Used Fuel Disposition R&D Campaign

Debrief for the *DOE-Managed Spent Nuclear Fuel and High Level Waste Research* (aka Defense Repository)

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Sandia National Laboratories

Used Fuel Disposition Working Group Meeting

Las Vegas, Nevada

June 7-9, 2016

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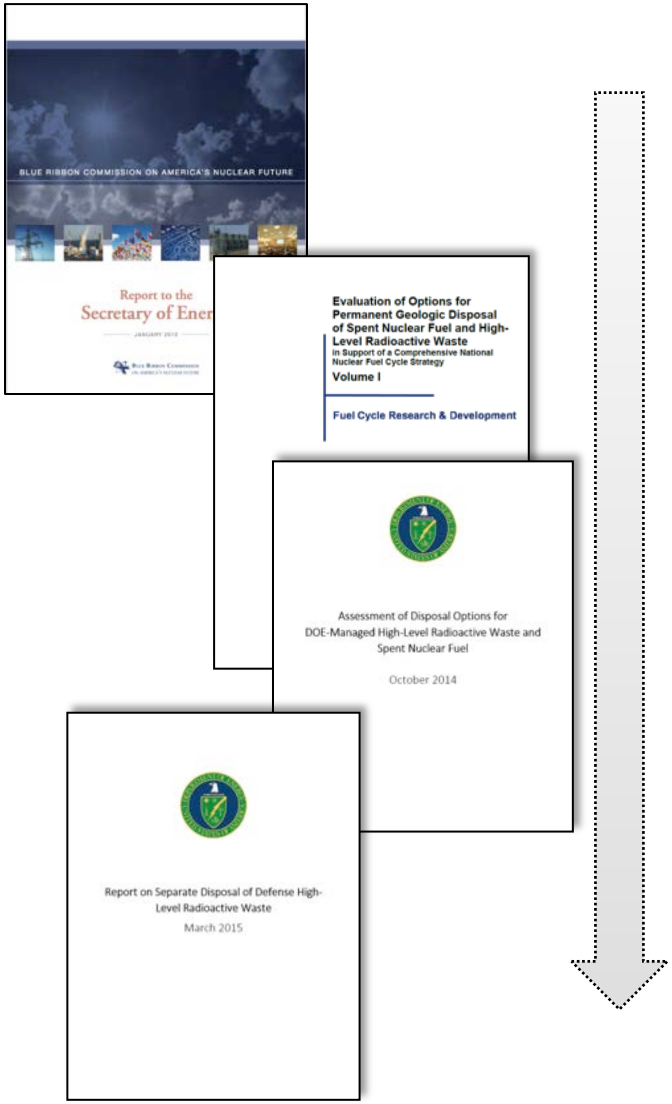
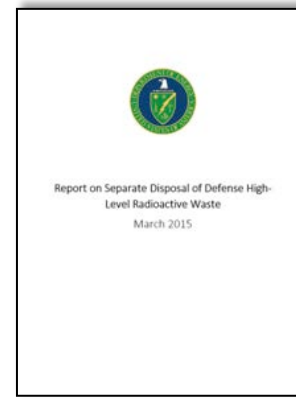
Recent Timeline for Separate Repository

- **January 2012 Blue Ribbon Commission (BRC) on America's Nuclear Future report to the Secretary of Energy**
  - Recommends review of "single repository" policy, whereby defense-related and commercial wastes are commingled
- **April 2014 UFD report "Evaluation of Options for Disposal…"**
  - Concludes that both commingled and separate repositories are technically feasible
- **October 2014 DOE report "Assessment of Disposal Options…"**
  - Recommends that the DOE begin implementation of a phased, adaptive, and consent-based strategy with development of a separate repository for some DOE-managed HLW and SNF
  - Also recommends the DOE retain flexibility to consider deep borehole disposal of some DOE-managed waste forms
- **March 2015 DOE report "…Separate Disposal of Defense High-Level Radioactive Waste"**
  - Presents the basis for a decision in the context of the Nuclear Waste Policy Act



Six Factors Analyzed for the Separate Repository Decision

- **From March 2015 DOE report "…Separate Disposal of Defense High-Level Radioactive Waste"**
  - <u>Cost Efficiency</u>: "…*on balance, cost efficiency favors development of a Defense HLW Repository.*"
  - <u>Health and Safety</u>: "…*would advance long-term health and safety by eliminating the need for active human control and maintenance of waste at various DOE sites.*"
  - <u>Regulation</u>: "…*could simplify the licensing of a subsequent repository by providing important lessons learned…*"
  - <u>Transportation</u>: "…*an earlier opportunity to develop the institutional processes for the transportation of waste prior to the development of a subsequent repository.*"
  - <u>Public Acceptability</u>: "*would provide useful experience in siting future facilities*" (by using the more publically acceptable "*phased, adaptive, consent-based siting approach*")
  - <u>National Security</u>: "…*the likely earlier availability of a Defense HLW Repository could provide additional support to national security objectives…*"


Report on Separate Disposal of Defense High-Level Radioactive Waste

March 2015

The March 24, 2015 Decision

The White House

Office of the Press Secretary

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For Immediate Release March 24, 2015

Presidential Memorandum -- Disposal of Defense High-Level Radioactive Waste in a Separate Repository

MEMORANDUM FOR THE SECRETARY OF ENERGY

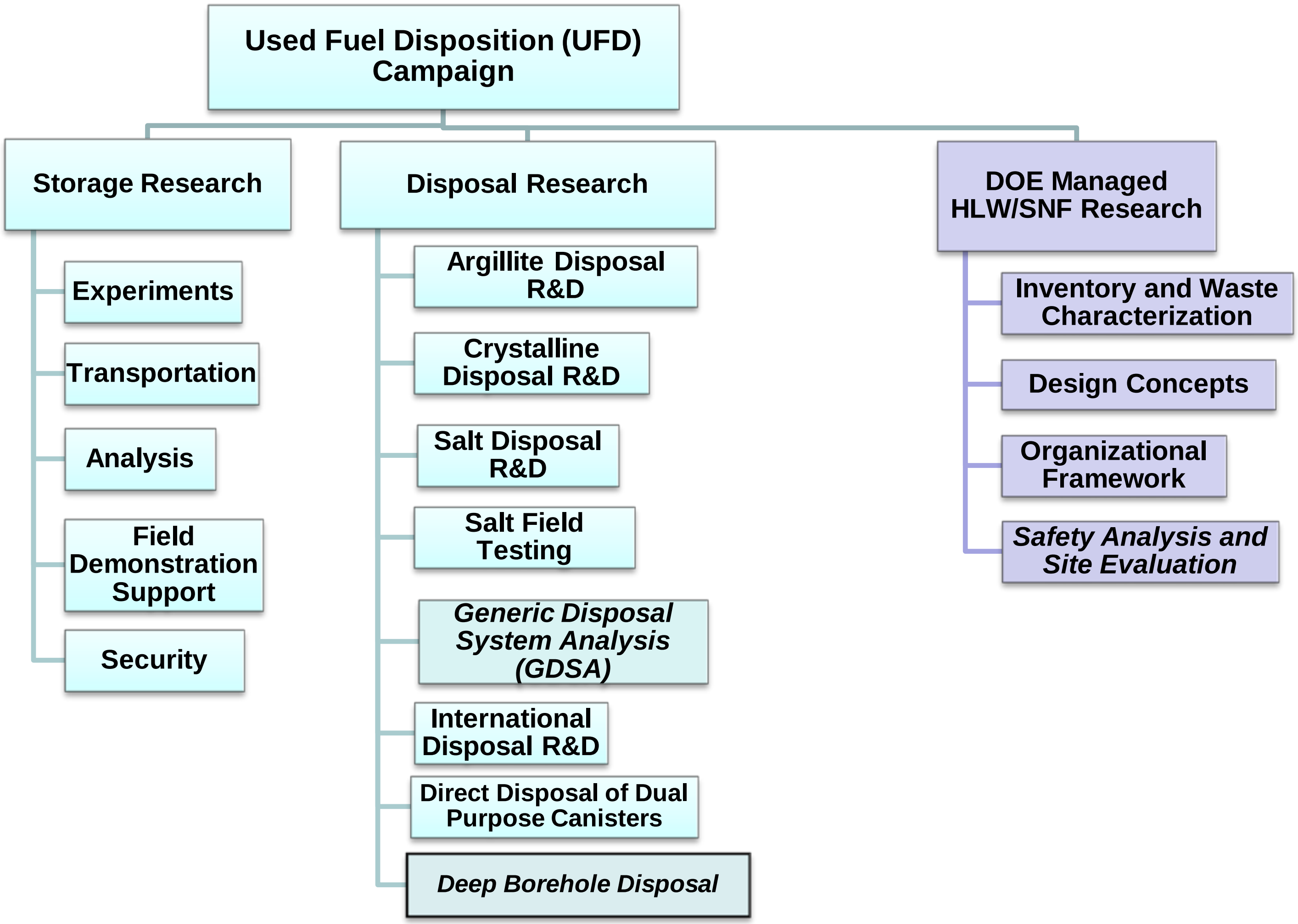
SUBJECT: Disposal of Defense High-Level Radioactive Waste in a Separate Repository

Your memorandum and accompanying report of January 9, 2015, analyze the factors enumerated in section 8 of the Nuclear Waste Policy Act of 1982 (the "Act") concerning disposal of high-level radioactive waste resulting from atomic energy defense activities, conclude that a strong basis exists to find a separate repository is required pursuant to section 8 of the Act, and recommend that I make this finding.

In accordance with the Act, I find the development of a repository for the disposal of high-level radioactive waste resulting from atomic energy defense activities only is required.

BARACK OBAMA

Work Structure for the R&D Program



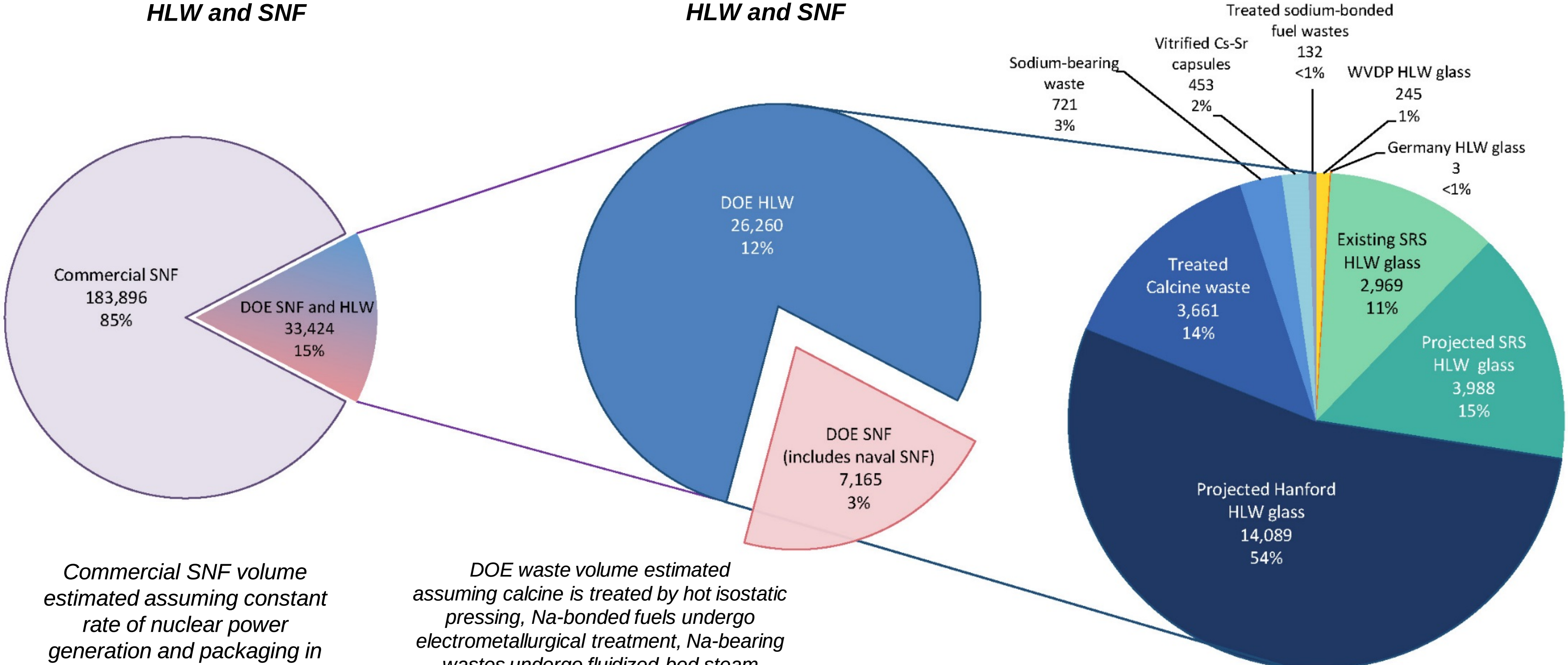
Projected Volumes of DOE-managed HLW and SNF in 2048

Projected volumes in m^3

Commercial and DOE-Managed HLW and SNF

DOE-Managed HLW and SNF

DOE-Managed HLW

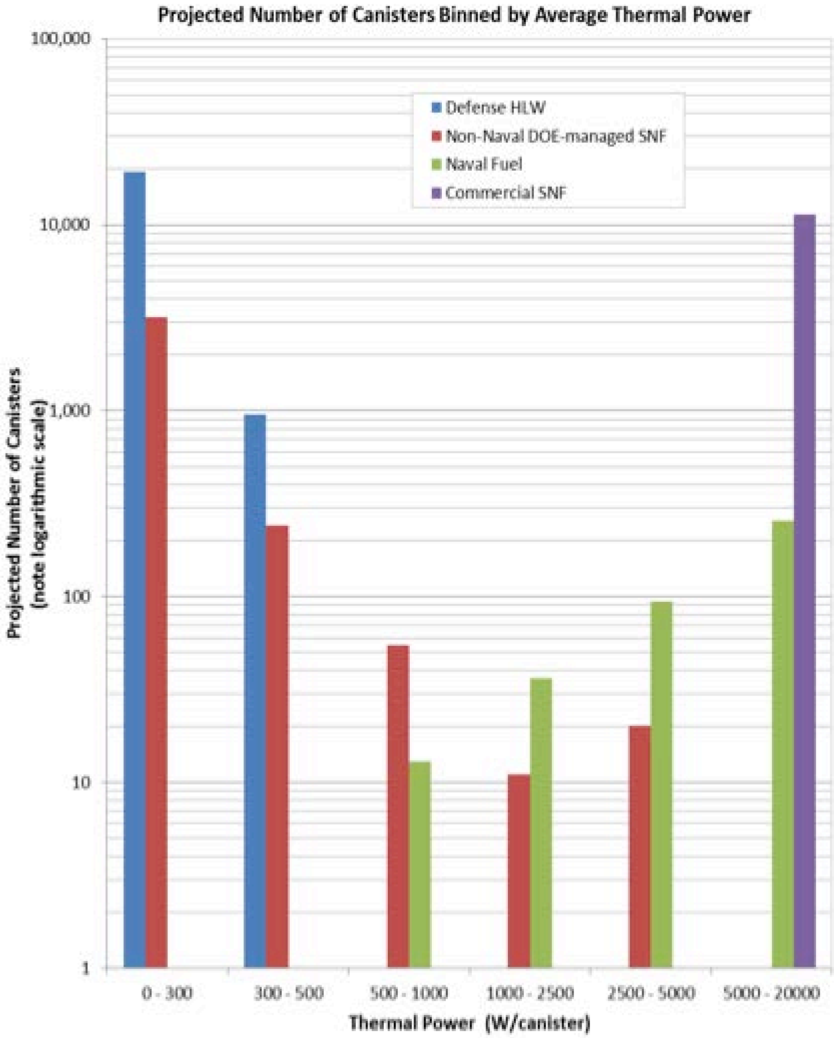


Commercial SNF volume estimated assuming constant rate of nuclear power generation and packaging in dual purpose canisters of existing design

DOE waste volume estimated assuming calcine is treated by hot isostatic pressing, Na-bonded fuels undergo electrometallurgical treatment, Na-bearing wastes undergo fluidized bed steam reforming, and all other HLW wastes are vitrified. Naval SNF estimated as of 2035

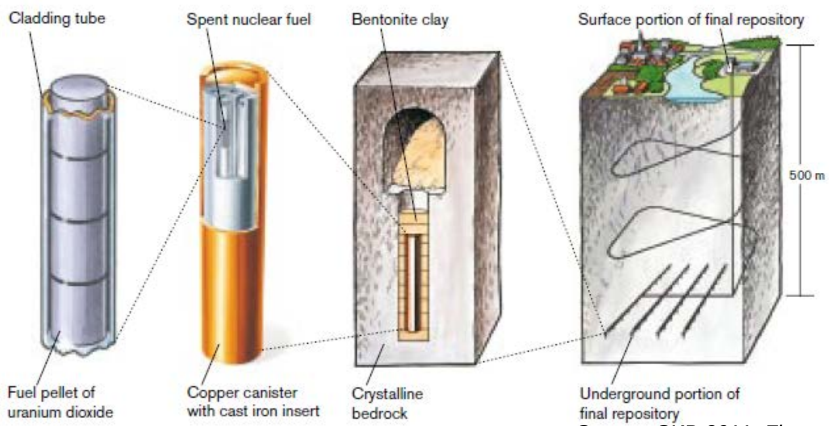
Thermal Characteristics of HLW and SNF Affect Disposal Strategies

- **Repository designs and operational concepts can be engineered to address waste-form thermal characteristics:**
  - All Defense HLW is relatively cold: less than 500 W per canister
  - Most DOE-managed SNF is relatively cold: less than 1000 W per canister
  - All commercial SNF has comparatively high thermal output
  - Some naval SNF is comparable in thermal power to commercial SNF
- **Initial R&D will limit EBS/repository designs to canisters of approximately less than 1000 W**



Potential Disposal Concepts

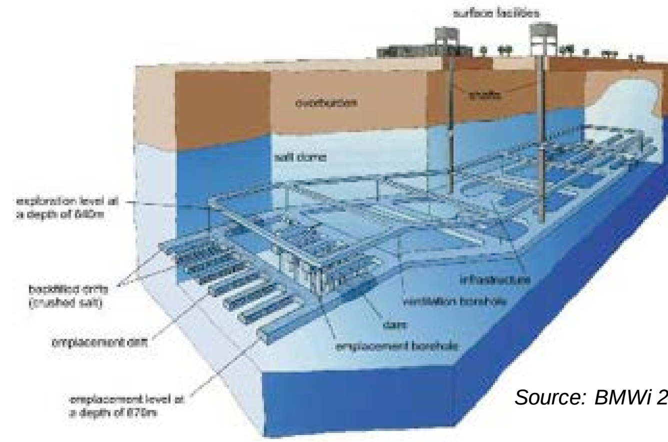
Mined repository in granite or other hard rock



Source: SKB 2011, Figure S-1.

(primary focus of FY16, in conjunction with GDSA work)

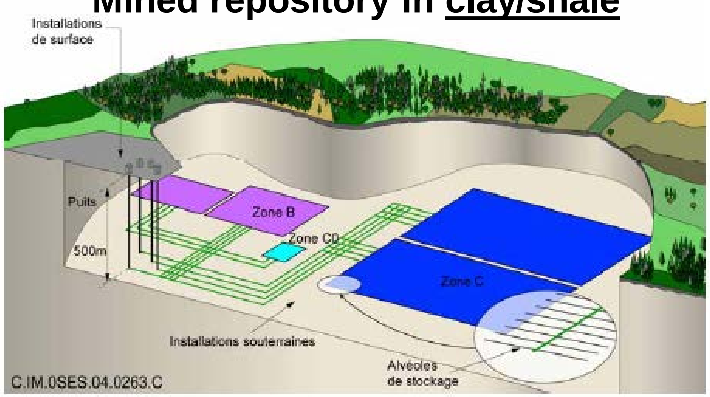
Mined repository in bedded salt



Source: BMWi 2008, Figure 15.

(some work in FY15; hope to update for FY16)

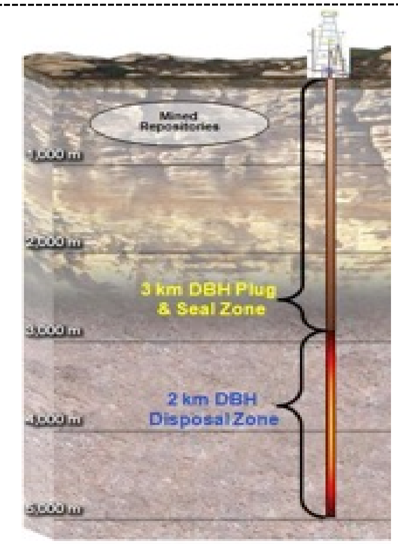
Mined repository in clay/shale



(deferred due to funding cut) *Source: ANDRA 2005b.*

Deep borehole in crystalline basement rock

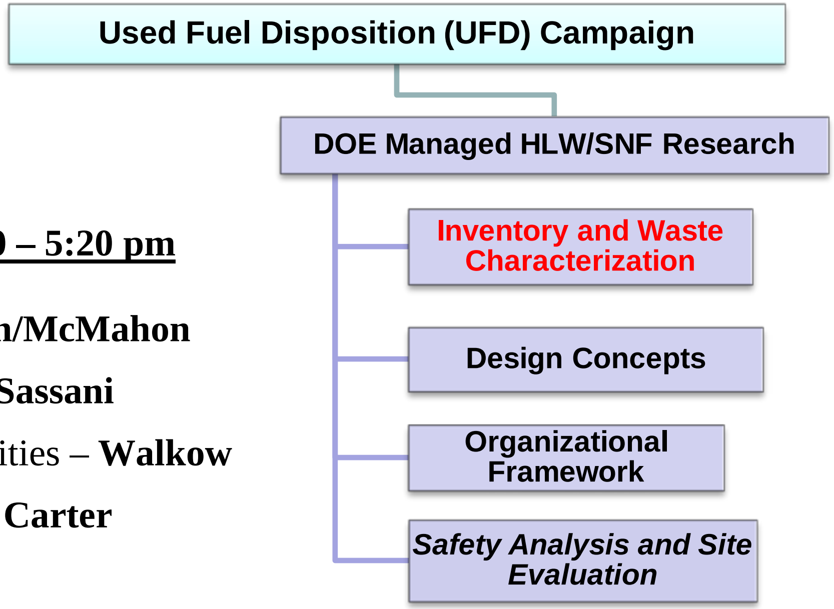
(R&D conducted under DBFT WPs)



Used Fuel Disposition

Agenda

Session 1: Tuesday, 3:30 – 5:20 pm, June 7 – Rm. 1243



Session 1: Defense Inventory and Waste Characterization, 3:30 – 5:20 pm

3:30 – 3:40: Introduction to Defense Repository R&D – **Sevougian/McMahon**

3:40 – 4:00: Overview of Inventory and Waste Characterization – **Sassani**

4:00 – 4:25: On-Line Waste Library (OWL) Database and Capabilities – **Walkow**

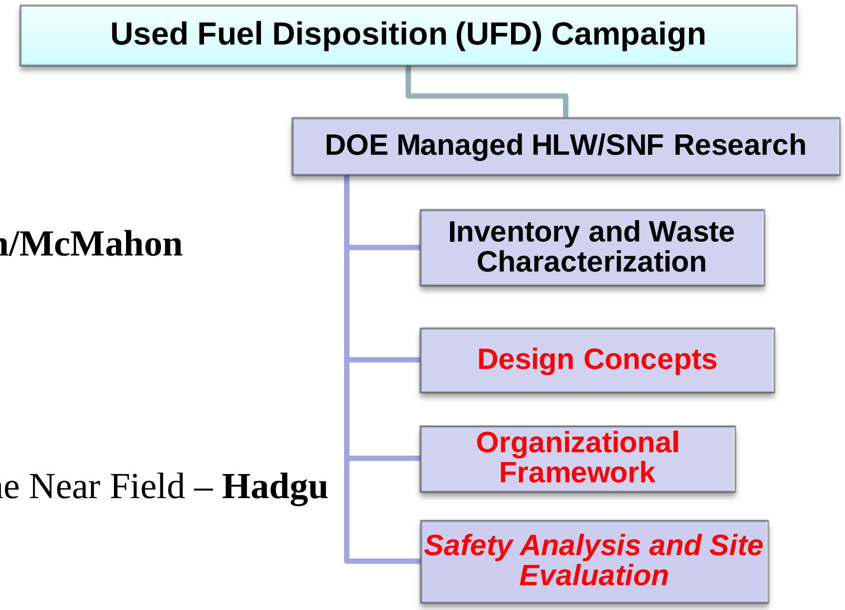
4:25 – 5:00: Decay Heat and Inventory of DOE-Managed Waste – **Carter**

5:00 – 5:20: OWL Hands-on Database Demo – **Walkow**

Agenda (continued)

Session 2: Thursday, 8:00 – 9:50 am, June 9 – Rm. 1243

Session 3: Thursday, 10:10 am – 12:00, June 9 – Rm. 1243



Session 2: Preliminary EBS Design Concepts, 8:00 – 9:50 am

8:00 – 8:10: Introduction to Defense Repository R&D – **Sevougian/McMahon**

8:10 – 8:30: Overview of EBS Design Concepts – **Matteo**

8:30 – 8:45: Waste Package Considerations – **Rigali**

8:45 – 9:15: EBS Design Alternatives – **Hardin**

9:15 – 9:30: Preliminary Analysis of the Effect of Decay Heat in the Near Field – **Hadgu**

9:30 – 9:45: Brainstorming on Design Alternatives – **All**

9:45 – 10:10 *Break*

Session 3: Safety Analysis and Organization/Procedural Frameworks, 10:10 am – 12:00 n

10:10 – 10:30: Overview of D-Repo Safety Analysis R&D – **Sevougian**

10:30 – 10:50: Regional Geology Investigations – **Perry**

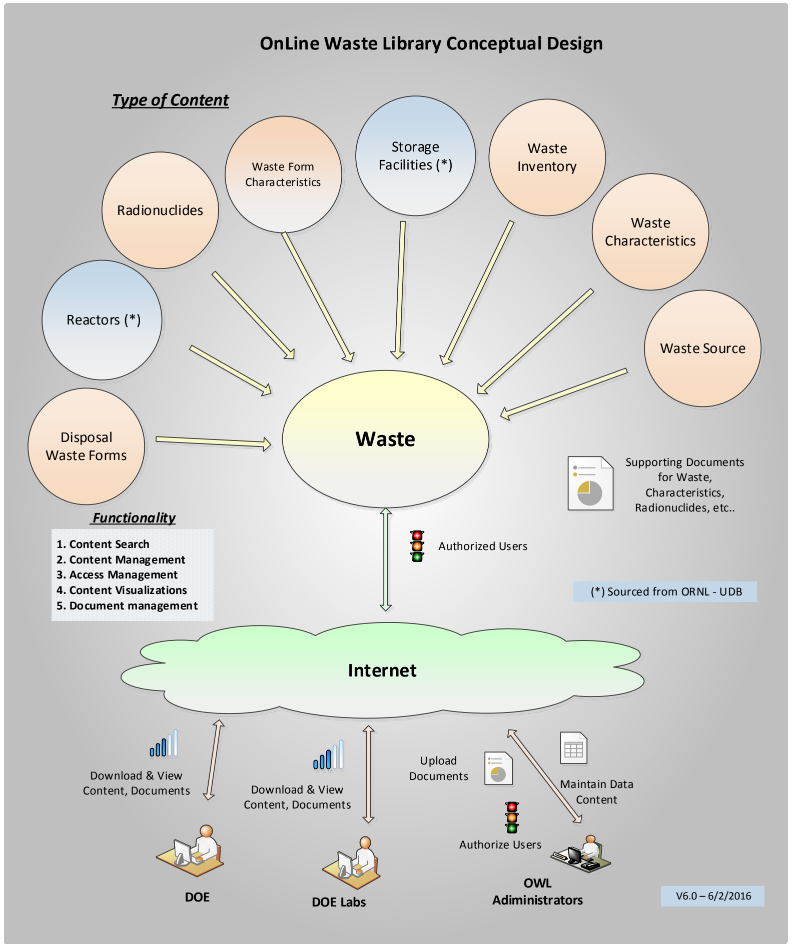
10:50 – 11:20: D-Repo Repository Reference Case and Preliminary PA Simulations – **Stein**

11:20 – 11:35: Draft Program Plan: Organizational and Procedural Frameworks – **Swift**

11:35 – 11:50: Wrap-up and Brainstorming on Future Directions – **All**

Used Fuel Disposition

OWL Conceptual Design



Current Status

- **Database design has been implemented at SNL**
- **Sample content has been added to validate that design supports HLW**
- **Sample Reports developed to provide content searching**
- **Sample Reports developed to display waste detail**
- **Sample visualizations developed to expose possible future capabilities**
  - Demonstration of OWL capabilities at later session today (see schedule)

Geologic Setting Classification (Baldwin *et al.*, 2008)

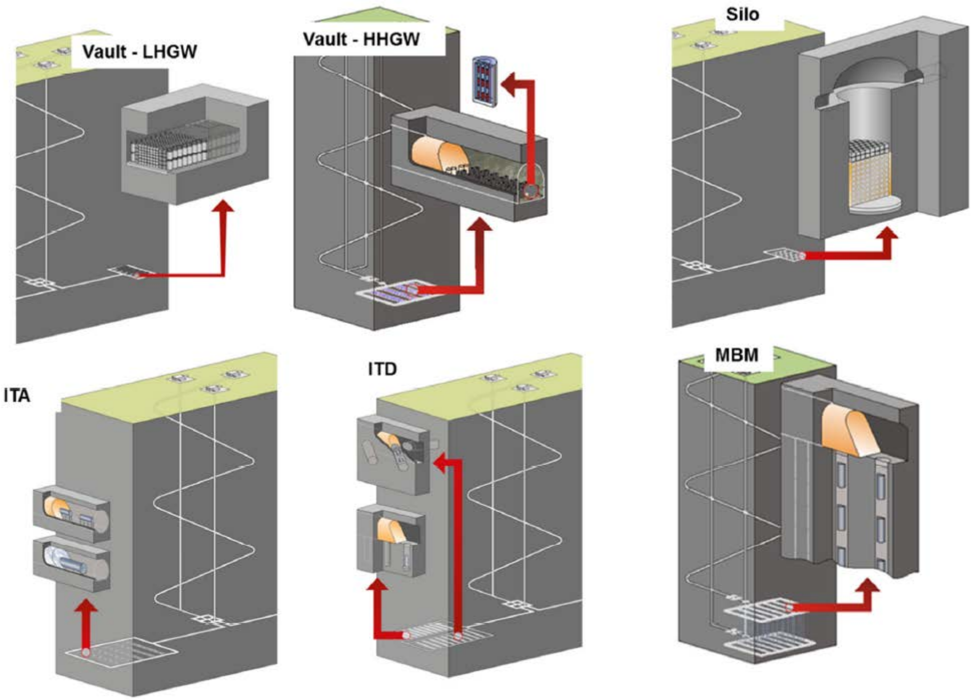
No	General Description	Host rock	Overlying rocks
G1	Stronger rocks with very low flow of likely saline waters	Crystalline rock	Low permeability sedimentary rock formations
			High permeability sedimentary rock formations
G2	Stronger rocks with higher water flow; probably relatively fresh water	Crystalline rock	Low permeability sedimentary rock formations
			High permeability sedimentary rock formations
			Crystalline rock to surface
		Carbonate	Sedimentary rock formations (permeability unspecified)
G3	Weaker rocks with no effective flow and relatively saline waters in pores (transport is dominated by diffusion with no advective flow)	Indurated low permeability sedimentary rock formation	Low permeability sedimentary rock formations
			High permeability sedimentary rock formations
		Plastic low permeability sedimentary rock formation	Sedimentary rock formations (permeability unspecified)
G4	Weaker rocks with very low water flow and relatively saline waters in pores (there is some advective flow)	Indurated low permeability sedimentary rock formation	Low permeability sedimentary rock formations
			High permeability sedimentary rock formations
G5	Evaporite formations: plastic, with no water flow and little accessible water (brine) content	Evaporites - salt dome & bedded salt	Sedimentary rock formations (permeability unspecified)

Disposal Concepts in Baldwin's Schema

Key feature	Variants	Concept No.
In-tunnel (borehole)	Vertical borehole	1
	Horizontal borehole	2
In-tunnel (axial)	Short-lived canister and buffer	3
	Long-lived canister and buffer	4
In-tunnel (axial) with supercontainer	Small working annulus	5
	Small annulus + concrete buffer	6
	Large working annulus	7
Caverns with cooling, delayed backfilling	Steel multi-purpose transport/storage/disposal containers (MPC) + bentonite backfill	8
	Steel or concrete/DUCRETE container + cement backfill	9
Mined deep borehole matrix		10
Hydraulic cage	Around a cavern repository	11
Very deep boreholes		12

Disposal Concepts for a DRep in Crystalline Rock: KBS-3 + Other Crystalline Concepts

- **Pinawa (AECL, Canada)**
  - Ti or Cu packaging
  - Vertical-borehole emplacement
  - Buffer and backfill
  - Clay and/or cement-based
- **Mizunami (PNC, Japan)**
  - KBS-3H and KBS-3V reference
  - Concrete vaults
- **UK (RWM Ltd.) concepts >>>**
  - Vaults, in-drift and borehole
  - Pumpable buffer/backfill



Source: Watson, S. et al. 2014. *Disposal Concepts for Multi-Purpose Containers*. QRS-1567G-R7 Version 1. Radioactive Waste Management, Ltd., UK.

Disposal Concepts for a DRep in Crystalline Rock: NDA/EPRI Options Studies (1/5)

Table B-2
Key features and variants leading to the UNF and HLW disposal Concepts.

Key Feature	Variants	Concept No.
In-tunnel (borehole)	Vertical borehole	1
	Horizontal borehole	2
In-tunnel (axial)	Short-lived canister	3
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In-tunnel (axial) with supercontainer	Small working annulus	5
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	Steel or concrete/DUCRETE container + cement backfill	9
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Hydraulic cage	Around a cavern repository	11
Very deep boreholes		12

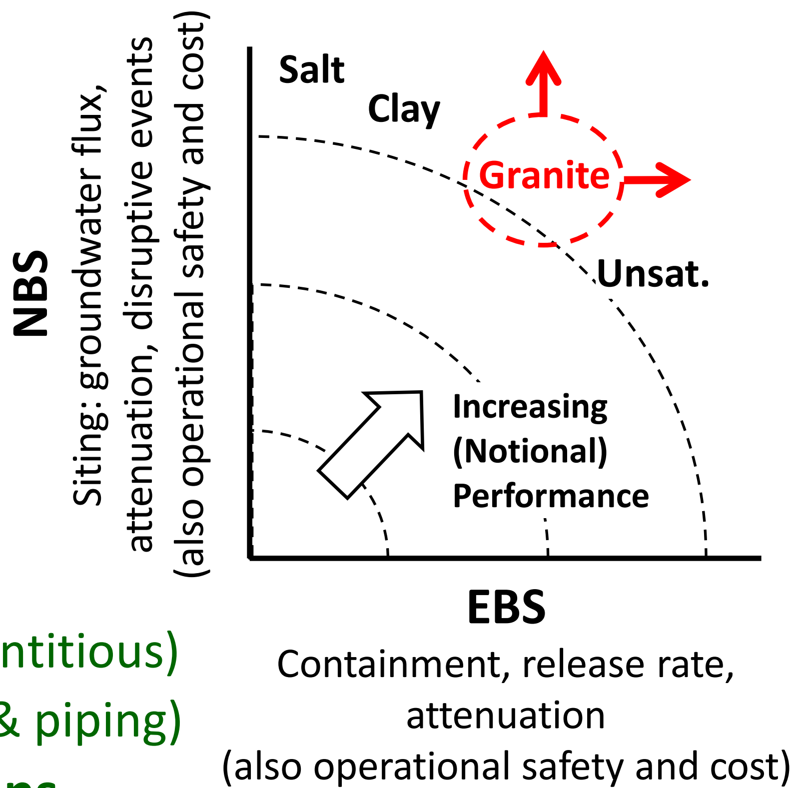
Sources for this and slides 9 - 13:

EPRI Review of Geologic Disposal for Used Fuel and High Level Radioactive Waste Volume III—Review of National Repository Programs. 1021614. December, 2010.

(After Baldwin, T., et al. 2008. *Geological Disposal Options for High-Level Waste and Spent Fuel*. Prepared for the UK Nuclear Decommissioning Authority, January, 2008.)

Disposal Concepts for a DRep in Crystalline Rock:
So How Can We Improve on These EBS Concepts For Crystalline Rock?

- **Use D-Waste Characteristics**
  - Small, cool canisters & modest shielding
- **Simplicity & Technical Maturity**
  - Favorable (generic) site characteristics
  - Consider published approaches
- **Discriminate Final State from Engineering/Construction Methods**
- **Identify R&D Opportunities:**
  - Packaging materials (metals, coatings)
  - Buffer materials (clay, clay-sand & cementitious)
  - Pre-fabrication (buffer density, erosion & piping)
- **Cautiously Approach Cost Considerations**
  - Claim constructability and low cost; include engineering R&D cost
  - Correct attribution of GDSA performance



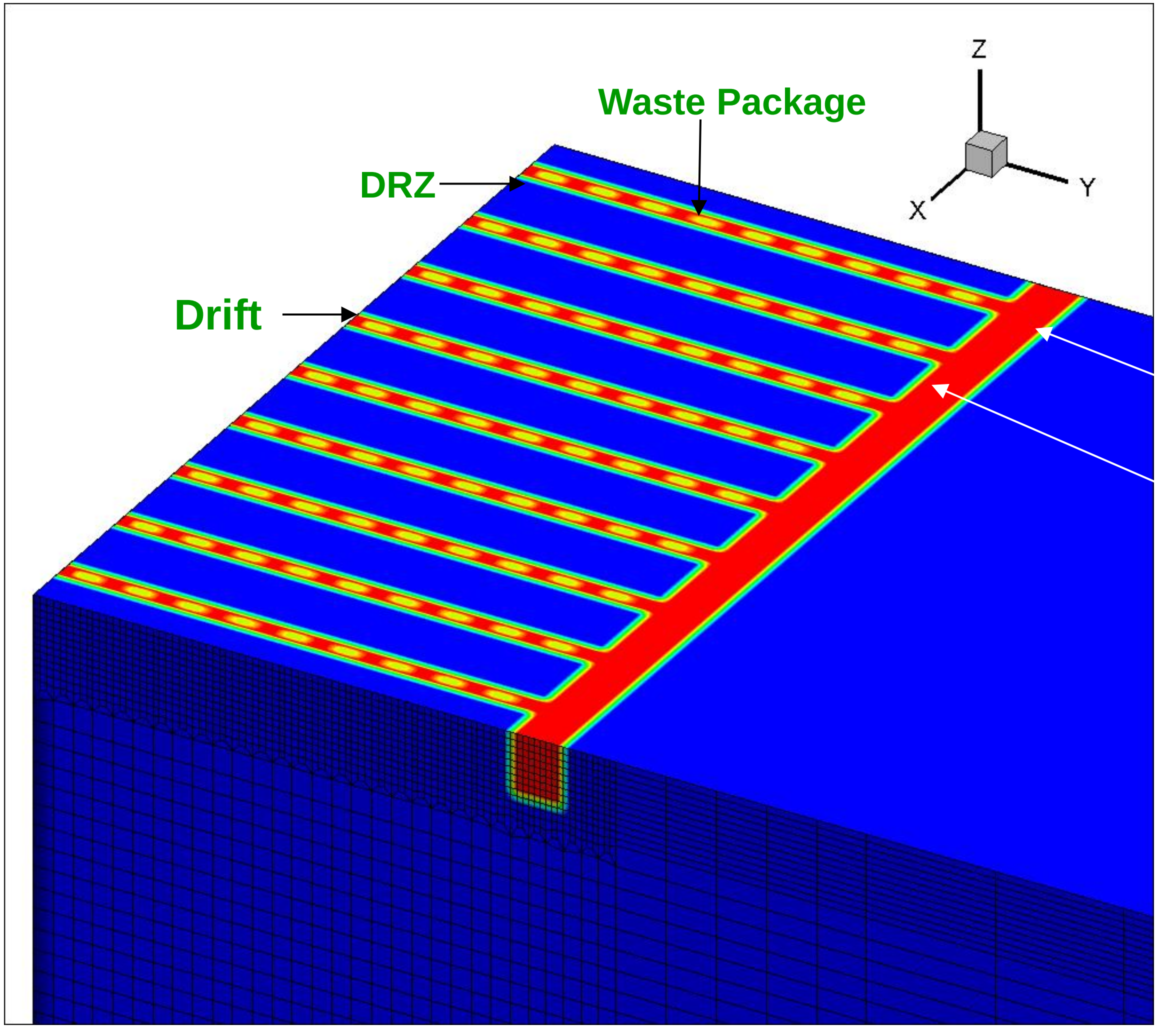
Disposal Concepts for a DRep in Crystalline Rock:
Crystalline DRep Recommendations

- **Panel Layout by Waste Form***

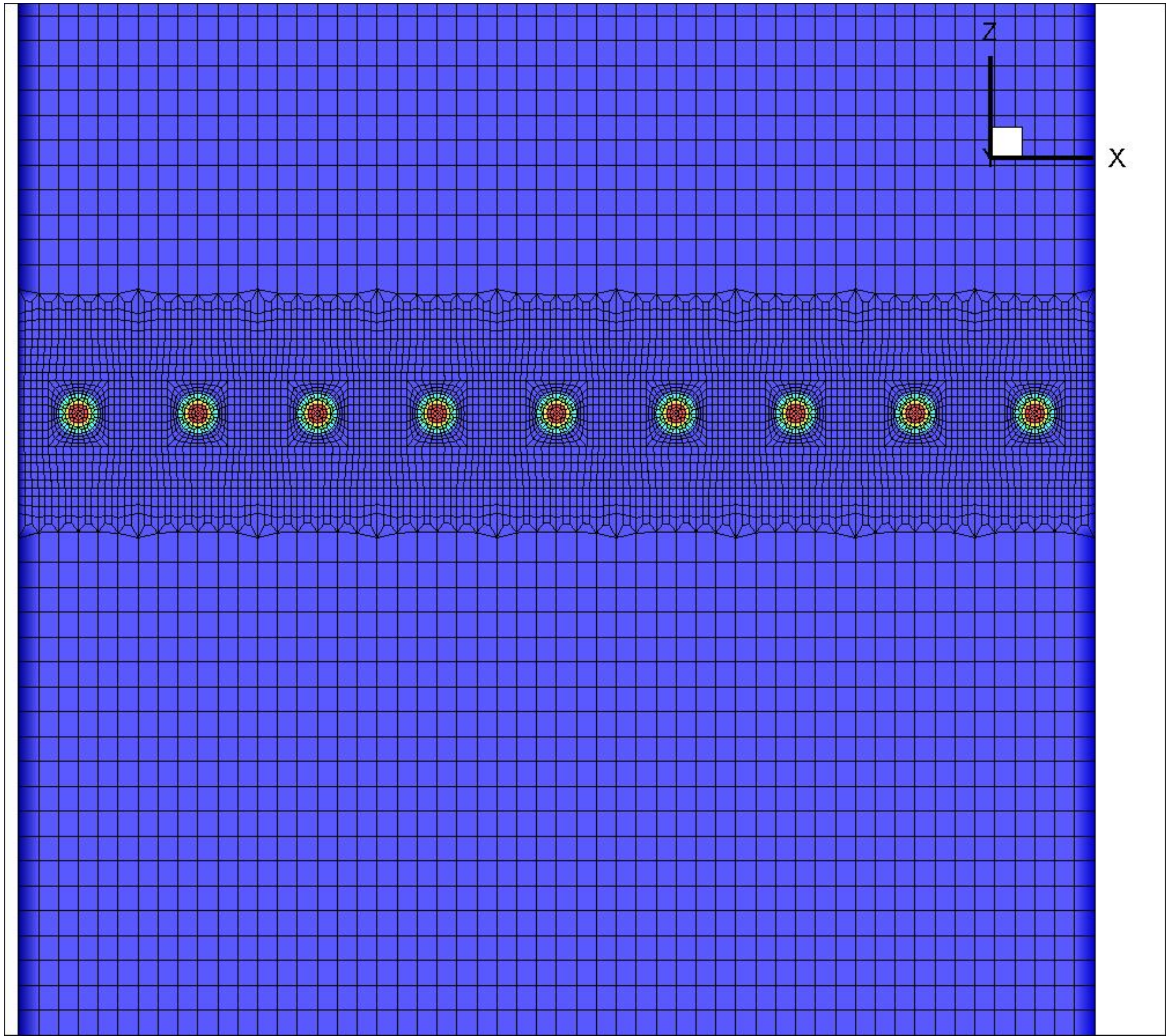
*** Used in current GDSA models**

- **Corrosion-Resistant Packaging***
  - Use existing HLW and DSNF canisters
  - Corrosion-resistant overpack performance
- **Low-Permeability Buffer and Backfill Materials***
  - Clay-based materials
- **In-Drift Emplacement (larger packages)***
  - Minimize tunnel volume, characterize inflow conditions
- **Borehole Emplacement (smaller DSNF packages)***
  - Short vertical or horizontal boreholes
- **Favorable Site Characteristics***

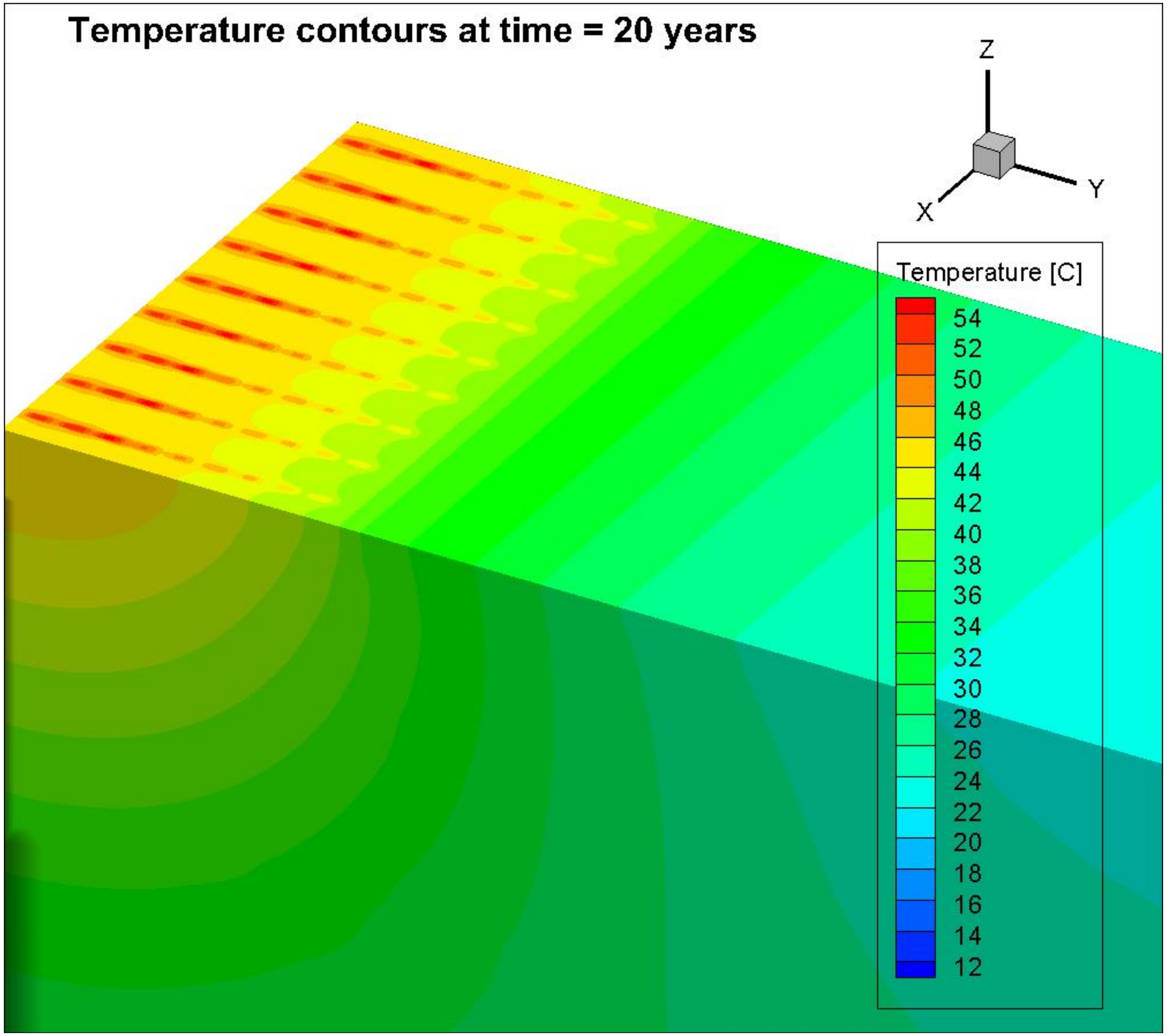
Thermal-Hydrologic Model Mesh, Contd.
Crystalline Host Rock



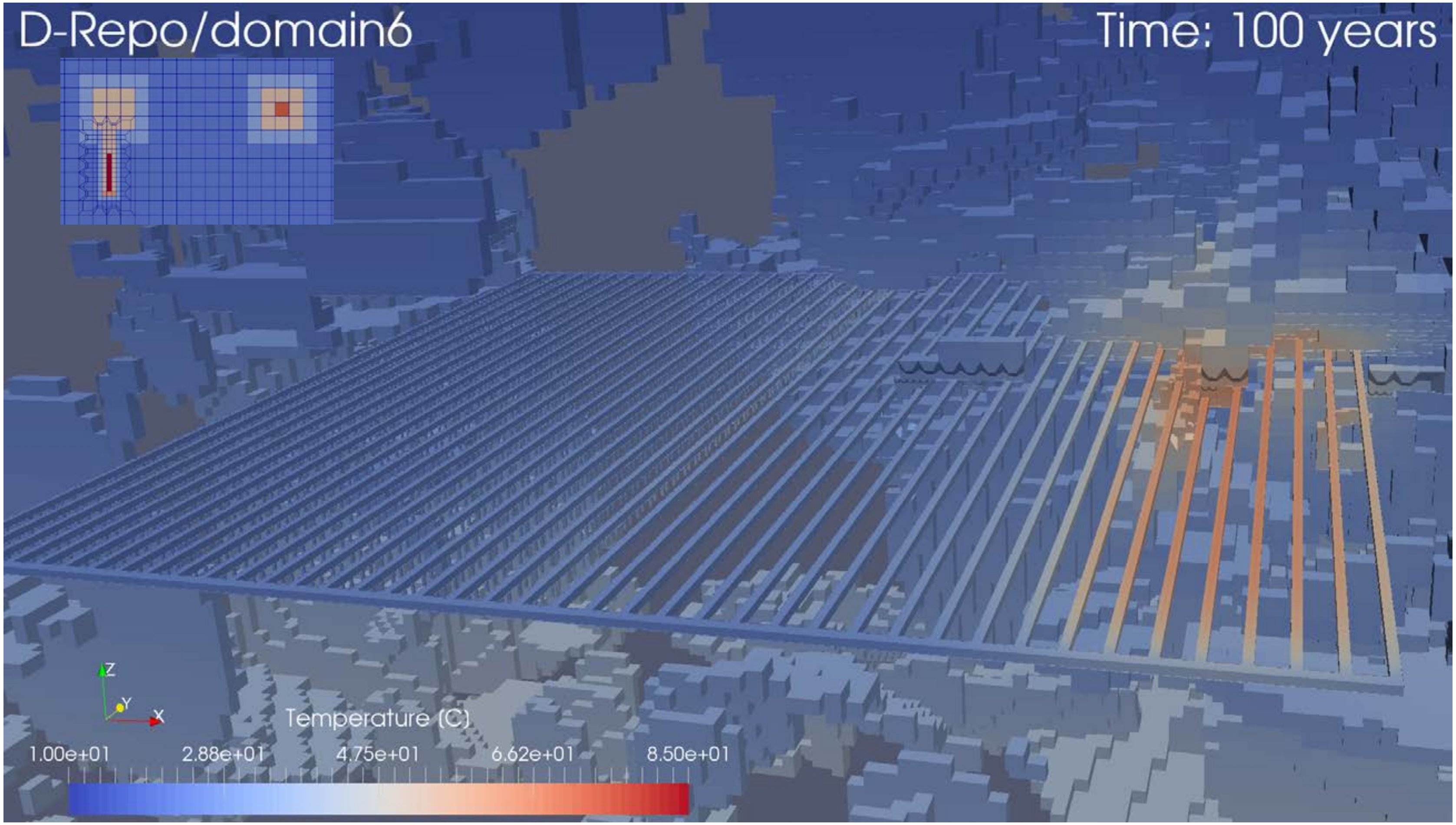
Thermal-Hydrologic Model Mesh, Contd. – Crystalline Host Rock



Thermal-Hydrologic Model: Preliminary Results – Crystalline Host Rock



Deterministic Results: Temperature



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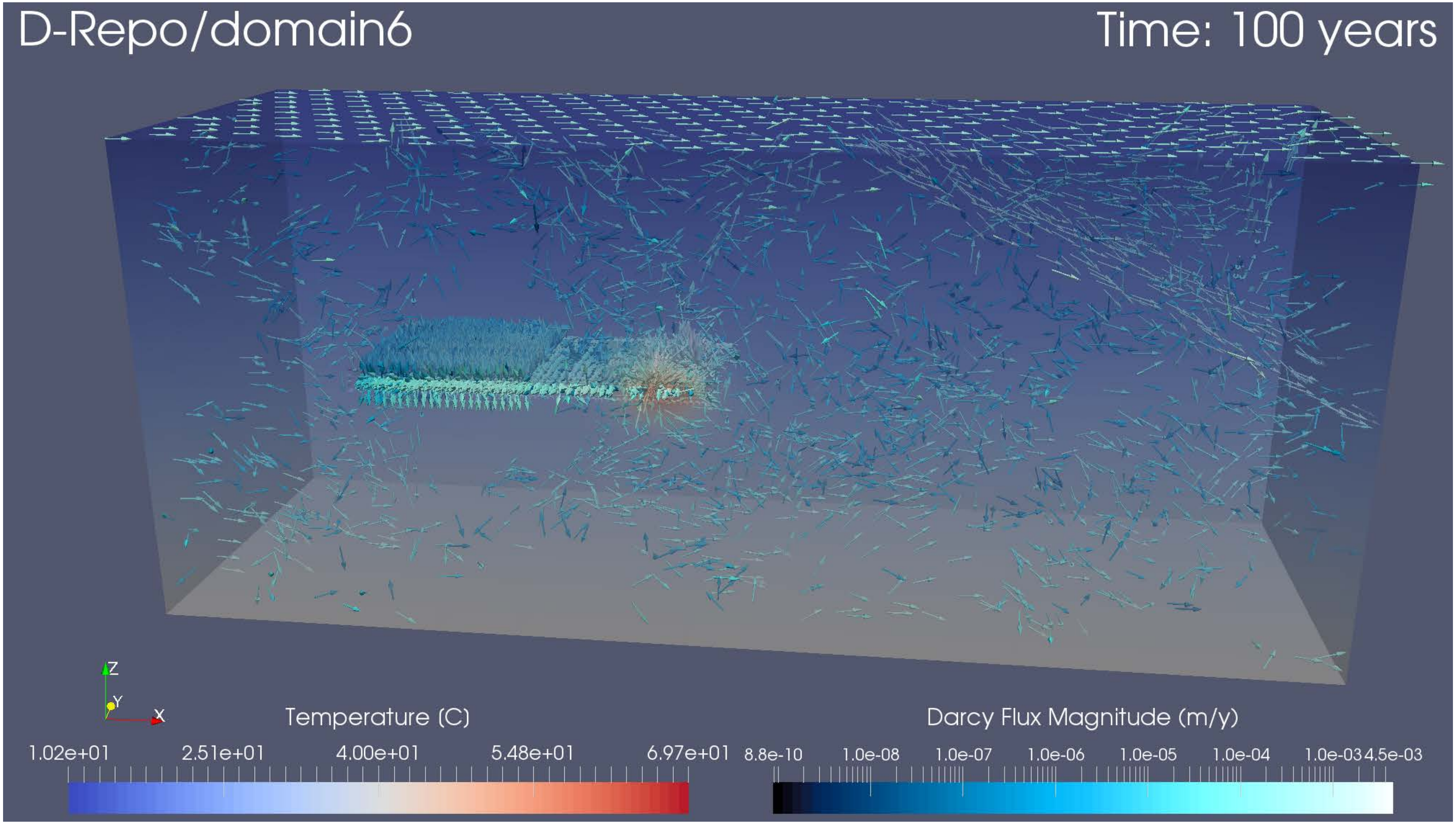
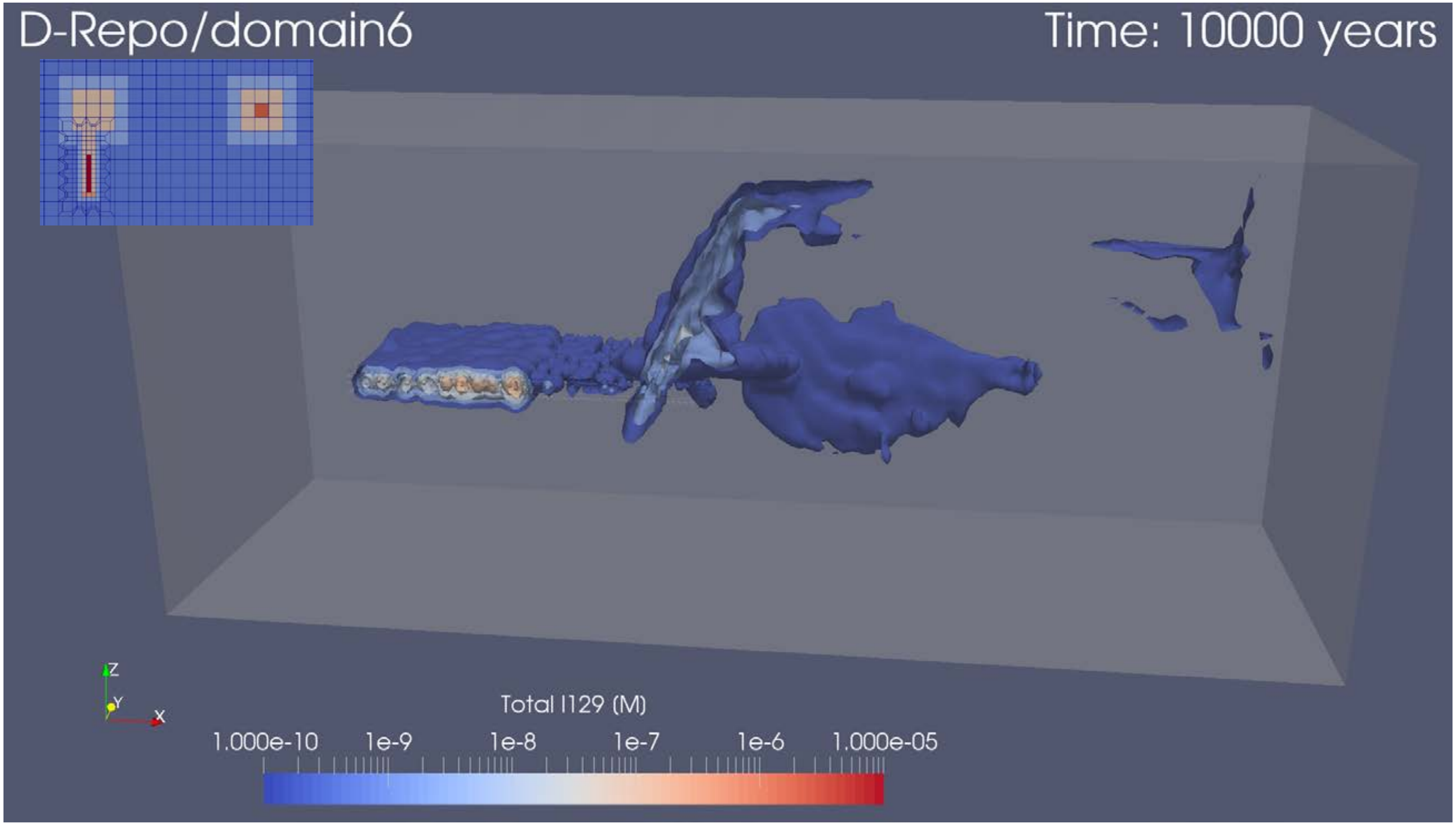
Deterministic Results: Darcy Flux

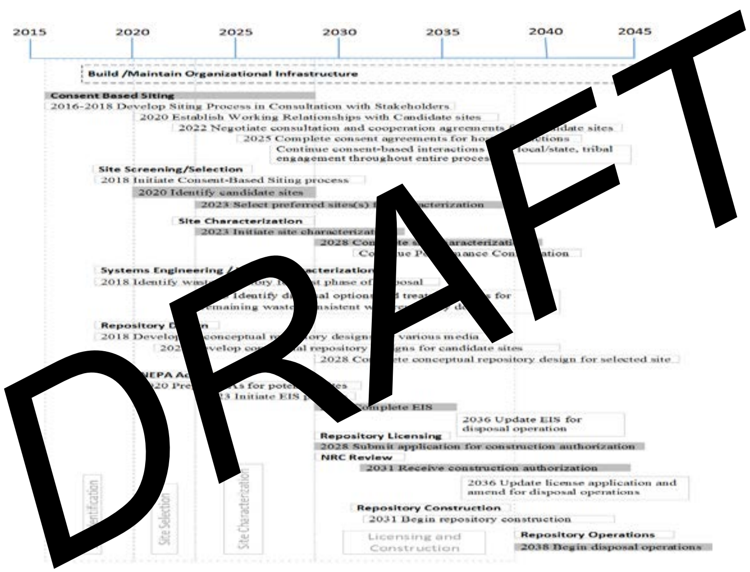


Deterministic Results: ^{129}I Concentration



DOE Managed HLW and SNF Research: *Program Planning Work Product (cont.)*

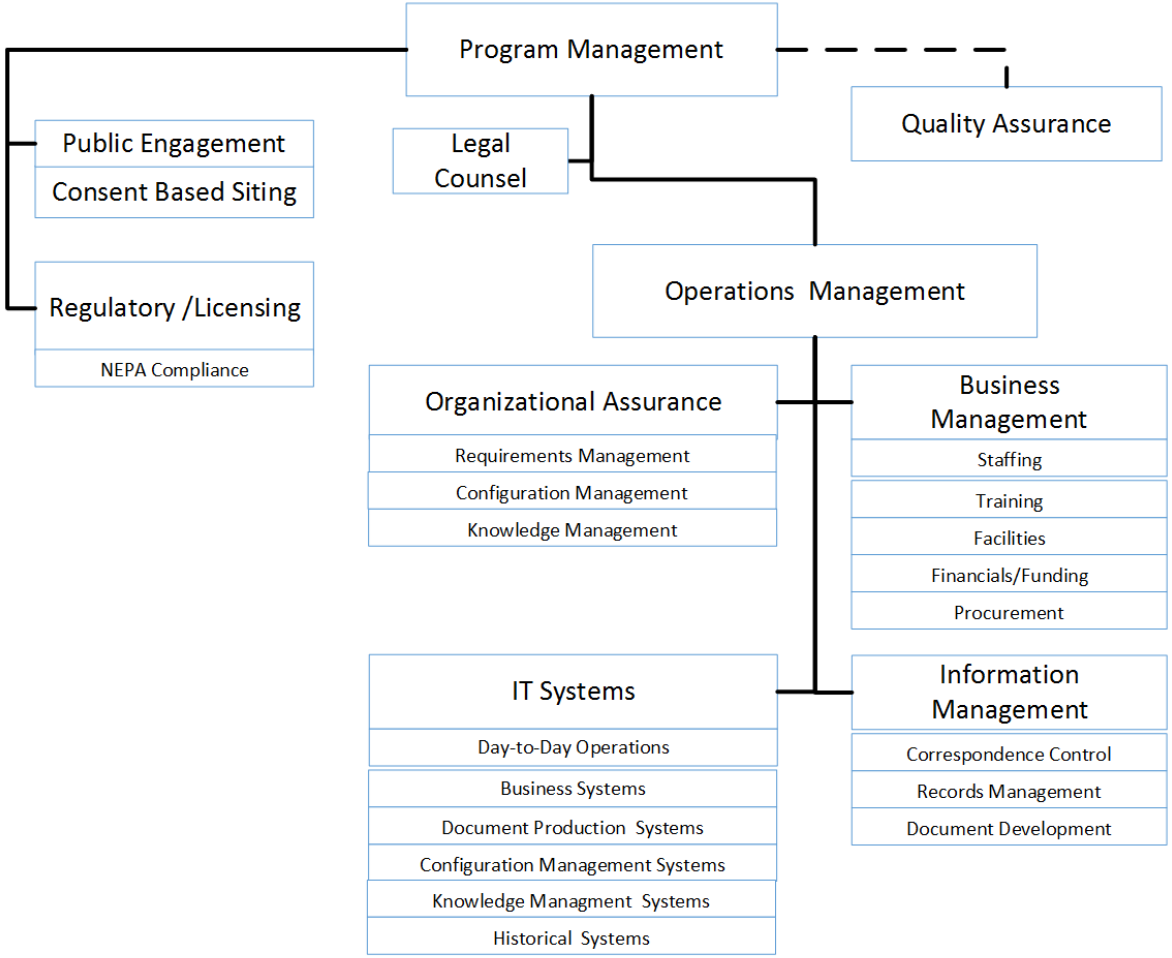
Timeline



Used Fuel Disposition

Organization for Startup Phase

Phase : Startup



Used
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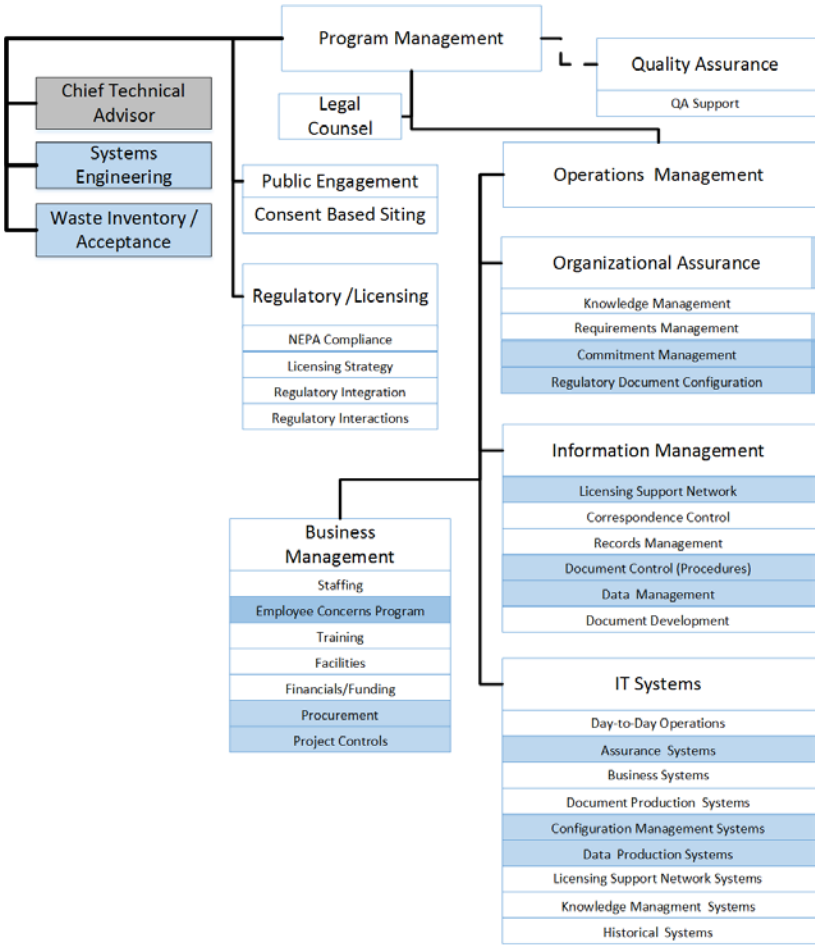
Organization for Initiation Phase

Phase : Initiation



Note: Blue shaded boxes are added in this phase.

Back-Up Slides