Used Fuel Disposition Campaign

Deep Borehole Disposal (DBD) Safety Case Framework

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UFD Working Group Meeting

Las Vegas, NV

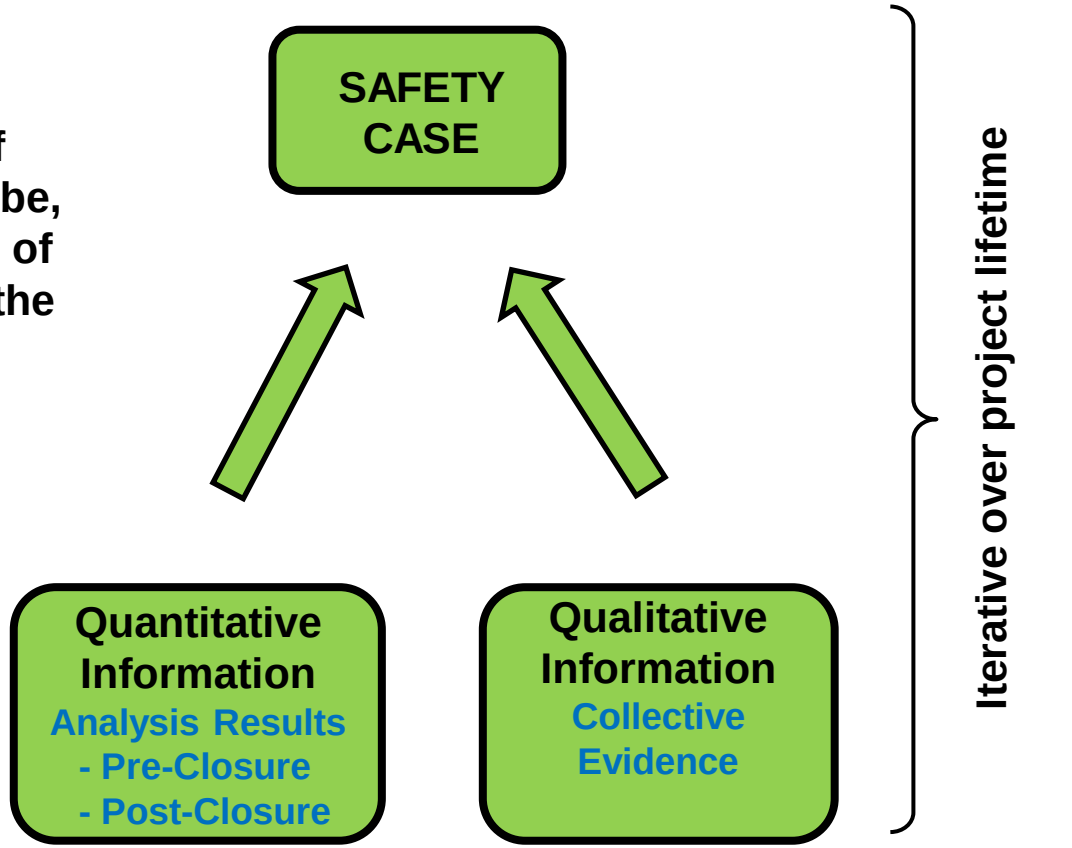
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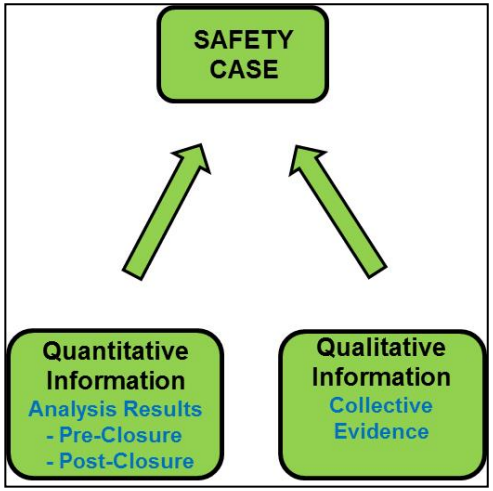
Safety Case Overview

"The safety case is an integration of arguments and evidence that describe, quantify and substantiate the safety of the geological disposal facility and the associated level of confidence"

NEA (2012, Section 3.1)



DBD Safety Case Framework



Deep Borehole Field Test

- **Arnold et al. (2013, App. A)**
- **Freeze et al. (2013)**
- **Freeze et al. (2016) –-► [Sep 2016]**

Purpose and Context

Safety Strategy

Management Strategy
- Organizational/management structure
- Oversight groups / stakeholders
- Safety culture and QA
- Planning and work control
- Knowledge management

Siting and Design Strategy
- National laws (e.g., NWPA)
- Site selection methodology
- Socio-political acceptance
- Disposal concepts
- Design and engineering requirements

Assessment Strategy
- Regulations
- Safety goals/criteria
- Safety functions/multiple barriers
- Assessment methodologies

Assessment Basis

Pre-Closure Basis
- Repository design and layout
- Excavation / construction methods
- Operation procedures
- Waste acceptance criteria
- Potential impact of pre-closure activities on post-closure safety

Site Selection Basis
- Consent-based siting methodology
- Repository concept selection
- FEP analysis
- Technology development
- Transportation considerations
- Integration with storage facilities

Post-Closure Basis: Waste and Engineered Barriers
- Inventory characterization
- Waste form characterization
- Waste package characterization
- Buffer and backfill characterization
- Drift/room characterization
- Seals and liners characterization
- Potential impact of external events
- Assessment of uncertainties

Post-Closure Basis: Geosphere / Natural Barriers
- DRZ characterization
- Host rock characterization
- Other geologic unit characterization
- Potential impact of external events
- Assessment of uncertainties
- Discussion of synergy between natural and engineered barriers

Post-Closure Basis: Biosphere and Surface Environment
- Surface envir. characterization
- Flora and fauna characterization
- Human behavior characterization

Safety Assessment

Pre-Closure Safety Analysis
- Transportation safety analysis
- Construction safety analysis
- Operational safety analysis

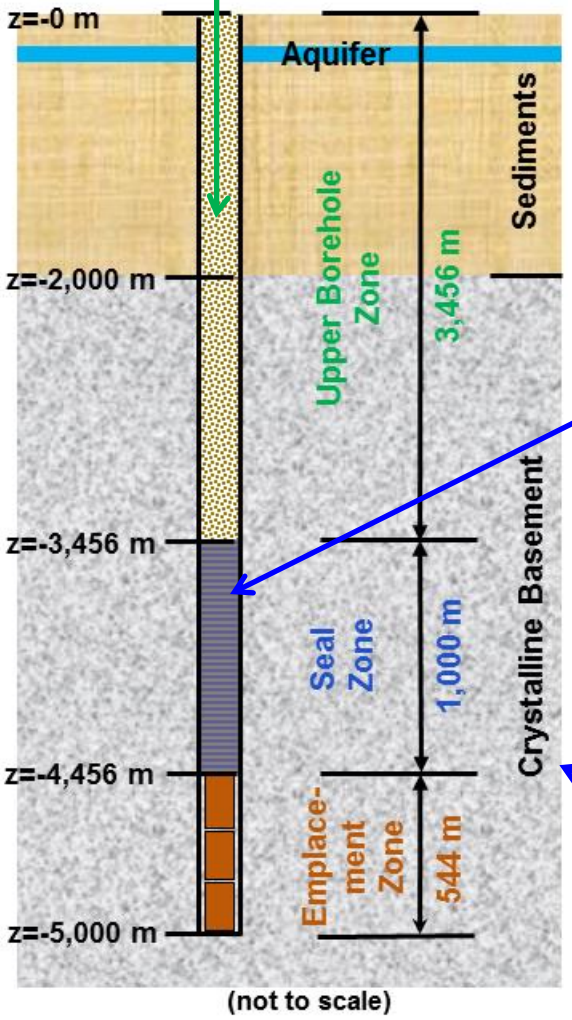
Post-Closure Performance Assessment
- FEP analysis
- Scenario development
- Model development
- Software/model validation
- PA model analyses
- Uncertainty and sensitivity analyses

Confidence Enhancement
- Independent evidence
- Natural analogues
- Technical arguments
- Long-term extrapolation
- Detailed process modeling

Synthesis and Conclusions
- Key findings and statement(s) of confidence
- Discussion/disposition of remaining uncertainties
- Path forward

DBD of Cs/Sr Capsules – Design (for this iteration of the Safety Case)

- **All 1936 Cs/Sr capsules fit in a single borehole with a 544-m Emplacement Zone**
  - 108 WPs (4.76 m each)
    - 34 Sr WPs in upper EZ
    - 74 Cs WPs in lower EZ
  - 3 cement plugs (10 m each)
  - Bottom-hole diameter = 31.1 cm (12.25 in)
- **WPs are lowered, one at a time, on wireline inside a removable guidance casing**



Pre-Closure

Waste package emplacement system can be engineered to maintain structural integrity and operational safety during surface handling and downhole emplacement

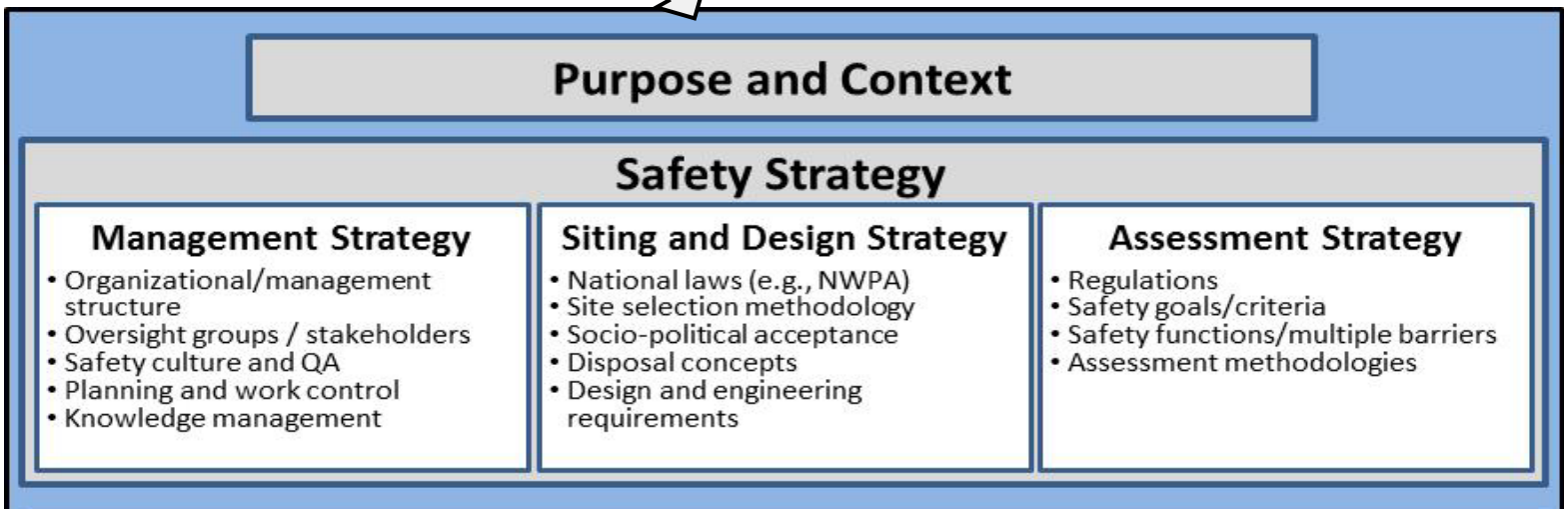
Post-Closure

Borehole seals (and disturbed rock zone (DRZ)) can be engineered/evolve to maintain a low-permeability barrier over the period of thermally-induced upward flow

Deep crystalline rocks typically have low permeability and lack hydraulic connection to shallow groundwater

DBD Safety Case – Purpose and Safety Strategy

Purpose and Context (for this iteration)
- Evaluation of concept feasibility

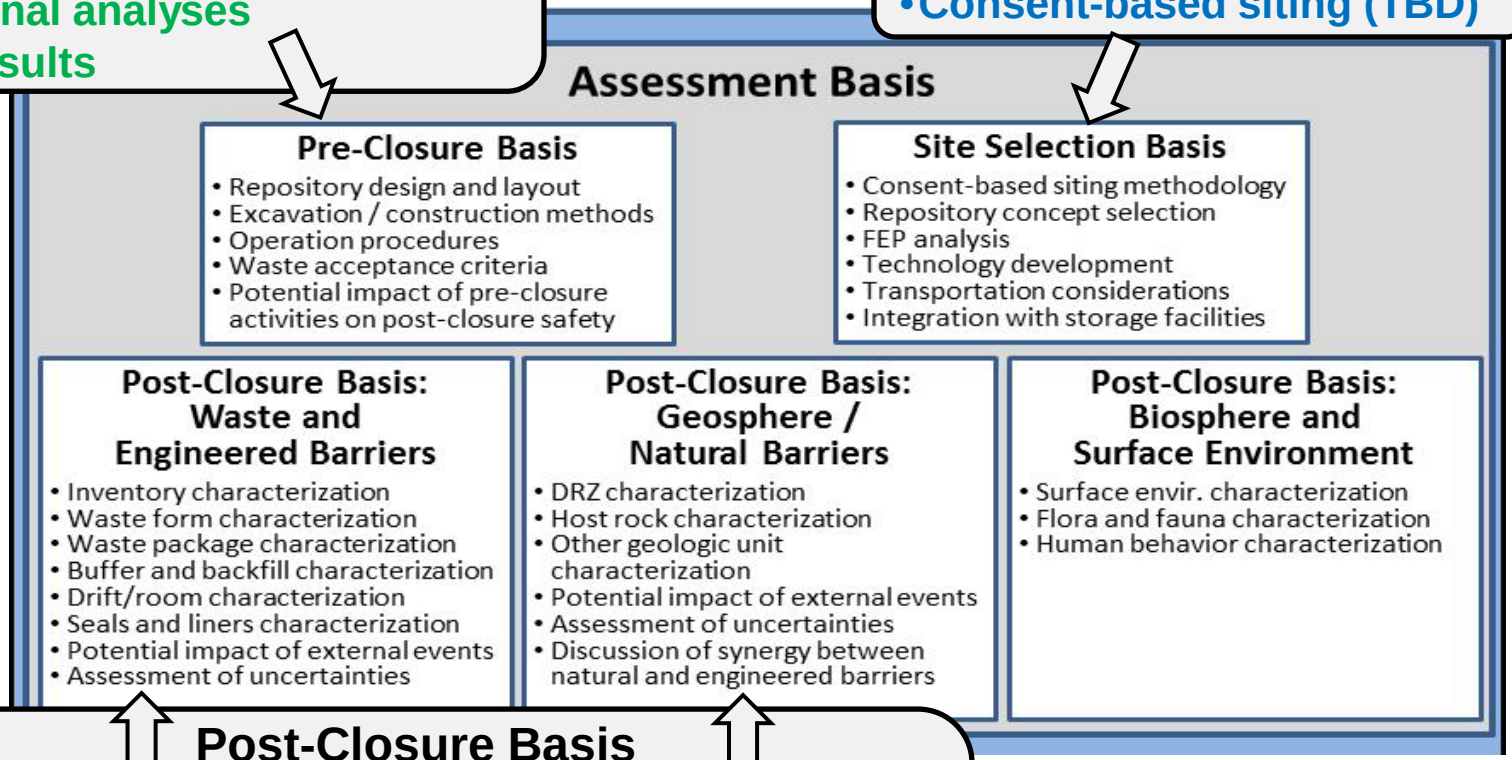


Safety Strategy
- National Laws and Policy (TBD)
- Regulations and Licensing (TBD)

DBD Safety Case – Assessment Basis

Pre-Closure Basis
- Engineering design and operational analyses
- DBFT results

Site Selection Basis
- Consent-based siting (TBD)



Post-Closure Basis
- Waste form and waste package design
- Emplacement Zone design and properties
- Seal design
- Generic THMC properties of host rock and DRZ
- DBFT results

DBD Safety Case – Safety Assessment

Safety Assessment

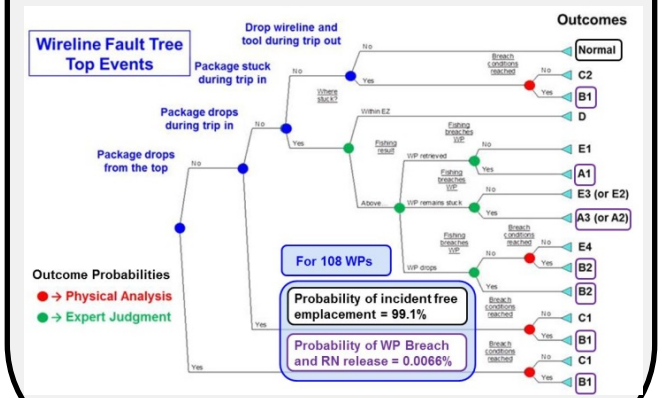
Pre-Closure Safety Analysis
- Transportation safety analysis
- Construction safety analysis
- Operational safety analysis

Post-Closure Performance Assessment
- FEP analysis
- Scenario development
- Model development
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Confidence Enhancement
- Independent evidence
- Natural analogues
- Technical arguments
- Long-term extrapolation
- Detailed process modeling

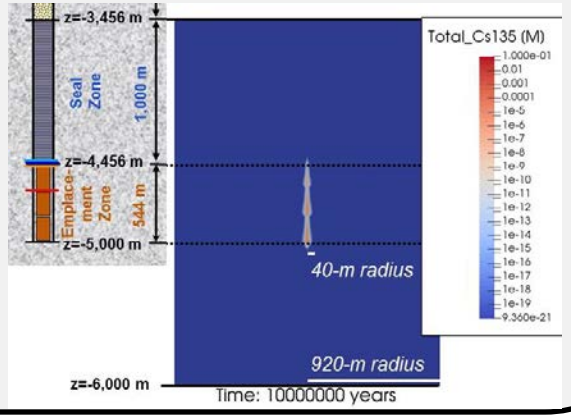
Pre-Closure Safety Analysis

- **Wireline emplacement hazards analysis**



Post-Closure Performance Assessment

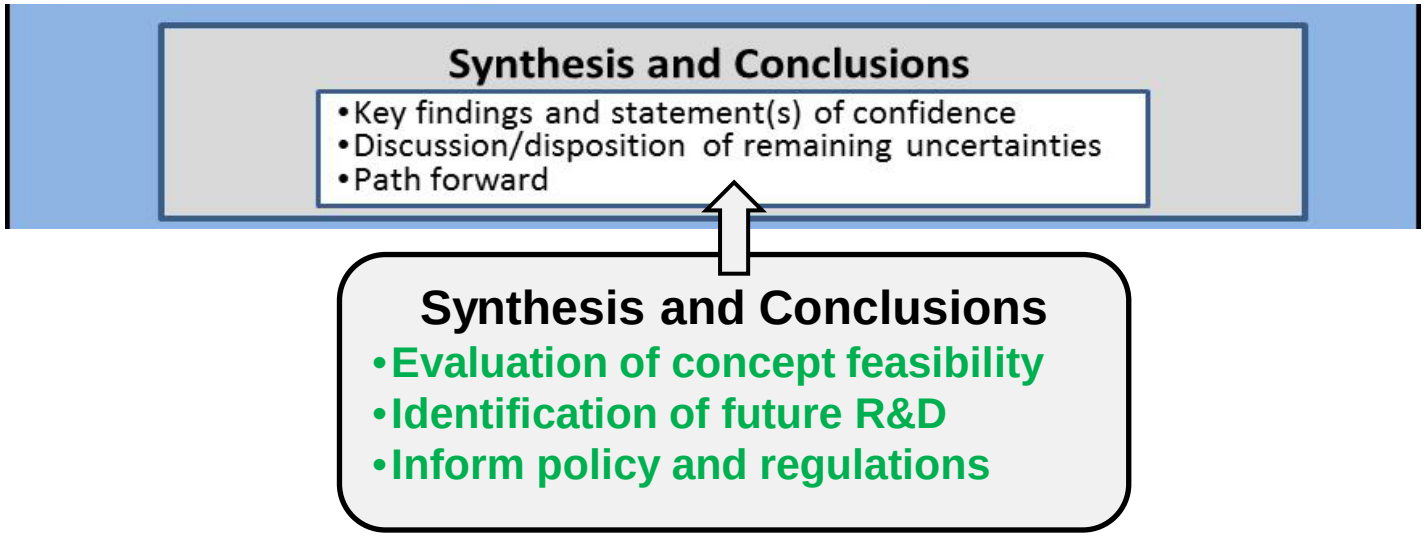
- **FEP identification and screening**
- **Scenarios (undisturbed)**
- **PA modeling**



Confidence Enhancement

- **Independent evidence**

DBD Safety Case – Synthesis and Conclusions



DBD Safety Case – Current Status

- **Pre-Closure Safety Case for Deep Borehole Disposal of Cs/Sr:**
  - Drilling and casing a large diameter borehole to 5,000 m depth in crystalline basement rock is achievable with existing drilling technology.
  - Surface handling and emplacement systems can be engineered to provide a high level of assurance that waste packages can be safely emplaced at the desired depth with minimal probability of packages becoming stuck and/or breached.
  - Additional hazard analyses needed for: transportation, worker exposure, surface handling, and external events (e.g., seismic, flooding, sabotage)
- **Post-Closure Safety Case for Deep Borehole Disposal of Cs/Sr:**
  - Waste emplacement is deep; in low-permeability crystalline basement rock with limited interaction with shallower groundwater.
  - Borehole seals can be engineered to maintain their physical integrity, at least over the approximately 100-year time period of thermally-induced upward groundwater flow.
  - Preliminary results from post-closure PA calculations suggest minimal radionuclide releases beyond the disposal zone and zero dose at biosphere.

DBD Safety Case – Current Status

- **The Deep Borehole Field Test (DBFT) objectives and scope specifically address key technologies and data necessary to evaluate the feasibility of the DBD concept, particularly unproven or especially critical components, e.g.,**
  - deep drilling
  - collecting diagnostic geochemical signatures from deep low-permeability crystalline rocks at possibly elevated temperatures
  - package handling and emplacement
- **This is a lesser scope than would be needed to site and fully characterize an actual DBD facility**
  - some activities required for DBD have a high technology readiness level (TRL) and therefore do not require explicit demonstration in the DBFT; these high-TRL activities are not included or in some cases minimally included in the DBFT scope

References

- Arnold, B.W, P. Brady, S. Altman, P. Vaughn, D. Nielson, J. Lee, F,. Gibb, P. Mariner, K. Travis, W. Halsey, J. Beswick, and J. Tillman 2013. *Deep Borehole Disposal Research: Demonstration Site Selection Guidelines, Borehole Seals Design, and RD&D Needs.* SAND2013-9490P, FCRD-USED-2013-000409. U.S. Department of Energy, Office of Used Nuclear Fuel Disposition, Washington, DC.
- DOE (U.S. Department of Energy) 2014. *Assessment of Disposal Options for DOE-Managed High-Level Radioactive Waste and Spent Nuclear Fuel* . October 2014, U.S. Department of Energy, Washington, DC.
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- NEA (Nuclear Energy Agency) 2012. *Methods for Safety Assessment of Geological Disposal Facilities for Radioactive Waste: Outcomes of the NEA MeSA Initiative*. NEA No. 6923. Organisation for Economic Co-operation and Development, Nuclear Energy Agency, Paris, France.