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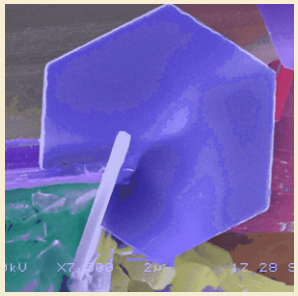



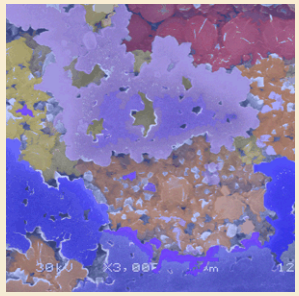

# Summary of US/German Workshop on Salt Repository Research, Design and Operation[1]

*ABC Salt Workshop; April 15- 17, 2013; Santa Fe, NM*

Christi D. Leigh, PhD

Repository Performance Department, 6212

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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# Where Are We Going

| | |
|---|---|
| We have an adequate understanding of and modeling capability for the coupled thermal-mechanical processes in bedded salt to support a safety case for disposal of non-heat generating waste | US/German Salt Workshop |
| We have an adequate understanding of and modeling capability for the coupled thermal-hydrologic processes in bedded salt to support a safety case for disposal of non-heat generating waste | Joint SNL-LANL (and DOE-NE/EM March 6-7 Workshop |
| We have an adequate understanding of and modeling capability for the coupled thermal-chemical processes in bedded salt to support a safety case for disposal of non-heat generating waste | High Temperature Aqueous Chemistry Laboratory |

# US/German Salt Workshop

- Third US/German Salt Workshop
  - Hosted by SNL in Albuquerque, NM
  - October 8—10, 2012
  - Co-located with 7th project meeting of Joint Project on:

    *Comparison of Current Constitutive Models and Simulation Procedures on the Basis of Model Calculations of the Thermo-Mechanical Behavior and Healing of Rock Salt*
  - Summary with Technical Presentations:

    Hansen et al., (2013). *Proceedings of 3rd US/German Workshop on Salt Repository Research, Design and Operation*. SAND2013-1231P.

# US/German Salt Workshop

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1. Safety Case for Heat-Generating Waste Salt Disposal
2. Benchmark modeling
3. Granular Salt Reconsolidation
4. US/German Collaboration Efforts
   - FEPs Catalog for Generic Salt Repository
   - Salt Knowledge Archive/Database
   - Potential uses for Underground Salt Research Laboratory

# 1. Safety Case

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- Goreleben (Domal Salt) Safety Case
  - High-Level Waste/Spent Nuclear Fuel (HLW/SNF)
  - German Ministry of Environment funding development
  - Multi-organization development
- Generic US Salt Repository Safety Case
  - Leverage US Repository Experience
    - Waste Isolation Pilot Plant (WIPP)
    - Yucca Mountain Project (YMP)
  - Leverage Historic Salt Thermal/Mechanical Testing
  - Leverage Deep Understanding of Salt Behavior

# 2. Benchmark Modeling

- Benchmarking Thermal/Mechanical Models
  - Joint Project initially between 6 German organizations
  - SNL became 7th partner (SIERRA Mechanics)
  - In-situ and laboratory studies for model comparison
    - Heated deep borehole convergence (Asse)
    - Healing of 100+ year-old drift with liner (Asse)
    - Room closure for heated/unheated (WIPP)
  - Systematic Testing Matrix proposed bedded salt
    - Bedded WIPP salt + German constitutive models
    - Proposed Salt Failure, Creep, and Healing Tests

# 3. Granular Salt Reconsolidation

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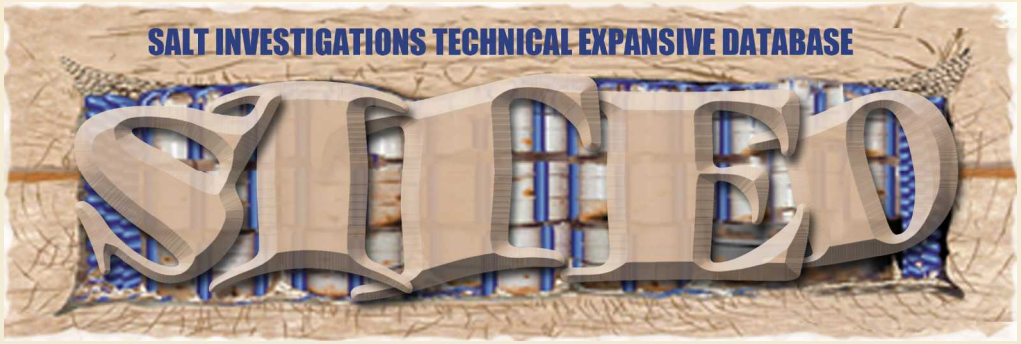
- State-of-the-Art Research
  - Physical Models of Reconsolidation Processes
  - Permeability of Granular Salt During Reconsolidation
  - Laboratory testing at Elevated Temperatures
- Applications in Regulatory Framework
  - WIPP Panel Closure Redesign
- Questionnaire Distributed to Attendees
  - Importance of Physical Processes (Hydraulic/Thermal/Mechanical)
  - Confidence in Model Predictions

# 4. Collaboration

- Nuclear Energy Agency (NEA) “Salt Club”
- FEPs Catalog for Generic Salt Repositories
- Salt Knowledge Archive/Database




- NEA Natural Analogue Workshop (Sept 4—6, 2012)
- Potential Underground Salt Research Laboratory
  - Mining Currently Underway at WIPP
  - Heated Borehole Tests
  - Large-Scale

# Joint SNL-LANL (and DOE-NE/EM March 6-7 Workshop on "Advancing the Science and Engineering Supporting Deep Geologic Disposal of Nuclear Waste in Salt"

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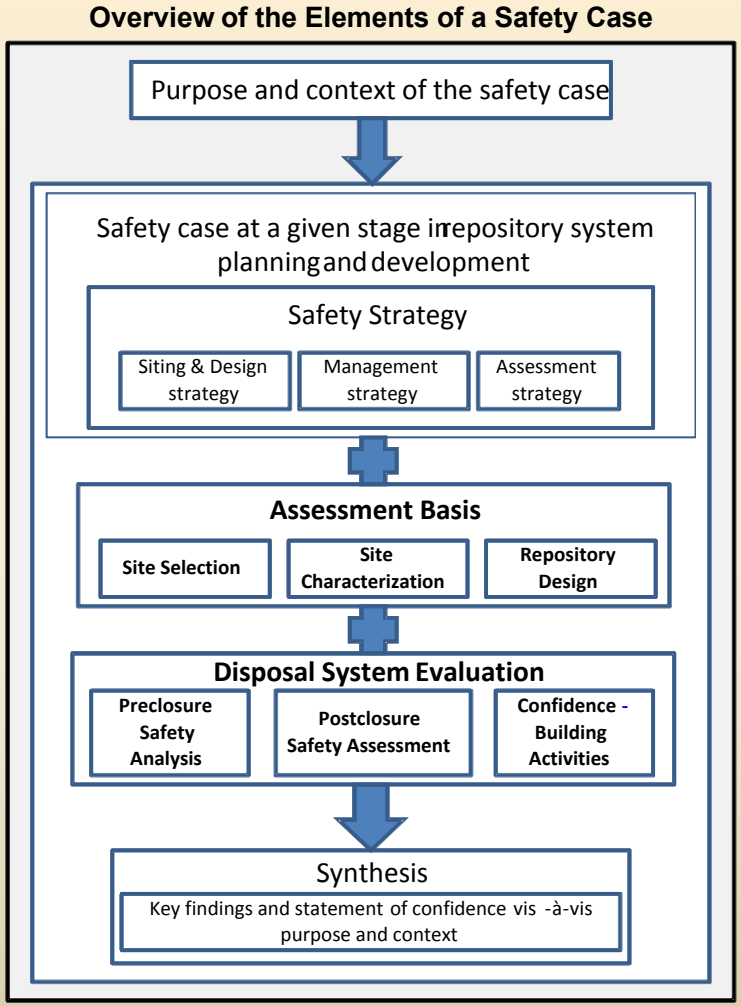
- Workshop Goals:
  1) Identify a comprehensive set of salt RD&D needs (remaining "issues") and a set of approaches (e.g., testing and modeling activities) for addressing them
  2) Elicit input to a decision-making framework that will be used subsequent to the workshop to formulate a salt RD&D plan
  3) Develop the input necessary to design a thermal field test/demonstration in Delaware Basin (or similar) bedded salt, beginning with the existing SDDI test proposal
- Agenda:
  - Day 1 Morning: Workshop objectives, background, and structure; Summary/status of U.S. salt repository technical basis
  - Day 1 Afternoon: Preclosure and postclosure breakout groups to evaluate the importance ratings of RD&D issues and to propose new test activities for a *generic* bedded salt repository
  - Day 2 Morning: History of *in situ* testing and proposals for underground tests in a generic salt URL, as well as for use of new underground space at WIPP
  - Day 2 Afternoon: Evaluation of the strawman SDDI *in situ* testing proposal

# Safety Case Structure for Prioritizing Research, Development, and Demonstration (RD&D) for a Generic HLW/SNF Bedded Salt Repository

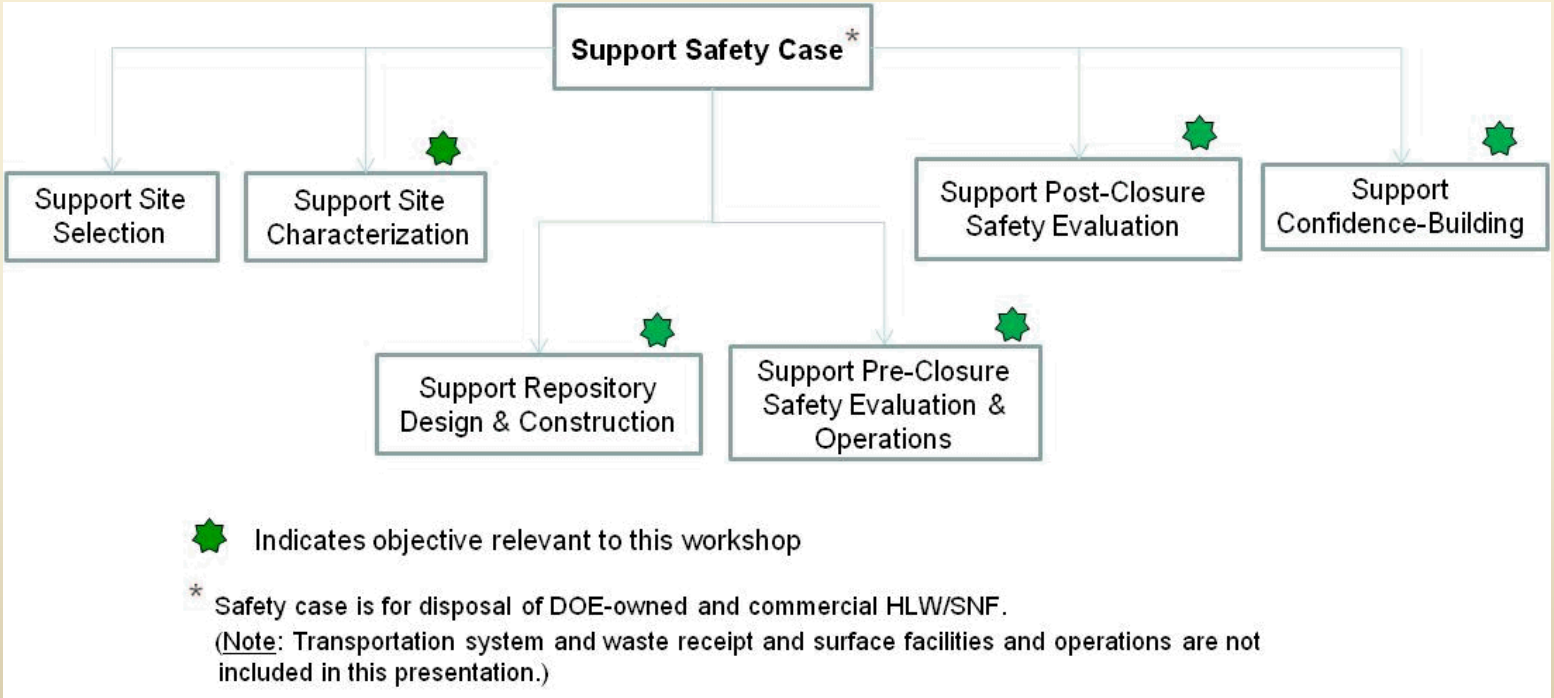
- A *safety case* is an integrated collection of evidence, analyses, and qualitative and quantitative arguments used to substantiate and demonstrate the safety of a *system*
- Although the post-closure safety assessment is a key element of the safety case, *there are several other elements that are also important*
- A safety case must present multiple lines of evidence and reasoning to support all elements of repository development and safety
- Development of the safety case should start early in the process of repository development




(modified from NEA 2004)

# Use of Safety Case Objectives

- A Safety Case provides a structured framework to assist in planning, organizing, and prioritizing the technical work
- What determines "importance" for an RD&D issue? This refers to importance to achieving a successful safety case, which has the following primary objectives:

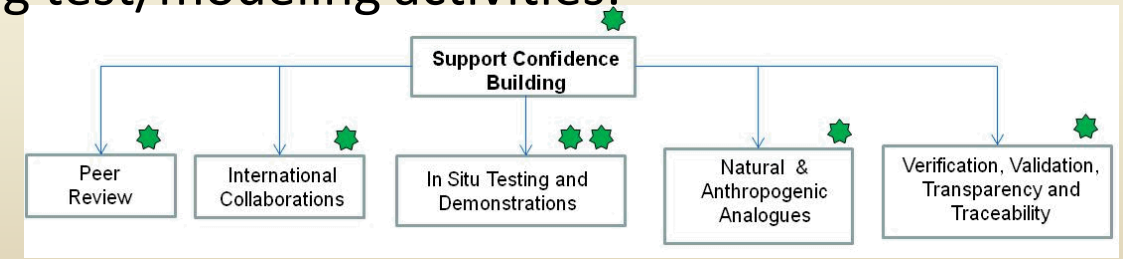


# Basis for Issue Importance Ratings

- Strawman salt RD&D issue list is primarily based on *postclosure safety* objective ("…arguably the most important part of the safety case..." NWTRB 2011):
  - Impact of RD&D Issue on performance of a safety/design function (nominal scenario):

| Function | Type | Importance | Definition | Examples of Key Associated Parameter(s) or Characteristic(s) |
|---|---|---|---|---|
| *Isolation/stability* | Safety | Primary (P) | Aspects of the repository that isolate the waste and the EBS from external events or changes, and therefore help maintain the integrity and longevity of the barriers. | (high) seal integrity; (thick) host rock zone horizon; non-communication between salt beds and interbeds |
| *Containment* | Safety | Primary (P) | Aspects of the repository that prevent fluid contact with the waste. | (very low) permeability |
| *Limited or delayed releases* | Safety | Secondary (S) | Aspects of the repository that reduce the transfer of radionuclides to the accessible environment after the containment function is compromised. | (high) sorption, (low) solubility, (low) dissolution rates |
| *Retrievability* | Design | Primary (P) | Aspects of the repository that allow for retrievability of the emplaced waste without any releases, for a specified period of time after closure. | (sufficient) WP thickness |

- *Confidence-building* is the other key objective to be considered in designing test/modeling activities:




  - Can be used to refine/revise the strawman RD&D list, e.g., to move a current "M" issue to an "H" level, based on current *"state-of-the-art" knowledge:*
  - Confidence-building activities are critical to a subset of key stakeholders

# RD&D Issues

- Four major categories of issues:
  - 30 Feature/process issues (EBS, Geosphere, Repository System FEPs-type issues)
  - 8 Modeling issues
  - 4 *In situ* testing/design/operations issues
  - 6 Confidence-building issues
- Typical feature/process issues:

| RD&D Technical Issue | Issue Importance Rating (H = High, M = Medium, L = Low) Based on (impact, function type) | Explanation of Issue Importance Rating | Safety Objective: D = Design & Construction PrSO = Preclosure Safety & Operations, PoS = Postclosure Safety | Breakout Group: 1 = Postclosure 2 = Preclosure & Design 3 = Field Testing | Current UFD Salt R&D Activity |
|---|---|---|---|---|---|
| **Wastes and Engineered Features (EBS) Feature/Process Issues** | | | | | |
| 1. Inventory and WP Loading | M (= I,P) | Indirectly related to limited and delayed releases through elemental composition of inventory (L = I,S), but also indirectly related to containment (permeability) through heat loading density and associated affects (M = I,P) | D, PrSO, PoS | 2 | |
| 2. Physical-chemical properties of crushed salt backfill at emplacement | M (= I,P) | Indirectly related to the final state of the backfill permeability (containment function of the backfill) | D, PrSO, PoS | 1, 2 | |
| 3. Changes in physical-chemical properties of crushed salt backfill after waste emplacement | H (= D,P) | Directly related to maintaining the containment function of the backfill by directly changing its permeability | D, PrSO, PoS | 1, 2 | 3.1<br>3.2<br>4.4 |
| 4. Changes in chemical characteristics of brine in the backfill and EBS | M (= I,P) | Indirectly related to backfill permeability through WP corrosion and subsequent gas generation (M)<br>Indirectly related to limited and delayed releases (L) | D, PoS | 1 | 3.6<br>4.4 |
| 5. Mechanical response of backfill | H (= D,P) | Directly related to host rock permeability in the EDZ and to backfill permeability (i.e., to containment) | D, PrSO, PoS | 2 | 3.1<br>3.2<br>4.4 |

# Breakout Group Tasks

Day 1 Tasks:

Breakout Group 1: PostClosure Repository System (EBS postclosure processes within the excavation and NBS postclosure processes in the host salt formation)

Breakout Group 2: Preclosure Repository System (design, demonstration, and preclosure issues)

Breakout Groups will:

- Review RD&D strawman issue list and ranking; provide comments/revisions as necessary
- For high-priority items not currently being addressed define specific tests/modeling needed to advance the state of the art science & engineering
- Answer test questionnaire for each activity---(reassigned to be post-workshop)

Day 2 Tasks:

- Develop input necessary to design a thermal field test/demonstration, starting with strawman
- Develop input on potential additional research activities in the underground, starting with strawman
- Specific questions and topics that are to be addressed include:
  - What are the objectives of the proposed activity?
  - Which objective(s) of the safety case does the proposed activity support and why?
  - Define the data that will be collected/measured (e.g., process(es)/parameter(s), time duration, frequency, accuracy) to accomplish the objective(s).
  - Specify how the collected data will be used to support activity objectives.
  - Define the instrumentation that will be used to measure process(es)/parameter(s) and define the instrumentation placement or layout.
  - Define the pre-and post-test modeling/simulation needs for the activity.
  - Define the laboratory tests needed to support activity.

# High Temperature Aqueous Chemistry Laboratory at SNL Carlsbad Facility

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The SNL Carlsbad Facility is equipped with the hydrothermal experimental systems permitting to acquire high quality kinetic and equilibrium data at temperatures and pressures of interest up to 600°C and 1,000 bars (100 MPa). The capabilities include:

- Experiments investigating solid-liquid-gas phase equilibria to 343°C and 345 bars (below critical point of water);
- Experiments investigating solid-liquid phase equilibria to 600°C and 1,000 bars (above the critical point of water);
- High temperature corrosion experiments investigating the stability and corrosion rates of various waste forms for high level nuclear waste;
- High temperature corrosion experiments investigating the stability and corrosion rates of canisters and waste packages for high level nuclear waste;

# High Temperature Aqueous Chemistry Laboratory at SNL Carlsbad Facility (continued)

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- Directly measuring pH values in brines at high temperatures and pressures;
- Experiments at high temperatures and pressures investigating material stability in a deep borehole environment;
- High temperature corrosion experiments investigating the stability and corrosion rates of nuclear reactor cooling systems;
- High temperature hydrothermal synthesis and characterization;
- Experiments investigating transport and formation of ore deposits with strategic importance such as rare earth elements (REE), beryllium, cobalt gallium, indium, and telluride deposits, etc.


WARNING
HOT