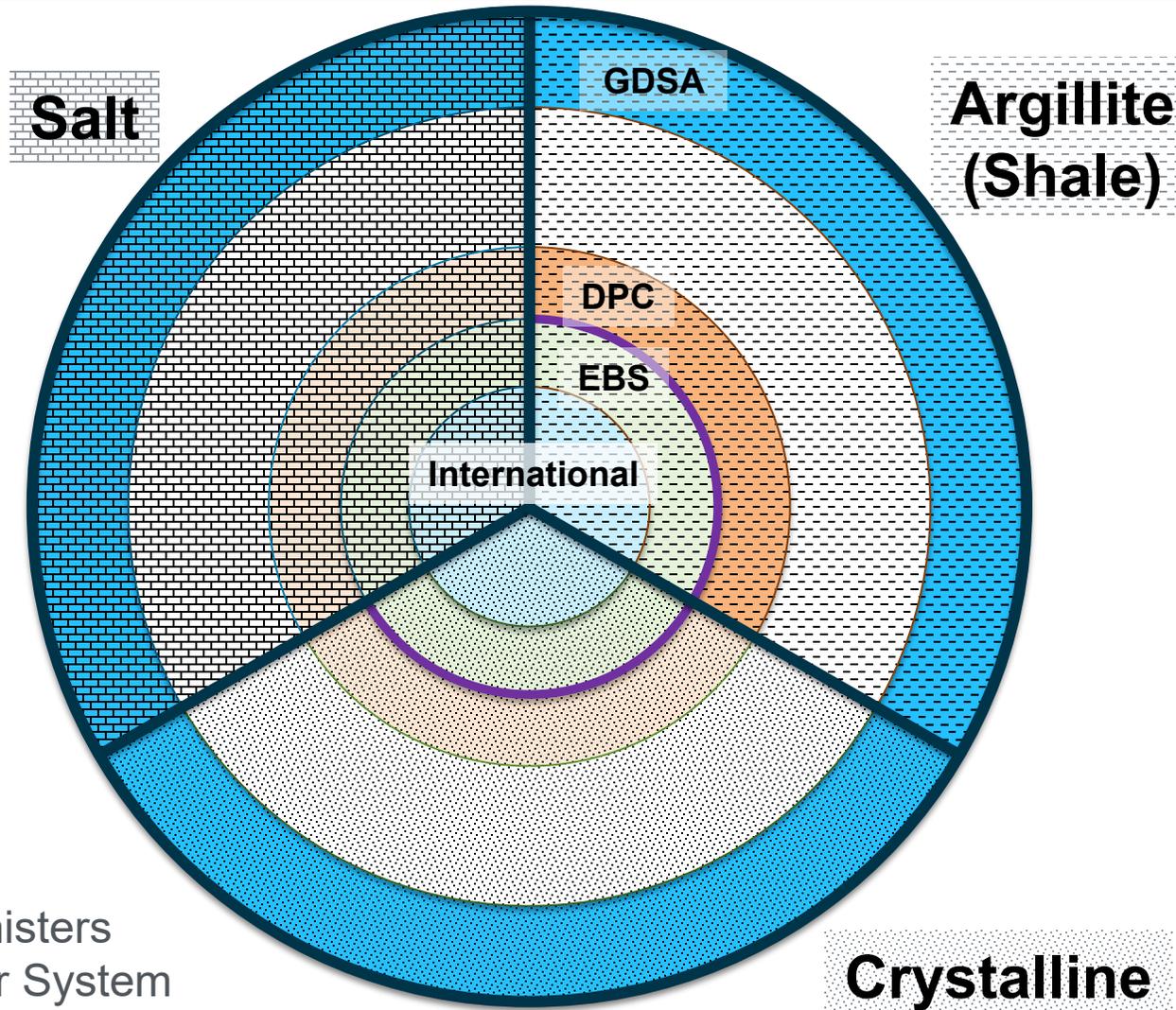


FY 21 Updates SFWST Disposal Research R&D Campaign Structure (from PICS NE 1.08.01)

- **Integration** Within Disposal Research for Waste Forms (SNF)
 - With Storage and Transportation (S&T) R&D
 - With Integrated Waste Management (IWM) Campaign
 - Further...



Visual Depiction of Disposal Research Host Rock and Cross-cutting Technical Areas



- Patterned Wedges: Host Rock Areas
- Colored Overlay Rings: Cross-cutting Areas
 - Shading indicates focus of Cross-cutting activities

- Host-rock Investigations
 - Argillite/shale
 - Crystalline
 - Salt
- Cross-cutting Investigations
 - International
 - Engineered Barrier System
 - Dual Purpose Canisters
 - Geologic Disposal Safety Assessment
 - Inventory/Waste Form
 - SNF testing
 - Finalize planning FY21
 - Initiating Testing?
 - Underground Research Laboratory
- Unsaturated Zone Activities (less mature)

DPC = Dual Purpose Canisters
 EBS = Engineered Barrier System
 GDSA = Geologic Disposal Safety Assessment
 SNF = Spent Nuclear Fuel

Summary and Conclusions

- Generic Disposal Research R&D Planning/Prioritization has Multiple Drivers
 - Program Direction
 - Generic nature of R&D studies
 - GDSA capabilities in multiple geologic disposal concepts
 - International investigations including site-specific work
- Within the UFD/SFWST Campaign(s), Detailed Planning Activities Occurred
 - 2012 Roadmap - Based on Features, Events, and Processes
 - Prioritized both for Safety Importance and Knowledge State
 - 2019 Roadmap Update - Based on Campaign Activities (i.e., Technical Progress)
 - Prioritized both for Safety Importance and Updated Knowledge State
- Developed Disposal Research (DR) Five-year Plan for R&D Priorities in
 - Near term (1-2 years)
 - Longer term (3-5 years)
 - Integrating technical thrusts within Disposal Research R&D with
 - Storage & Transportation R&D and Integrated Waste Mgt (DOE NE-82)...and beyond

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To the extent discussions or recommendations in this presentation conflict with the provisions of the Standard Contract, the Standard Contract governs the obligations of the parties, and this presentation in no manner supersedes, overrides, or amends the Standard Contract.

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Questions?

Backup and Reference Materials

References

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