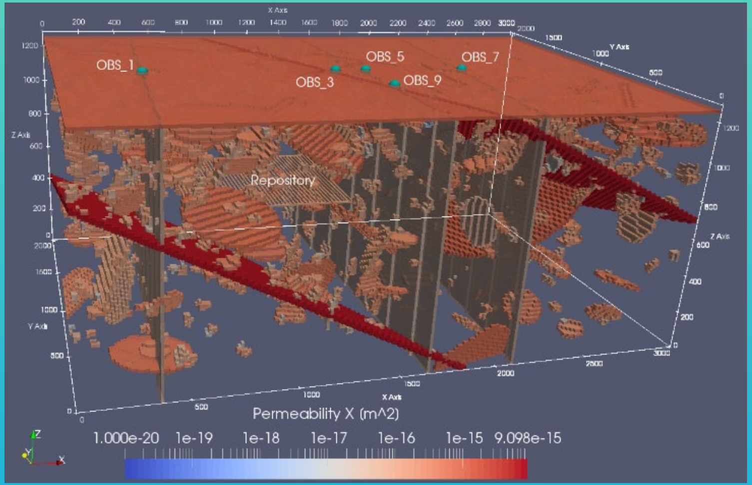

Update on DOE's Dual-Purpose Canister (DPC) Direct Disposal Activities

SAND2022-2040 PE

U.S. Nuclear Waste Technical Review Board
Winter 2022 Board Meeting (Virtual)
March 1-2, 2022

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Disclaimer

This is a technical presentation that does not take into account the contractual limitations or obligations under the Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste (Standard Contract) (10 CFR Part 961). For example, under the provisions of the Standard Contract, spent nuclear fuel in multi-assembly canisters is not an acceptable waste form, absent a mutually agreed to contract amendment.

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.

This presentation reflects technical work which could support future decision making by DOE. No inferences should be drawn from this presentation regarding future actions by DOE, which are limited both by the terms of the Standard Contract and Congressional appropriations for the Department to fulfill its obligations under the Nuclear Waste Policy Act including licensing and construction of a spent nuclear fuel repository.

Meeting Organization

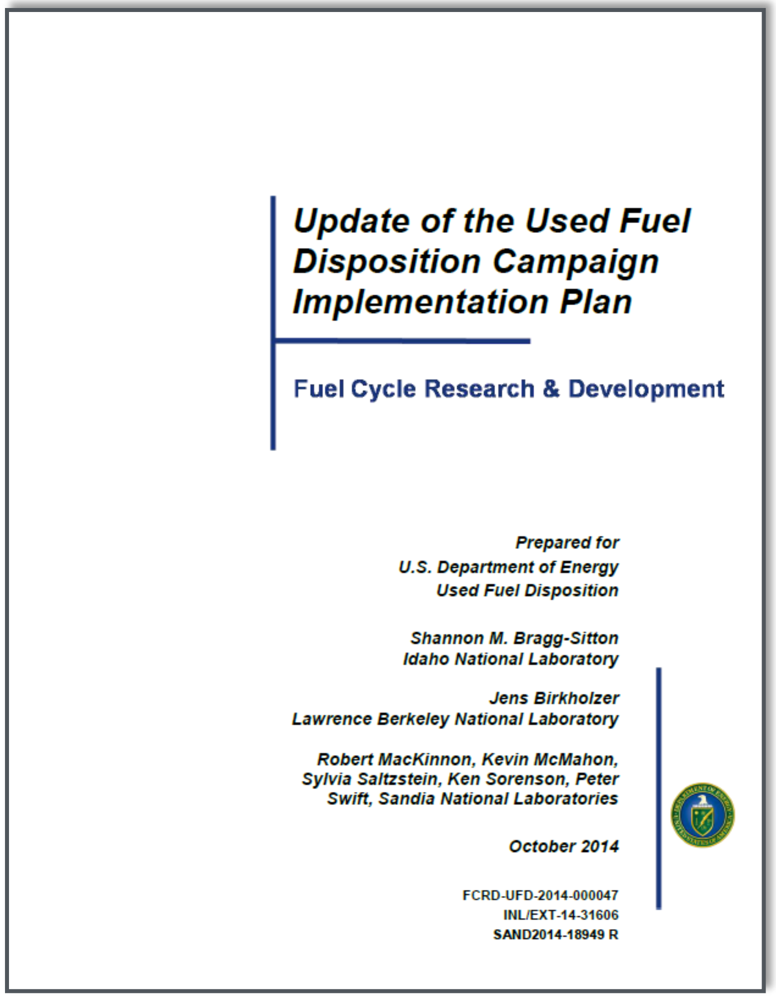
DOE Spent Fuel and Waste Disposition (SFWD)

- **Spent Fuel and Waste Science and Technology (SFWST)**
  - **Update on DOE's Dual-Purpose Canister (DPC) Direct Disposal Activities**
    - **Disposal Research and Development (R&D) Program**
    - **DPC Direct Disposal R&D Activities**
  - **DOE's Storage and Transportation R&D Activities**
- **Integrated Waste Management (IWM) Activities**
- **Consent-Based Siting**

Spent Fuel and Waste Science and Technology Program Mission and Purpose

The mission of the Spent Fuel and Waste Science and Technology Disposition (SFWST) Campaign is to identify alternatives and conduct scientific research and technology development to enable storage, transportation and disposal of used nuclear fuel and wastes generated by existing and future nuclear fuel cycles.

Update of the Used Fuel Disposition Campaign Implementation Plan. FCRD-UFD-2014-000047, October 2014



Update of the Used Fuel Disposition Campaign Implementation Plan

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Used Fuel Disposition

Shannon M. Bragg-Sitton
Idaho National Laboratory

Jens Birkholzer
Lawrence Berkeley National Laboratory

Robert MacKinnon, Kevin McMahon, Sylvia Saltzstein, Ken Sorenson, Peter Swift, Sandia National Laboratories

October 2014

FCRD-UFD-2014-000047
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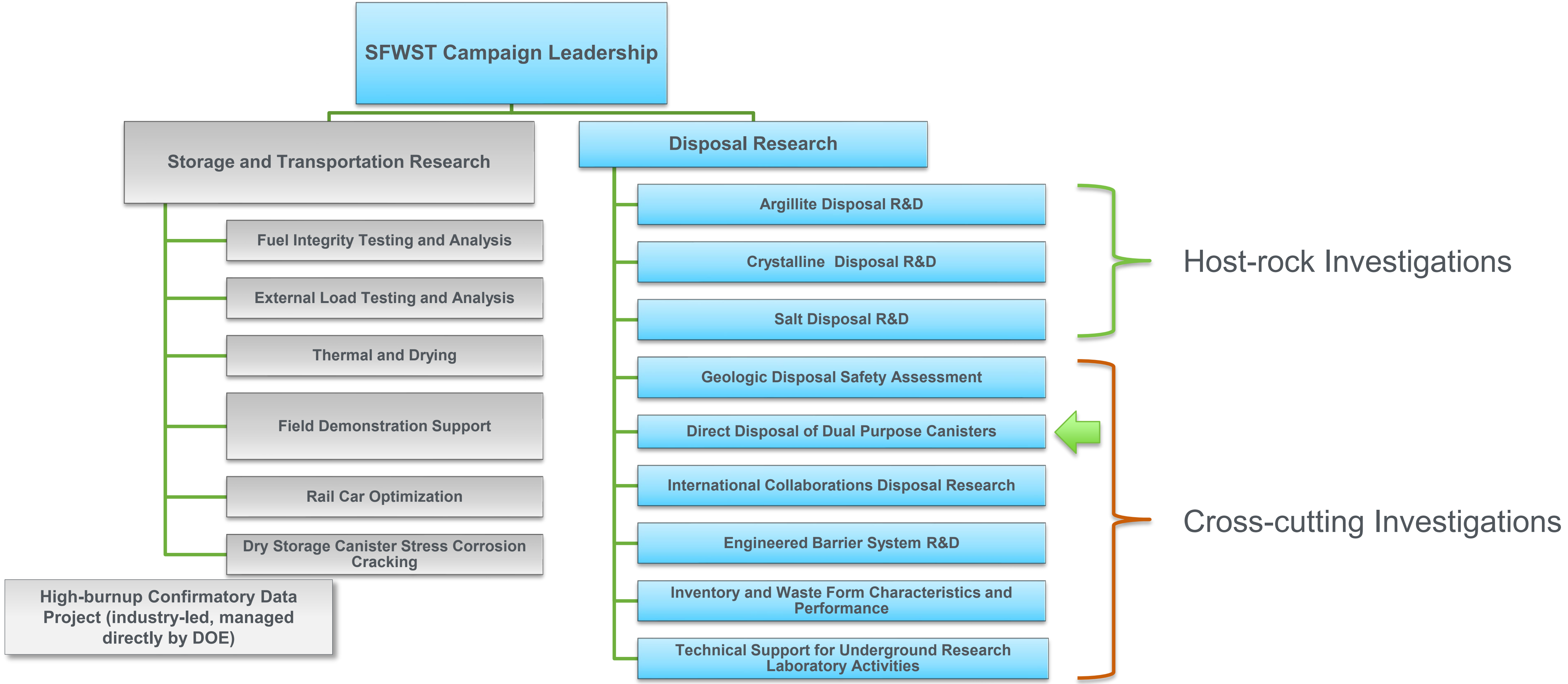
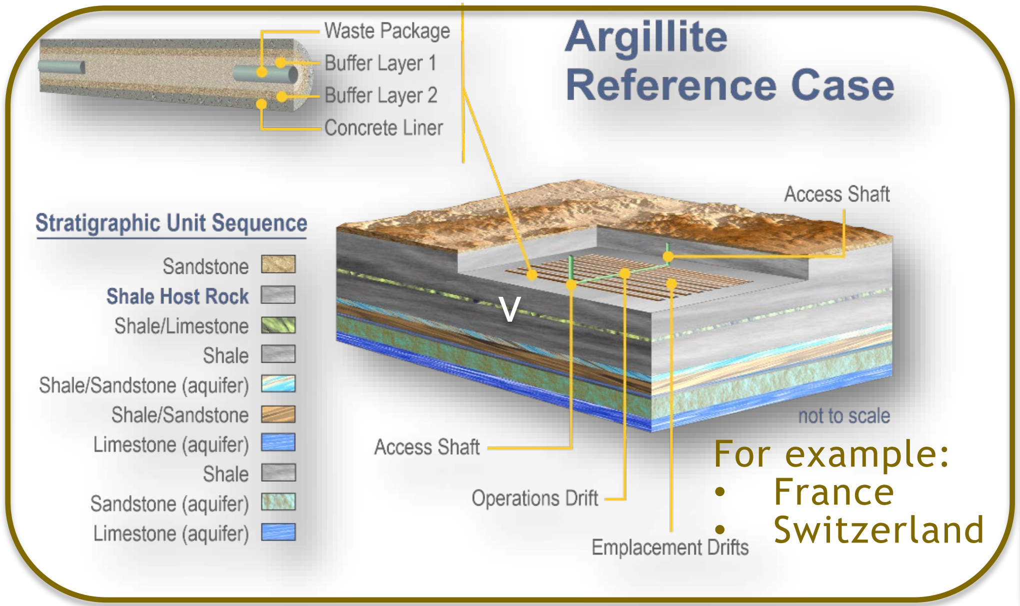
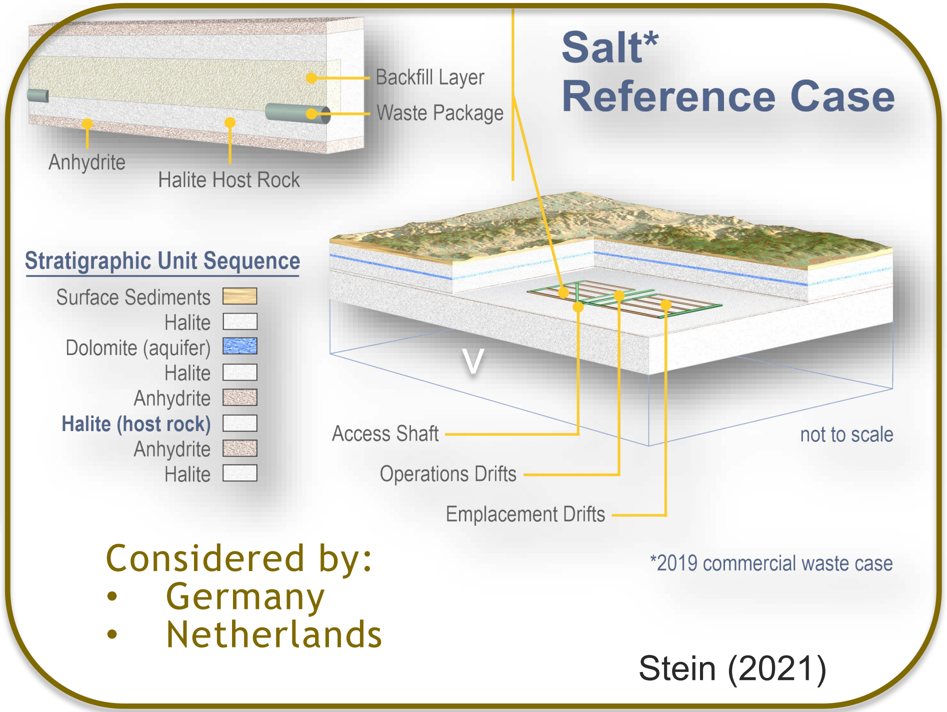
FY 22 SFWST R&D Campaign Structure

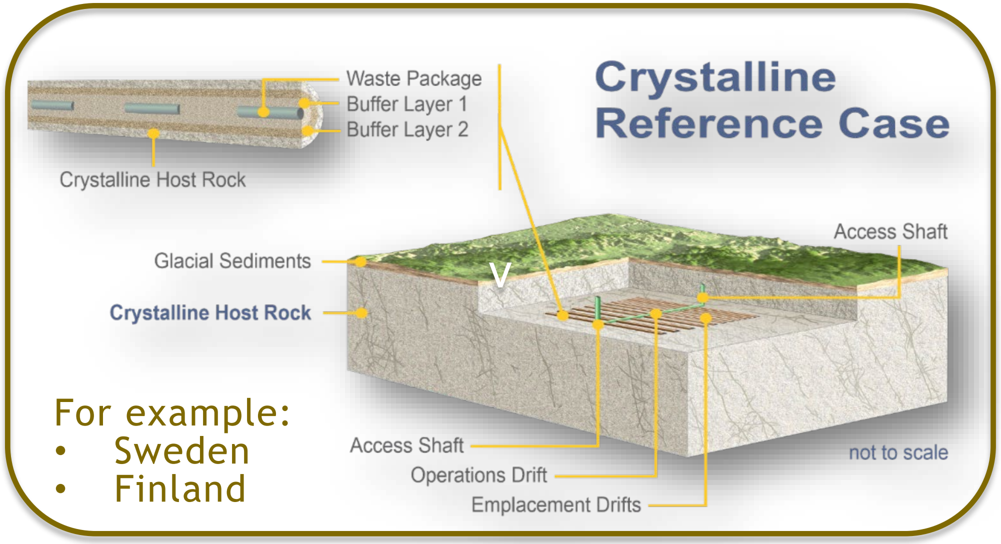


Generic (Non-Site Specific) Disposal R&D: Concepts and Goals

- 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
- Utilize international experience and develop U.S. program capabilities

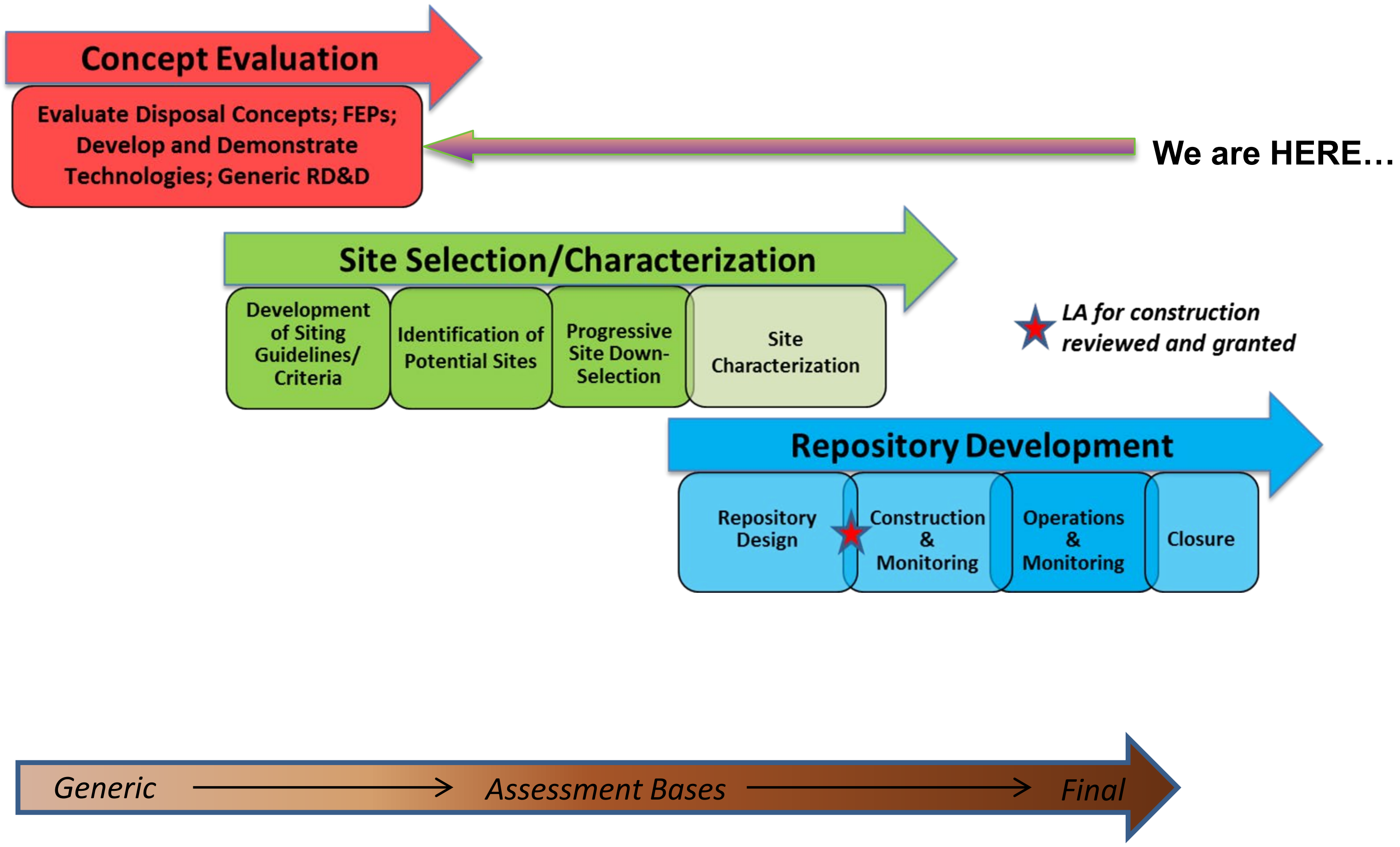






- Deep Geologic Disposal Options
  - Spent nuclear fuel (SNF)
    - Commercial
    - DOE-managed
  - High-level radioactive waste (HLW)

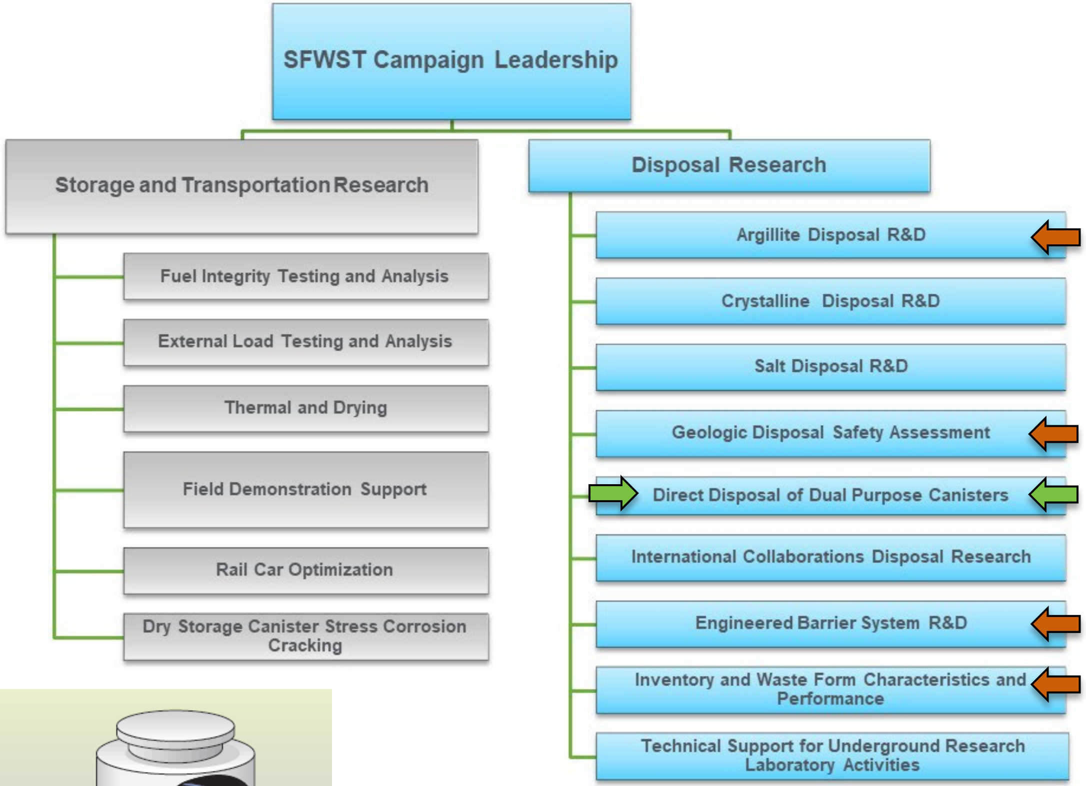
Disposal Research Program Conceptual Timeline

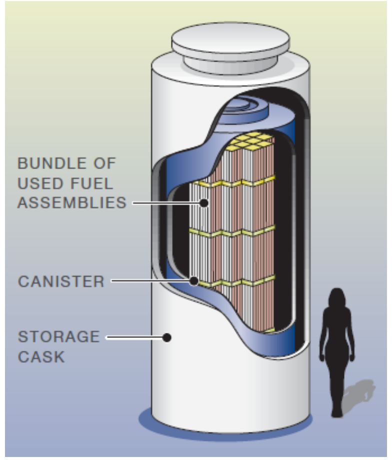


FEPs = features, events, and processes
LA = License Application

DPC Direct Disposal R&D - Introduction

- Investigate the feasibility of repository disposal of commercial SNF (CSNF) in dual-purpose canisters (DPCs) in overpacks
  - This work is a multi-lab effort led by Sandia National Laboratories (SNL)
    - includes Oak Ridge National Laboratory (ORNL), Idaho National Laboratory (INL), Pacific Northwest National Laboratory (PNNL), Los Alamos National Laboratory (LANL), and Lawrence Berkeley National Laboratory (LBNL)
- The term DPC is used here to collectively refer to the large multi-assembly canisters currently loaded with CSNF for dry storage
- DPCs are designed and licensed for storage and transportation of SNF (hence “dual purpose”), but not with consideration for ultimate geologic disposal
  - Direct disposal of CSNF in DPCs is an alternative to repackaging CSNF into disposal-ready canisters

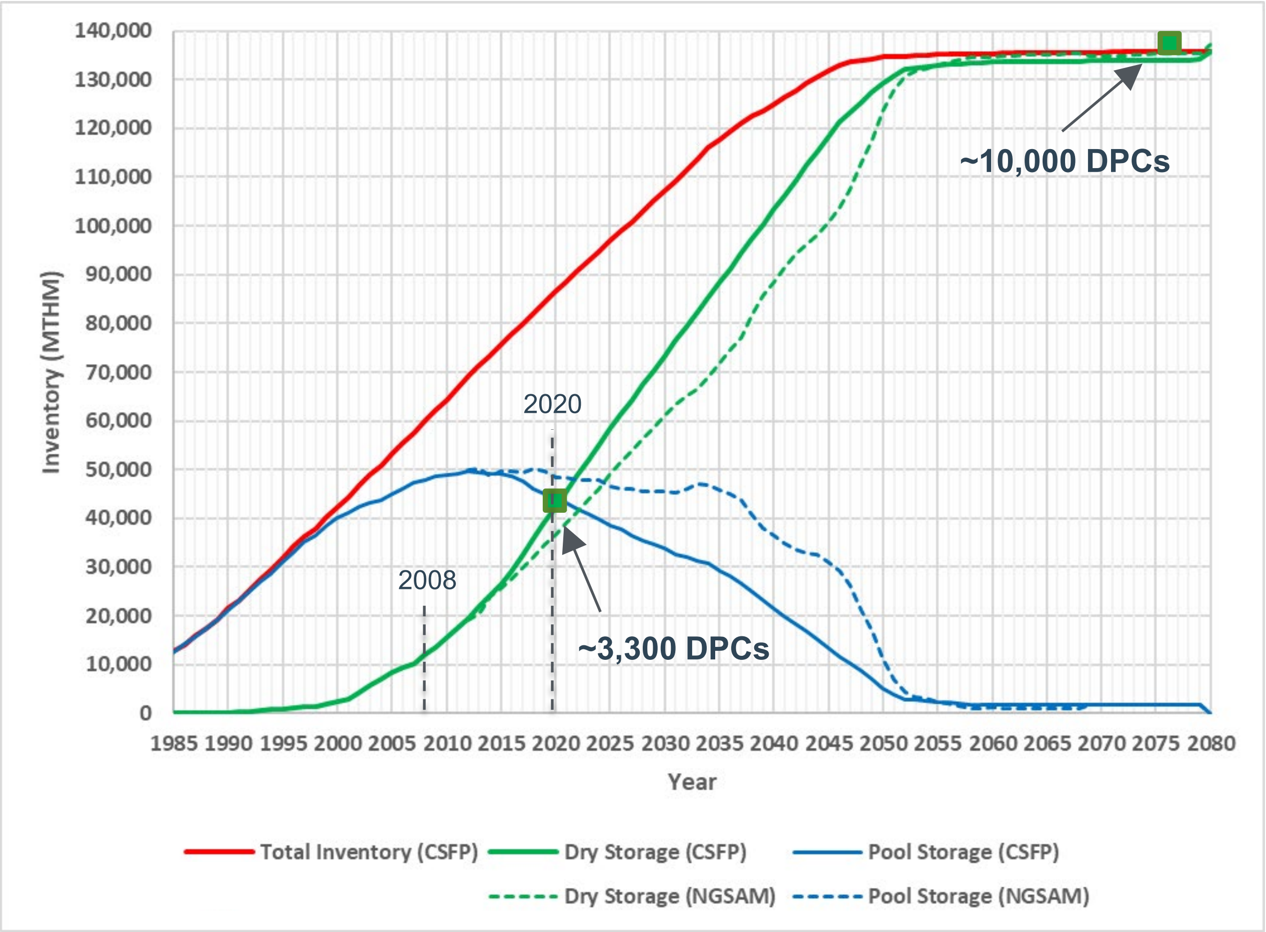




(Source: BRC 2012, Figure 4)

DPC Disposal – Projected Inventory

Projected Inventory of US CSNF in Storage – No Replacement Scenario



[Source: adapted from Freeze et al. (2021, Figure 2-3) and Peters et al. (2020, Figure 2-13)]

- In 2008, at the time of the DOE Repository License Application (LA), most CSNF was still in pool storage and the plan was for the CSNF to be loaded into disposal-ready transportation, aging, and disposal (TAD) canisters, which were specifically designed for permanent disposal under the unsaturated hydrogeochemical conditions present at the proposed repository
- As of December 2020, there were ~42,000 metric tons of heavy metal (MTHM) of CSNF in dry storage in ~3,300 DPCs (Peters et al. 2021)
- By 2075, it is projected that there will be ~140,000 MTHM in dry storage in ~10,000 DPCs

CSNF is at 77 Independent Spent Fuel Storage Installation (ISFSI) sites in 35 states around the country:

- 72 operating and shutdown reactor sites
- 5 away-from-reactor ISFSIs

[Data as of November 2020 (Freeze et al. 2021, Section 3.1.2)]

DPC Disposal – Waste Management Options

(1) Repackage SNF in the future prior to disposal

- Would be costly with radiological, operational safety, and management risks
- The cost of repackaging SNF could be on the order of $20 billion (Freeze et al. 2019)
  - Disposal canister procurement costs
  - Repackaging operations
  - Disposal of DPC shells and baskets as low-level waste
- Ideally, to design specialized or standardized canisters, it is beneficial to know the geology and design of the repository (TADs were specific to DOE LA)

(2) Dry storage of SNF at surface facilities indefinitely, repackaging as needed

- Continued storage for an additional 100 years after the short-term timeframe for a total of 160 years after the end of a reactor's licensed life for operation (NUREG-2157)

(3) Construct a repository(s) that can accommodate DPC-based waste packages (WPs) without repackaging

- Subject of ongoing SFWST DPC Direct Disposal R&D

DPC Direct Disposal R&D - Activities

- The direct disposal of DPCs should consider:
  - Operational (Pre-closure) and Post-closure Safety
    - Geologic Disposal Safety Assessment (GDSA) generic reference cases
  - Engineering Feasibility
    - DPC WPs only 10-20% larger size and weight than TAD WPs
  - Thermal Management
    - Media-dependent WP and drift spacing, aging/cooling
    - DPC WPs are 32(37) PWR / 68(89) BWR whereas TAD WPs are 21 PWR / 44 PWR
  - Post-Closure Criticality
    - DPC fuel baskets are designed to control criticality for short-term operations (fuel pools, dry storage) or transportation accidents
    - After disposal (1,000-100,000 yrs), some packages could eventually breach and flood
      - Groundwater is a moderator
      - Aluminum-based neutron absorbing materials readily corrode from long-term exposure to groundwater
    - Eventual fuel and package degradation → potential critical configuration

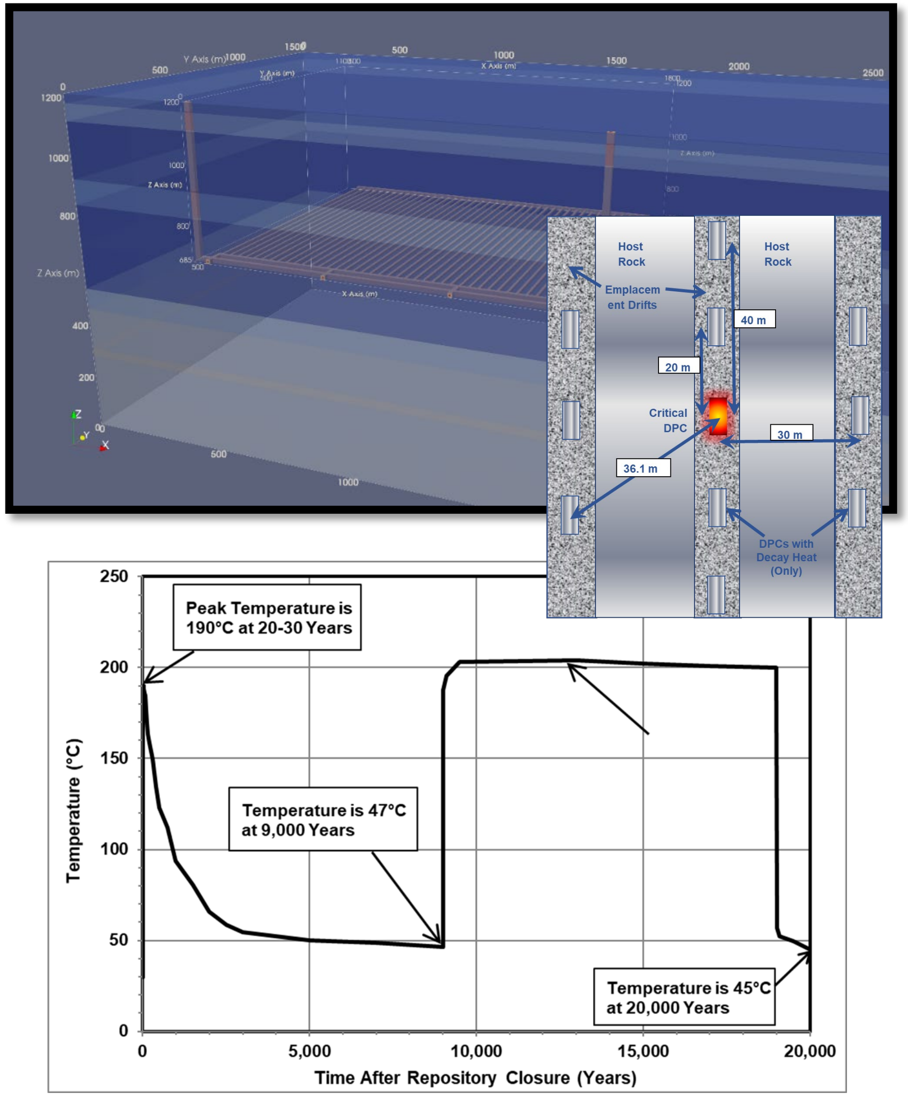
Prior R&D (Hardin et al. 2015, SNL 2021) suggests achievable for multiple geologic media

- salt
- clay
- crystalline
- unsaturated

Focus of ongoing R&D

Post-Closure Criticality Ongoing R&D

- DPC Disposal Without Modification
  [Already Loaded and Future Loaded DPCs]
  - Reactivity margin
    - As-loaded analyses (early-loaded DPCs, burnup credit, etc.)
    - PWRs are generally more reactive than BWRs
    - Insufficient groundwater to flood packages
      – e.g., High-performance overpack or unsaturated conditions
    - High-salinity groundwater/brine (Cl limits reactivity)
  - Criticality Consequence Studies
    - Post-closure performance assessments using PFLOTRAN-based GDSA Framework coupled to neutronics calculations
      – Hypothetical saturated shale repository
      – Hypothetical unsaturated alluvium repository
    - Steady-State Criticality (low power, long duration)
      – 50 W to 4 kW for 1000’s of years
    - Transient Criticality (high power, short duration)
      – 10^2 to 10^5 MW for 0.01 to 10 seconds



Post-Closure Criticality Ongoing R&D

- ## DPC Disposal With Modification

  [Already Loaded DPCs]

  - Injectable Fillers – liquids that solidify to exclude/displace the groundwater moderator
    - Cementitious – calcium phosphates
    - Molten metals – low melting point

  [Future Loaded DPCs]

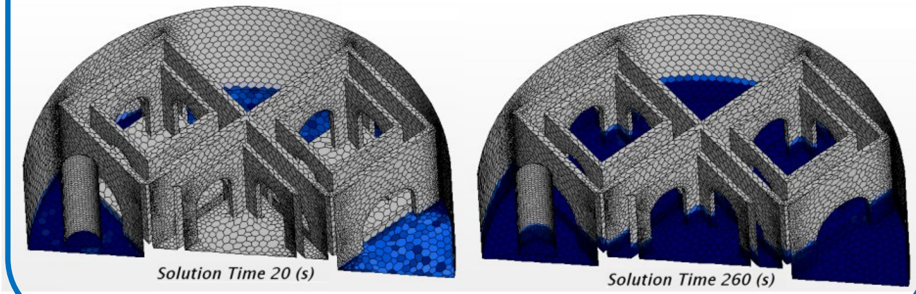
  - Fuel Assembly Modifications
    - disposal criticality control features (PWR control rods, BWR fuel channels with advanced neutron absorbers (ANAs))
    - zone loading
  - Basket Redesign
    - Addition of built-in corrosion-resistant neutron absorbing features (chevron insets, absorber plates)

Laboratory Filler Experiments

Phosphate-Based Cements

Low Melting Point Metals

Simulation of Fillers



DPC Direct Disposal Independent Technical Review (ITR)

- ITR Objective
  - Review representative technical reports and other information to answer the following questions that will provide R&D steering input for the use of DOE managers in taking the Program forward:
    1. Are the technical approaches being investigated for DPC direct disposal clearly defined?
    2. Do any of the R&D activities/results reviewed use incorrect assumptions/data, or omit important information or process that could impact successful implementation?
    3. Are there any new approach(es) to DPC direct disposal that could provide benefit to the R&D program, and why?
    4. Are there any technical approaches under study that are not providing benefit to the R&D program, and why?
    5. Which approaches (one or more) of those presented are more likely to result in successful direct disposal of a substantial number of DPCs (e.g., 5,000 or more)?

DPC Direct Disposal Independent Technical Review (ITR)

- ITR Members
  - Carl Chagnon, Orano Federal Services, Review Team Manager
  - Adam H. Levin, AHL Consulting, ITR Chair
    - Licensing, Nuclear Engineering, Nuclear Physics
  - Robert W. Andrews, INTERA Inc.
    - Post-Closure Performance Assessment
  - Sven O. Bader, Orano Federal Services
    - Licensing, Nuclear Engineering, Nuclear Physics
  - Robert Sindelar, Savannah River National Laboratory
    - Corrosion of Fuel, Canister, and Basket Materials
  - Marek Zreda, University of Arizona
    - Geohydrology

- DOE is currently evaluating ITR observations

Summary of DPC Direct Disposal R&D

R&D Topical Areas:

- Safety
- Engineering challenges
- Thermal management

Achievable for multiple geologic media (e.g., salt, clay, crystalline, unsaturated)

- Post-Closure criticality

Focus of ongoing R&D

Ongoing R&D is summarized in SNL (2020) and SNL (2021)

Technology		Applicable to Currently Loaded DPCs	Applicable to Future Loaded DPCs
Reactivity Margin	PWR	Yes	No
	BWR	Yes	Yes
Criticality Consequence Analysis		Yes	Yes
Injectable Fillers	Cements	Yes	Yes
	Metals	Yes	Yes
Fuel Assembly Modifications	PWR Control Rods	No	Yes
	BWR Rechannel	No	Yes
	Zone Loading	No	Yes
Basket Redesign	Chevron Inserts	No	Yes
	Absorber Plates	No	Yes
Dry Particle Fillers		not currently addressed by SFWST R&D	
Repackaging		not currently addressed by SFWST R&D	

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Questions?