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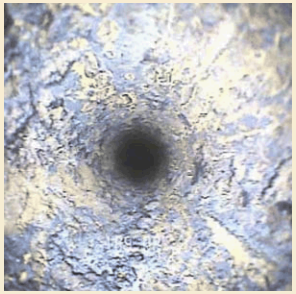

Demonstrating Long-term Safety for a HLW Repository in Salt

US/German Salt Workshop; November 9-10, 2011; Piene, Germany

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Topics to Be Addressed

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- Why did the NAS (1957) recommend salt?
- How to Develop A Safety Case
- Some Safety Case Models
- How to Involve the Regulator
- How to Involve the Public
- What about HLW and Salt?

Why did the NAS (1957) recommend salt?

Multiple Barriers Contribute to Waste Isolation

- Upper Natural Barrier System
  - Topography and surficial soils
  - Unsaturated zone above the repository
- Engineered Barrier System
  - Drift environment
  - Drip Shield
  - Waste Package
  - Waste forms and associated shipping containers
  - Emplacement pallet
  - Drift invert
- Lower Natural Barrier System
  - Unsaturated zone below the repository
  - Saturated zone between the repository and the accessible environment

Bedded Salt Deposits are Deep, Thick and Expansive

Extensive Engineered Barriers are Not Needed for Salt

Transport through Salt to an aquifer (above or below) in an undisturbed case will not occur

Safety Case Development

A Safety Case addresses four questions:

- What events and processes can take place at the facility?
- How likely are these events or processes?
- What are the consequences of these events or processes?
- How reliable are the answers to the first 3 questions?

Each repository program addresses the safety case in a manner prescribed by national context

What events and processes can take place at the facility?

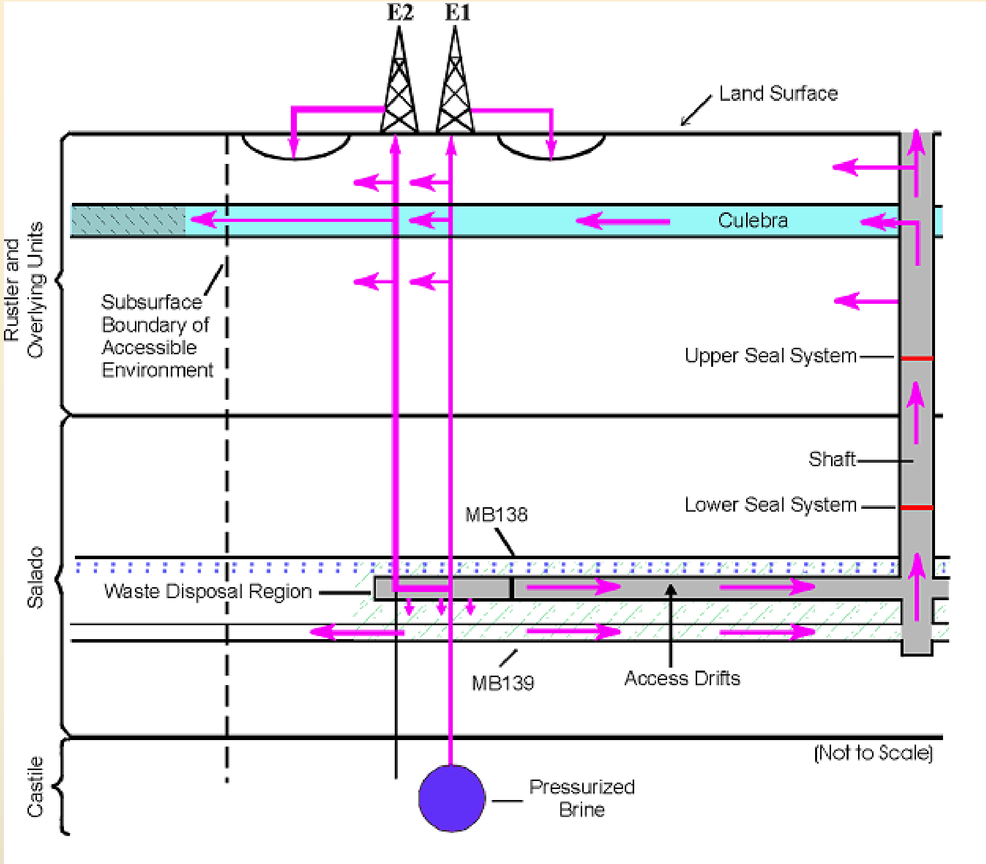
Identification begins with a large list of FEPs:

- Use is made of existing FEPs lists
- USA programs have used the international list for salt and volcanic tuff
- Our collaborations could develop a FEPs list for HLW in salt and serve as a foundation for analyses

Some possible FEPs for a HLW repository in salt: Response of the DRZ to combined thermal and mechanical forces, Consolidation of backfill materials, Availability and movement of brine, Vapor phase transport mechanisms, Radionuclide solubility controls, Potential radionuclide transport mechanisms, Waste form and/or waste package degradation, Gas generated and pressure buildup, Buoyancy of waste package, Radiolysis of waste materials, waste packages, and salt.

How likely are these events or processes?

FEPs are evaluated and scenarios are formed given the waste type, proposed repository location and geologic medium, and the concept of design



A scenario for an anticlinal salt formation or a salt dome would be different than a bedded salt—these depend on geology. Human intrusion and the possibility of mineral extraction (drilling?) also depend on geology. All of the Yucca Mountain scenarios are built around the geology: e.g., seismic or volcanism.

What are the consequences of these events or processes?

Consequences are estimated based on:

- Conceptual Models – conceptually, how will the system behave?
- Mathematical Models – how can the conceptual model be implemented mathematically?
- Computer Models – how can the mathematical model be solved using computing resources?

The international community is greatly advanced in its ability to estimate consequences related to a salt repository for HLW.

How reliable are the answers to the first 3 questions?

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Epistemic uncertainty incorporated through Latin hypercube sampling of cumulative distribution functions and Monte Carlo simulation with multiple realizations

Aleatory uncertainty incorporated through the design of the analysis

- Incomplete data
  - for example, limited hydrologic data from test wells
- Spatial variability and scaling issues
  - data may be available from small volumes (for example, porosity measurements from core samples), but may be used in the models to represent large volumes
- Measurement error
  - usually only a very minor source of uncertainty
- Lack of knowledge about the future state of the system
  - probabilities of disruptive events
- Alternative conceptual models

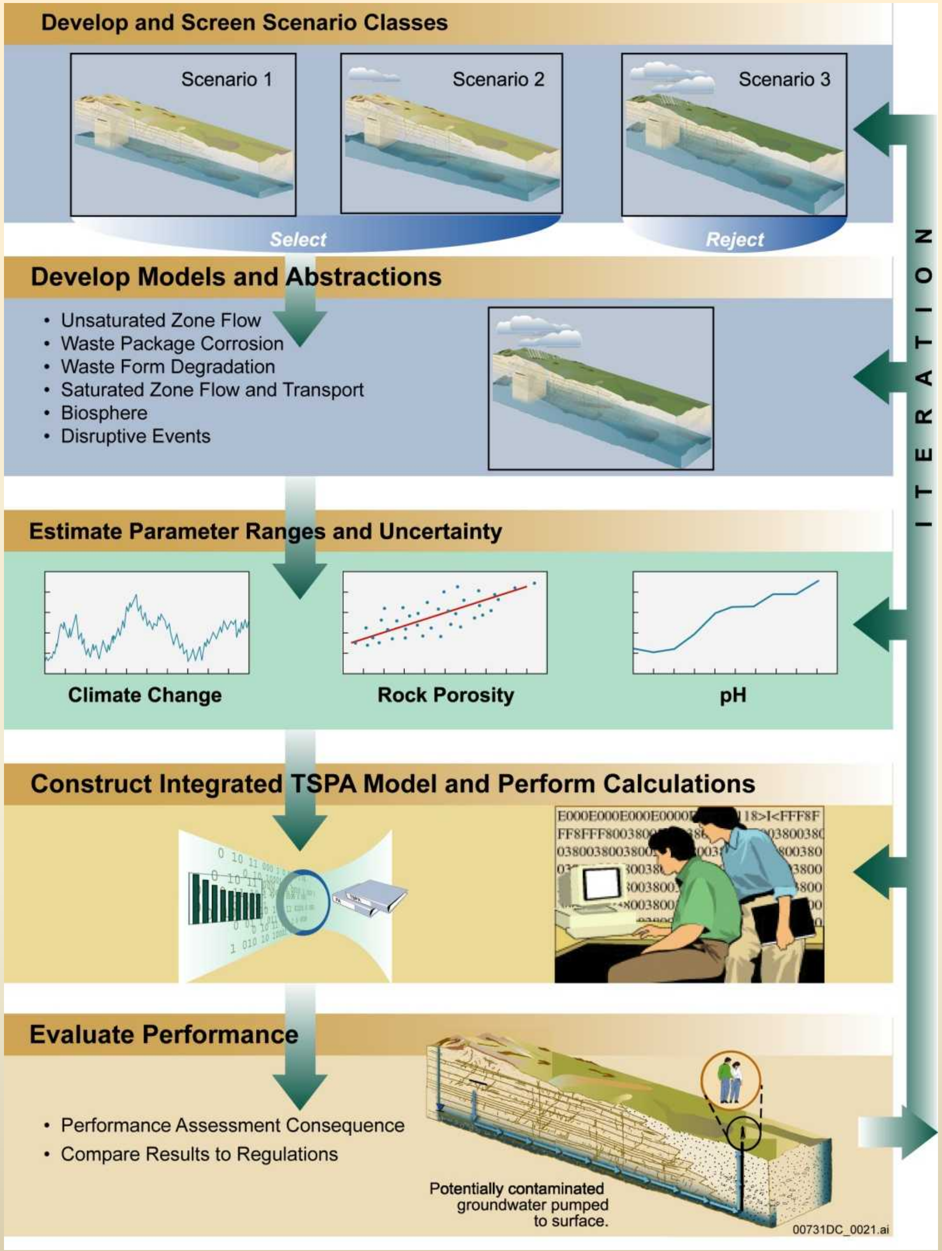
All analyses must be conducted within a Quality Assurance Framework

Some Safety Case Examples

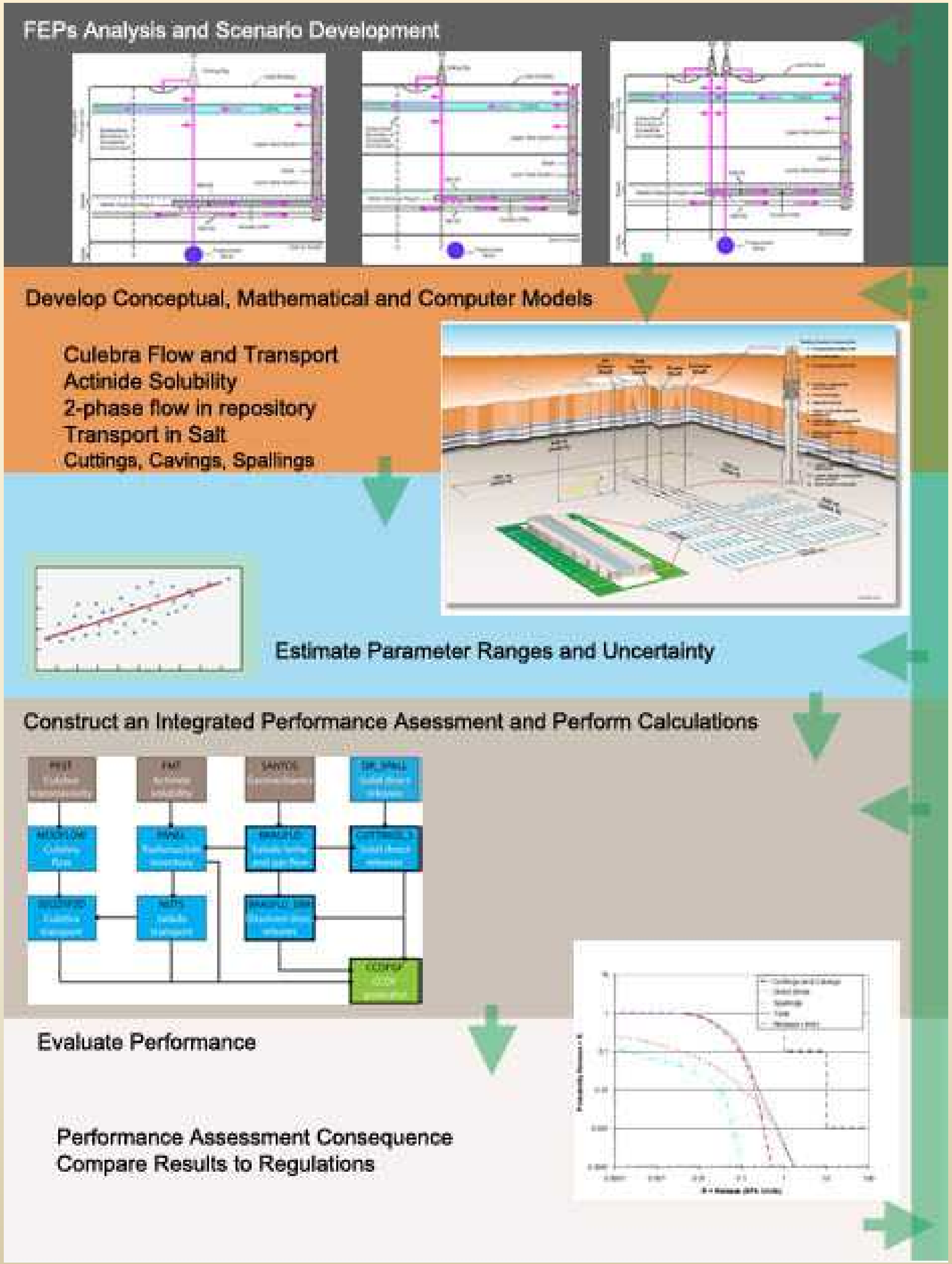
The U.S. Paradigm

- Screen FEPs and develop scenario classes
- Develop models and abstractions, along with their scientific basis, for logical groupings of FEPs within scenario classes
- Evaluate uncertainty in models and parameters
- Construct integrated TSPA model using all retained FEPs and perform calculations for the scenario classes and "modeling cases" within scenario classes
- Evaluate total-system performance; incorporating uncertainty through Monte Carlo simulation

Yucca Mountain



Waste Isolation Pilot Plant



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An Example from Belgium

(NOCA 2009. *Long-Term Testing and Monitoring Strategy—Final Report.*) Issue No. 1 3641390//SNL-URS

There is confidence that the safety concept and the design of the proposed disposal system show sufficient promise to proceed to the next program stage

DS The proposed disposal system is properly defined and its development has been guided by a well-defined and rational step-by-step safety strategy

DS 1 The waste to be disposed of, including its conditioning characteristics, is adequately known

DS 2 The application of the safety strategy takes proper account of the boundary conditions of the B&C program and of the available science and technology

SS The proposed disposal system will provide passive long-term safety if implemented according to design specifications

SS 1 The assessment basis provides evidence that the safety functions will be fulfilled as described by the safety concept

SS 2 Results from long-term safety evaluations confirm the safety of the disposal system

SS 3 Quality assurance procedures have been applied that favor confidence in assessment basis development and in the findings of long-term safety assessment

FS The proposed disposal system is feasible

FS 1 The assessment basis and feasibility assessment provide evidence of the engineering practicality of the disposal system

FS 2 Operational safety, as evaluated in feasibility assessment, will be provided, taking into account all relevant uncertainties

FS 3 Costs for the construction, operation and closure of the repository, as calculated in feasibility assessment, can be covered with the current funding mechanism

FS 4 Quality assurance procedures have been applied that favor confidence in assessment basis development and in the findings of feasibility assessment

US The residual uncertainties related to the proposed disposal system can be adequately dealt with in future program stages

US 1 There are no uncertainties that call into question the capacity of the system to fulfill the requirements

US 2 There are good prospects that it will be possible to incorporate reserve FEPs in future safety models, thereby leading to higher calculated safety margins

US 3 There are good prospects that future RD&D will enable relevant non-critical uncertainties to be reduced or even avoided

What about HLW and Salt?

- Each repository program addresses the safety case in a manner prescribed by national context
- Collaboration on a FEPs list for HLW may be a useful engagement. Each program could build and streamline from such a compendium
- FEPs are evaluated and scenarios are formed given the waste type, proposed repository location, geologic medium, and the concept of design
- The international community is greatly advanced in its ability to estimate consequences related to a salt repository
- All analyses must be conducted within a Quality Assurance Framework