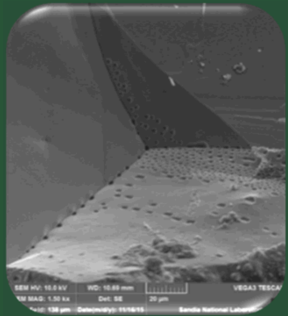

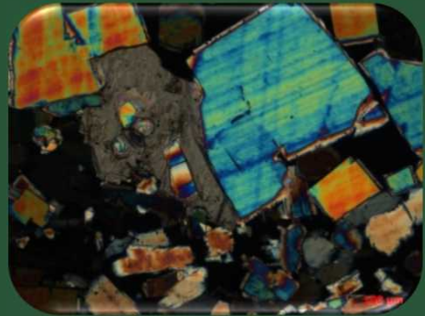

Discussion of Key Technical Issues Re: Components of the Safety Case

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Sandia National Laboratories

7th US/German Workshop on Salt Repository Research, Design, and Operation

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Typical Components of a Safety Case

1. Introduction, Purpose, and Context

2. Safety Strategy

- 2.1 Management Strategy
- 2.2 Siting & Design Strategy
- 2.3 Assessment Strategy

3. Technical Bases (or Assessment Basis)

- 3.1 Site Selection
- 3.2 Pre-closure Basis
  - Repository Design
  - Construction
  - Operations
- 3.3 Post-closure Basis (FEPs*)
  - Waste & Engineered Barriers
  - Geosphere/ Natural Barriers
    - Site Characterization
  - Biosphere & Surface Environment

4. Disposal System Safety Assessment

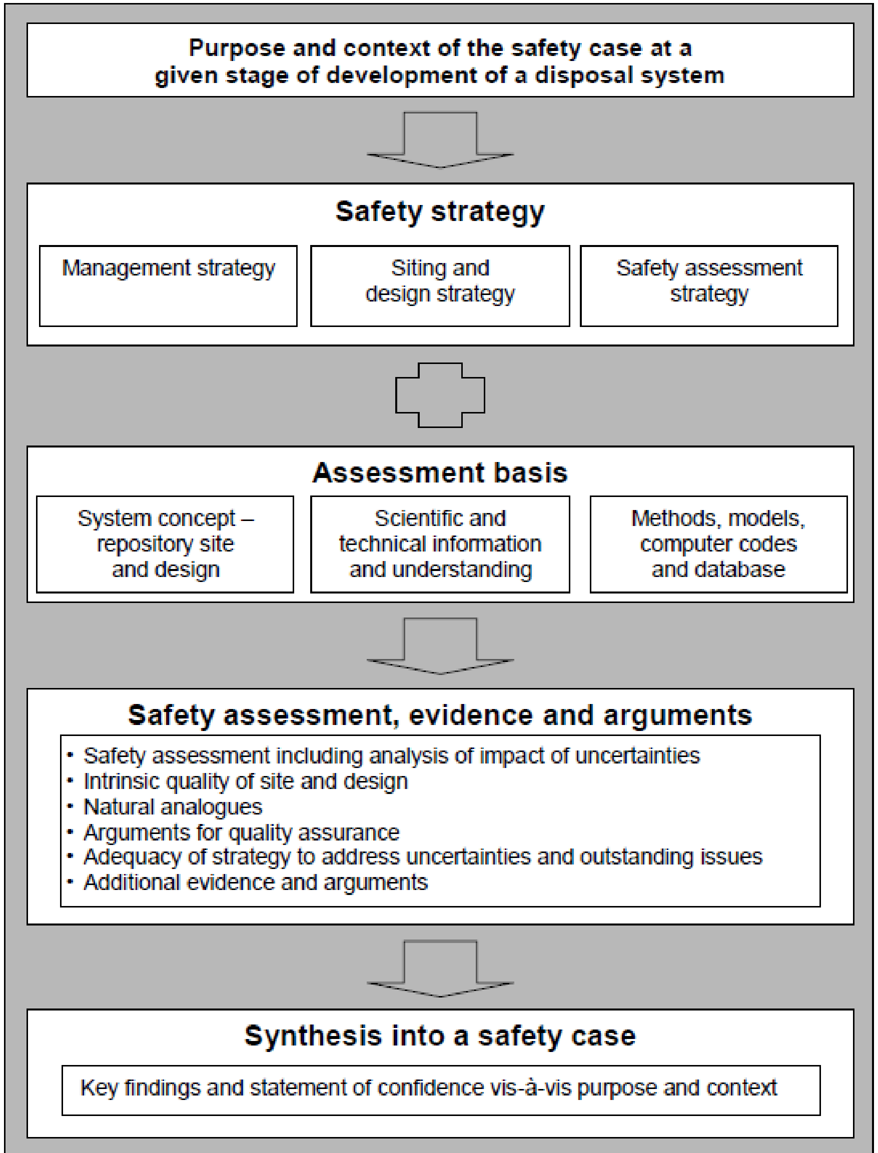
- 4.1 Pre-closure Safety Analysis
- 4.2 Post-closure Safety Assessment
- 4.3 Confidence Enhancement

5. Synthesis & Conclusions

*FEP = Feature, Event, or Process

Components of Safety Case – Other Examples

from NEA 2013a, No. 78121



from IAEA 2012, No. SSG-23

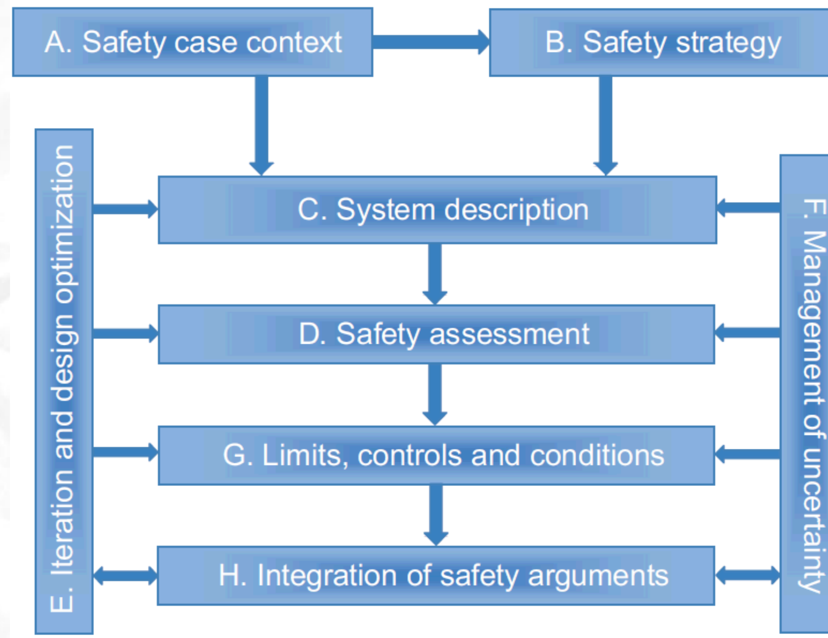
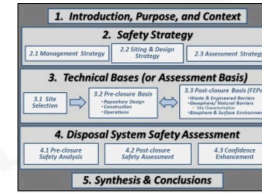


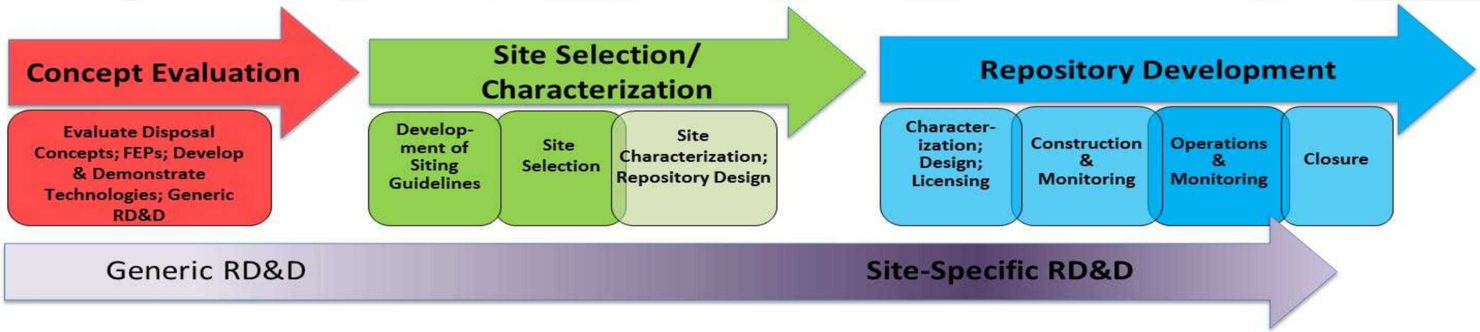
FIG 2. Components of the safety case.

Evolution and Iteration of the Safety Case



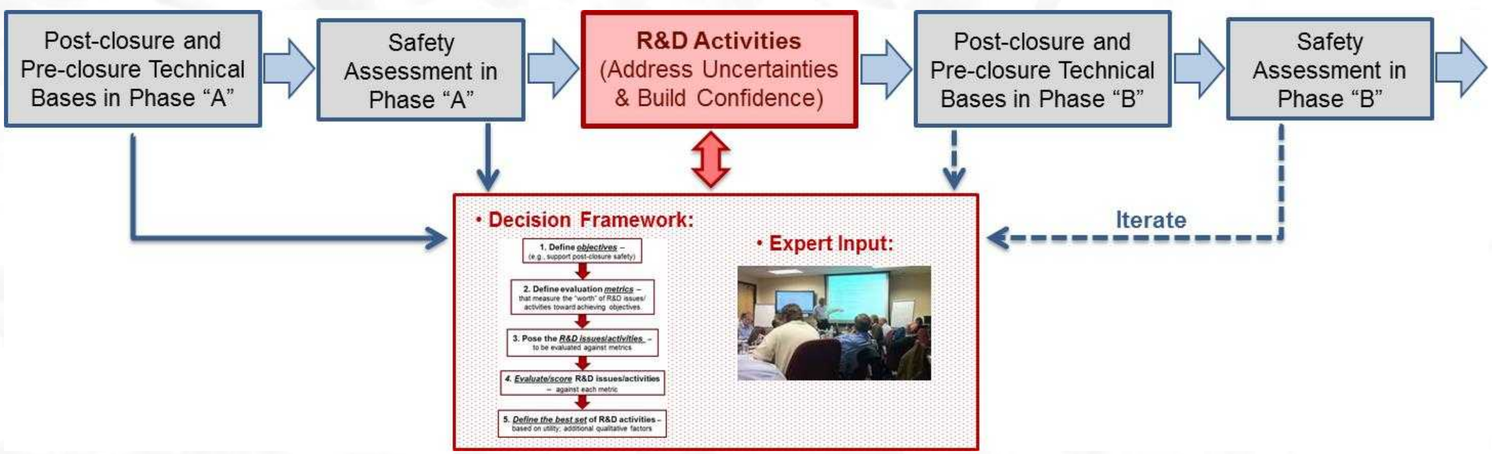
- Safety case and safety confidence *evolve* with the different phases of repository development, **via RD&D activities**

Repository Phases:



- *Iteration* of two major elements of the safety case—***technical bases*** and ***safety assessment***—guides RD&D activities:

Iteration: **(across phases)**



Safety Understanding Evolves Through "Issue Resolution"

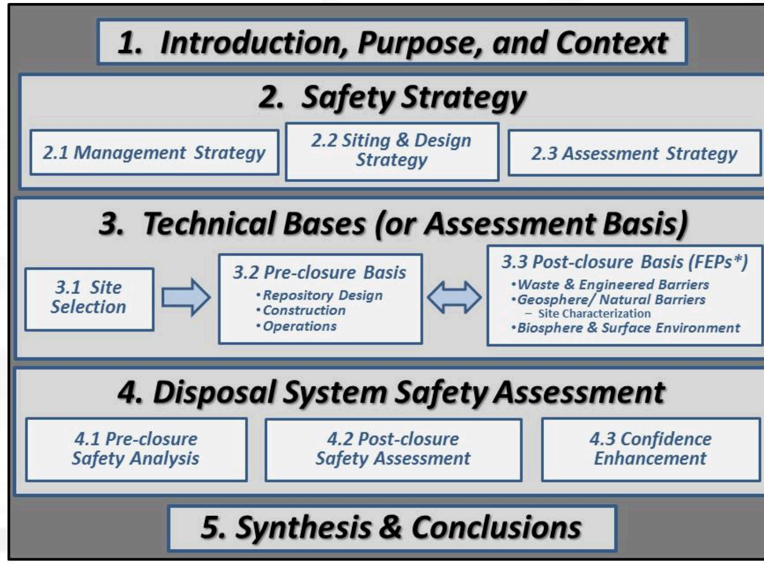
- **In a safety or licensing case, *all* outstanding issues* must ultimately be addressed with technical arguments and evidence****
  - During most phases of the safety case, limited resources ($,) requires prioritization of issues and the associated RD&D activities to resolve them
  - Set of remaining issues ("uncertainties") is based on inferences from the existing technical knowledge base — including lab, field, and *in situ* testing, as well as prior performance assessment modeling and process modeling
- **Typical issue "categories":**
  - Feature/process issues (FEPs)—"technical bases"
  - Modeling issues
  - Confidence-building issues
  - *In-situ* design/operations/testing issues

* Information need or knowledge gap.

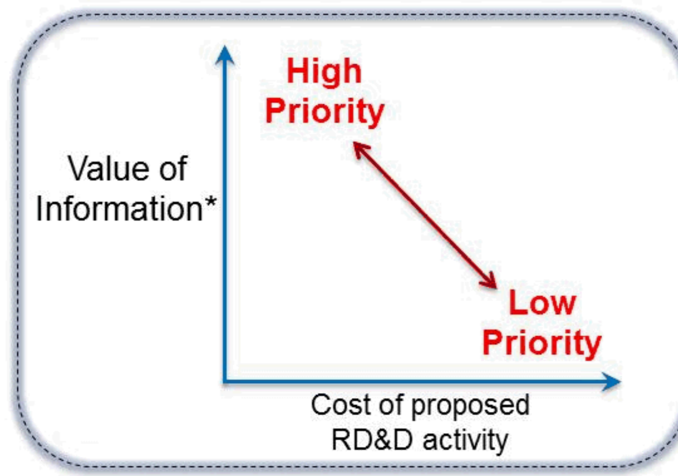
** An existing broad technical basis for either a generic repository or a site-specific repository implies a reduced set of high importance issues (also depends on program phase).

Prioritizing RD&D Activities

- **RD&D activities prioritized by**
  1. *Importance* to components of the *safety case*: safety assessment, technical bases, confidence-building →
  2. Potential to reduce key *uncertainties*
  3. Other factors (e.g., *cost*, maturity or TRL of activity, redundancies, synergies)



- **Prioritization process can be formalized**
  1. Identify a set of objectives and associated metrics, including
     - Value of information, maturity (TRL), cost, etc.
  2. Evaluate each RD&D activity using the metrics
  3. Define a "utility function" to combine the metric scores
  4. Compare utilities ("rankings") of the RD&D activities



* = *Func* {sensitivity of performance to the information obtained; uncertainty reduction potential (TRL)}

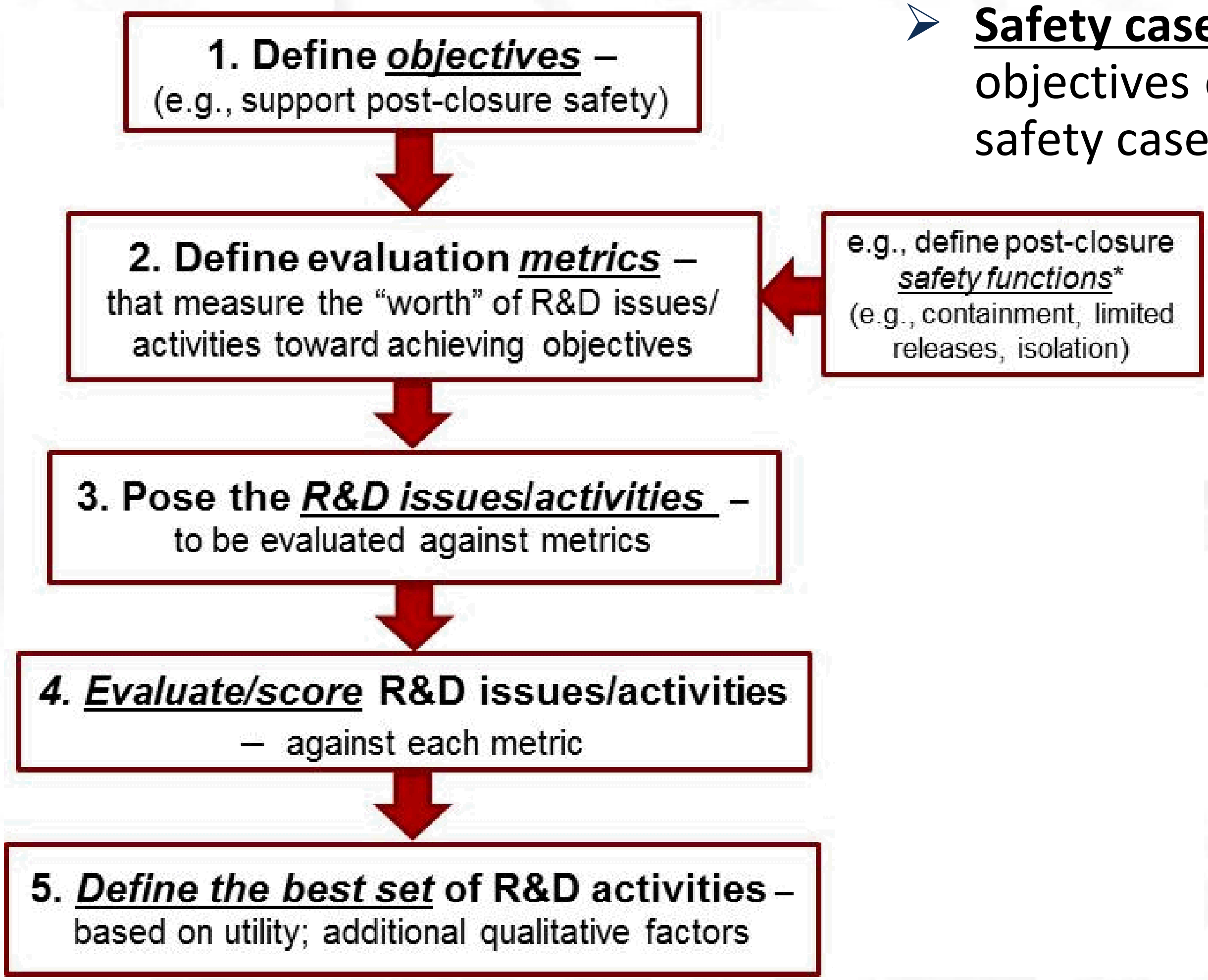
A Simplifying Assumption

- **Prioritize each proposed RD&D *activity* by evaluating the importance of the corresponding RD&D *issue* that the activity is designed to address:***
  - Example *issue* (FEP): "Changes in physical-chemical properties of host rock due to excavation, thermal, hydrological, and chemical effects"
  - Example *activity*: Single heater test
  - A metric designed to evaluate the importance of a particular RD&D *issue* to the safety case is a "proxy metric" for measuring the importance of the corresponding *activity*
  - Only rigorous if there is a one-to-one correspondence between issues and activities
    - There can be more than one activity to resolve an issue (e.g., lab test or *in situ* URL test; or two types of measurement techniques)
    - Can be more than one issue resolved by a single "activity"
    - Need to evaluate the importance of *issue-activity* <u>*pairs*</u>

*see Sevougian et al. 2013

RD&D Prioritization Methodology

- **Method:** Use standard decision analysis methodology to facilitate prioritization (similar to systems engineering methods):

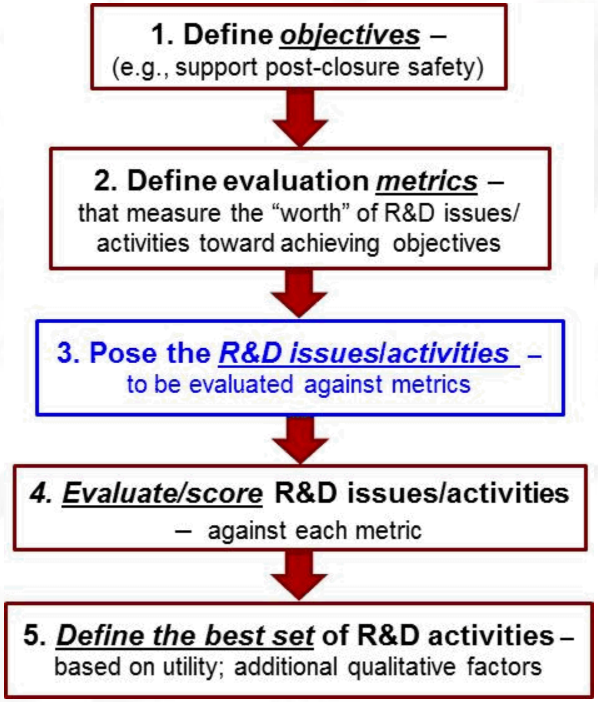


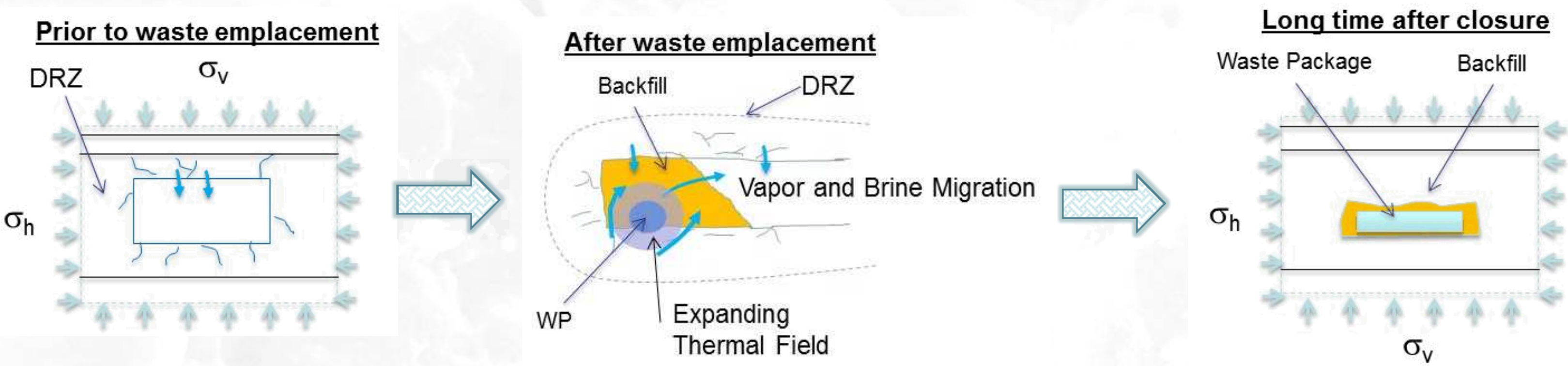
➢ **Safety case context:** base the objectives on elements of the safety case

*see Sevougian and MacKinnon 2014

Step 3. Pose the RD&D Issues

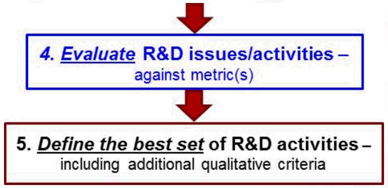
- Potential post-closure RD&D issues taken from FEPs catalogue (completeness)—e.g., DOE (2012)
- ***Important*** remaining RD&D issues based on the existing technical knowledge base— derived from lab, field, and *in situ* testing, as well as prior performance assessment modeling, process modeling, and uncertainty characterization
- Example for generic salt repositories: phenomena related to heat-generating waste given special consideration, e.g.,
  - Creep closure accelerated by elevated temperatures
  - Crushed salt backfill reconsolidation for elevated temperatures
  - Material property changes coupled to fluid movement enhanced by thermal-hydrologic-mechanical (THM) processes





Salt RD&D Feature/Process Issues

- 30 feature/process ("FEPs") issues were identified and given "pre-workshop" importance ratings—11 rated as "H"—then evaluated by experts during a DOE-NE/EM workshop, March 2013, in Albuquerque, NM
- Based on *nominal scenario* evolution and high heat load assumption – see Sevougian et al. 2013
- Two breakout groups (pre-closure and post-closure) reconsidered ratings, making a few changes



Salt RD&D Technical Issue	Issue Importance Rating
Wastes and Engineered Features (EBS) Feature/Process Issues	
1. Inventory and WP Loading	M (= I,P)
2. Physical-chemical properties of crushed salt backfill at emplacement	M (= I,P)
3. Changes in physical-chemical properties of crushed salt backfill after waste emplacement	H (= D,P)
4. Changes in chemical characteristics of brine in the backfill and EBS	M (= I,P)
5. Mechanical response of backfill	H (= D,P)
6. Impact of mechanical loading on performance of the WP	H (= D,P)
7. Brine and vapor movement in the backfill and emplacement drift, including evaporation and condensation	H (= D, P)
8. Corrosion performance of the waste package	M = (I,P)
9. Mechanical and chemical degradation of the waste forms	L (= D,S)
10. Brine flow through waste package	L (= D,S)
11. Changes in chemical characteristics of brine in the waste package	L (= I,S)
12. Radionuclide solubility in the waste package and EBS	L (= D,S)
13. Radionuclide transport in the waste package and EBS	L (= D,S)
Natural Barriers (Geosphere: Host Rock and EDZ) Feature/Process Issues	
14. Stratigraphy and physical-chemical properties of host rock	H (= D,P)
15. Changes in physical-chemical properties of host rock due to excavation, thermal, hydrological, and chemical effects	H (= D,P)
16. Mechanical response of host rock due to excavation (e.g., roof collapse, creep, drift deformation)	H (= D,P)
17. The formation and evolution of the EDZ	H (= D,P)
18. Brine and vapor movement through the host rock and EDZ, including evaporation and condensation	H (= D, P)
19. Chemical characteristics of brine in the host rock	L (= I,S)
20. Changes in chemical characteristics of brine in the host rock and EDZ	M (= I, P)
21. Radionuclide solubility in the host rock and EDZ	L (= D,S)
22. Radionuclide transport in the host rock and EDZ	L (= D,S)
Repository System (EBS and Geosphere combined) Feature/Process Issues	
23. Thermal response of EBS and Geosphere (heat transfer from waste and waste packages into the EBS and Geosphere)	H (= D,P)
24. Buoyancy of the waste packages	L (= W,P)
25. Gas generation and potential physical impacts to backfill, EDZ, and host rock	M = (I,P)
26. Microbial activity in the waste package, EBS, and host rock (including EDZ)	L (= I,S)
27. Colloid formation and transport in the waste package, EBS, and host rock (including EDZ)	L (= D,S)
28. Performance of seal system	H (= D,P)
29. Performance of ground support	L = (W,P,S)
30. Performance and effects of ventilation	M (= I,P)

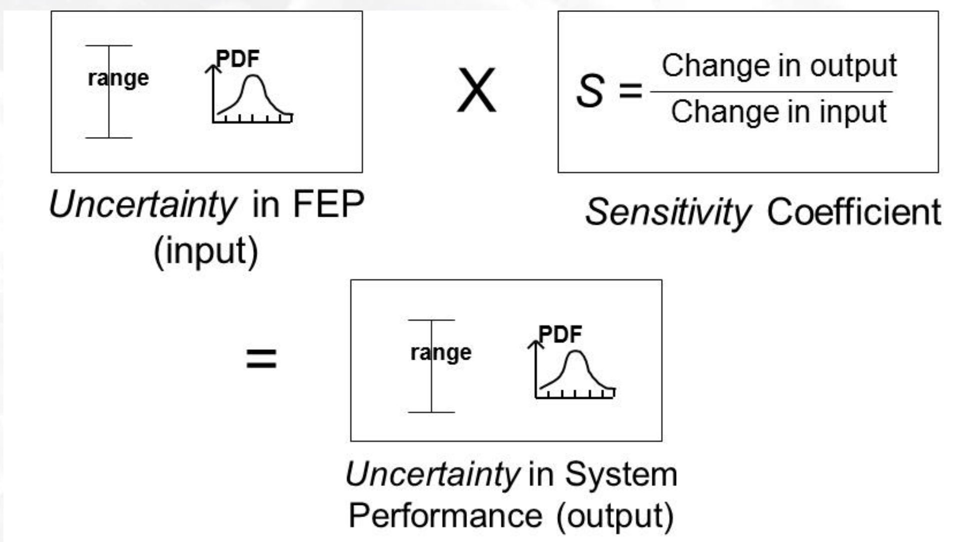
Post-Workshop RD&D Activity Proposals

Table 7-3. Summary of RD&D Test Proposals/Questionnaires Received after the Salt RD&D Integration Workshop

Table ID	Test Name	Test Type(s)	Principal Investigator(s) and Lab Affiliation
Primarily *in situ*, large-scale field testing (with modeling)			
H-1	Clay Seam Shear Testing	*In situ* tests in the new URL; Laboratory tests; Constitutive modeling; International collaborations	Frank Hansen (SNL)
H-2	Single Heater Test	Generic *in situ* tests in the new URL; International collaborations; Modeling prediction and validation	Frank Hansen (SNL), Carlos Jove-Colon (SNL)
H-3	Large-Scale Seal Test	*In situ* tests in the new URL; International collaborations; Modeling; Lab—ACI concrete testing	Frank Hansen (SNL)
H-4	Salt Defense Disposal Investigations (SDDI) Thermal Test	*In situ* thermal test; Laboratory tests; THM and THMC model validation	Doug Weaver (LANL)
H-5	Water migration tracer test during the proposed SDDI experiment	*In situ* field test with lab analysis; including pre-, during, and post-test transport modeling	Philip Stauffer (LANL), Florie Caporuscio (LANL), Paul Reimus (LANL), Ernie Hardin (SNL)
Laboratory testing, followed by *in situ* testing (with modeling)			
H-6	Salt Decrepitation Effects	Laboratory tests initially; borehole & *in situ* field testing later; THM process and constitutive modeling	Kris Kuhlman (SNL)
H-7	Development of an Integrated Geophysical Imaging System for Field-Scale Monitoring of Brine Migration and Mechanical Alteration in Salt Repositories	Laboratory tests; Field testing at LBNL Geophysical Measurement Facility (GMF); (no modeling initially but later some pre-test modeling)	T.M. Daley, Y. Wu, J. Birkholzer, and J.B. Ajo-Franklin (LBNL)
Laboratory testing, followed by *in situ* testing (no modeling)			
H-8	Geophysical and acoustical monitoring of fluid migration and fracture evolution for WIPP salt thermal tests	Initial lab sensitivity experiments; followed by *in situ* field tests at WIPP during SDDI thermal tests (no modeling)	Peter Roberts (LANL)
H-9	*In situ* and laboratory testing of moisture monitoring methods	Laboratory tests; *In situ* field tests (no simulation modeling mentioned)	Dan Levitt (LANL)
Laboratory testing (with modeling)			
H-10	Thermo-Hydro-Mechanical-Chemical Experiments to Study the Effect of Creep and Clay on Permeability and Brine Migration in Salt at High Temperatures and Pressures	Complex THMC laboratory experiments; coupled process modeling to predict/interpret the results	Tim Kneafsey and Seiji Nakagawa (LBNL)
Laboratory testing (no modeling)			
H-11	Long-term steel corrosion analyses from Room A1/B re-entry	Laboratory test; (no simulation modeling mentioned)	Pat Brady (SNL)
H-12	Imaging Brine Migration in Salt Using Neutron and Synchrotron X-ray Tomography	Laboratory tests (no simulation modeling)	Hongwu Xu (LANL), Jonathan Ajo-Franklin (LBL)
H-13	Validation of constitutive models and parameterization of unsaturated brine flow in intact and crushed salt	Laboratory test (no simulation modeling)	Kris Kuhlman (SNL); Bwalya Malama (SNL)
H-14	Stability of Polyhalite in the Salado Formation	Laboratory test (no simulation modeling)	Florie Caporuscio (LANL)
H-15	Stability of hydrous phases (corrensite, bassanite) in the Salado Formation	Laboratory test (applicable for SDDI waste emplacement studies)— (no simulation modeling)	Florie Caporuscio (LANL)
H-16	Use of ultra-low field (ULF) nuclear magnetic resonance (NMR) and magnetic resonance imaging (MRI)) to map and quantify brine content in an undisturbed salt core.	Laboratory test (no simulation modeling)	Florie Caporuscio (LANL)
H-17	Elevated-Temperature Measurements of Plutonium (III) and Neodymium(III) Solubility in Low to Moderate Ionic Strength Aqueous Solutions	Laboratory tests (no modeling)	Jonathan Icenhower and David Shuh (LBNL); Donald Reed (LANL)
H-18	Laboratory Study on the Long-term Porosity and Permeability Reduction in Salt Backfill Under Elevated Temperature Conditions	Laboratory tests (no modeling)	Tim Kneafsey and Seiji Nakagawa (LBNL)
Modeling and simulation studies only (no physical tests)			
H-19	Mechanistic modeling of brine and vapor movement	Theoretical and modeling study	Qinjun Kang (LANL)
H-20	THM Optimization of Preclosure Repository Design	Coupled process modeling	Jonny Rutqvist and Laura Blanco-Martin (LBNL); Phil Stauffer and Florie Caporuscio (LANL)
H-21	Benchmarking Simulations for THM Behavior of Rock Salt	THM(C) benchmark modeling—model-to model comparisons for a simplified repository, for a lab/field THM experiment; and for the planned SDDI test	Jonny Rutqvist and Jens Birkholzer (LBNL); Phil Stauffer and Bruce Robinson (LANL); Carlos Jove-Colon, Kristopher Kuhlman, and Ernest Hardin (SNL)
H-22	THM Model of Salt Rock Microstructural Damage and Healing	Mechanistic microstructure modeling of coupled processes in salt	Daisuke Asahina and Jim Houseworth (LBNL)
H-23	Brine Migration in Salt: Review and Constitutive Model Development	Constitutive models	Jim Houseworth, Jonny Rutqvist, Hui-Hai Liu, Jens Birkholzer (LBNL)

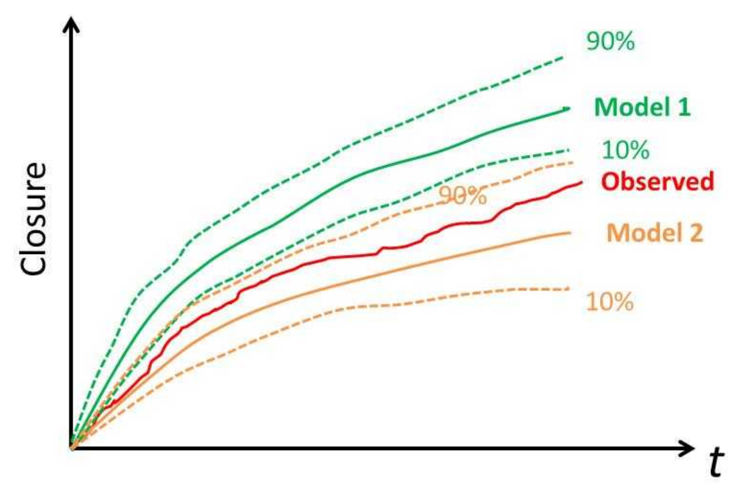
Effect of Uncertainty and/or TRL

- **Previous evaluation of issue significance was mostly based on their importance to system performance or safety:**
  - How *sensitive* is the system to the given issue or FEP?
- **Just as critical to any RD&D funding decision is our current state of knowledge (TRL) regarding the issue or FEP, i.e., *uncertainty* reduction potential**



Potential Focus Topic for Today

- *Uncertainty characterization for THM processes and models*
- **How can we know how uncertainty in THM models affects system performance (e.g., total dose), in order to know how much additional RD&D is necessary?**
- **How to characterize uncertainty in model input parameters?**
- **Which constitutive model or how many models are needed to encompass potential behavior?**

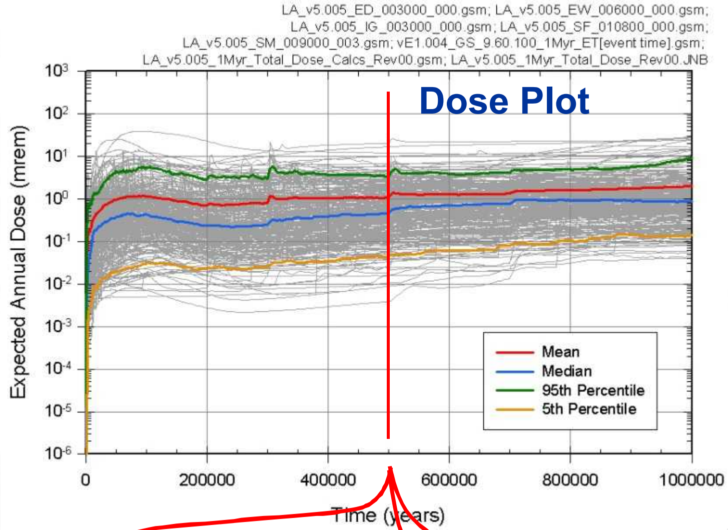


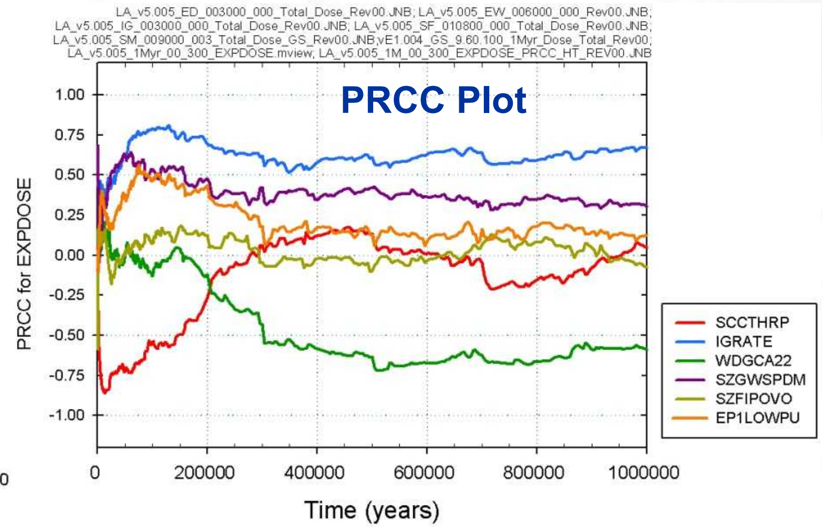
Uncertainty in YM Total Expected Dose
(Sum over All Scenario Classes and RNs)

IGRATE – Frequency of igneous events

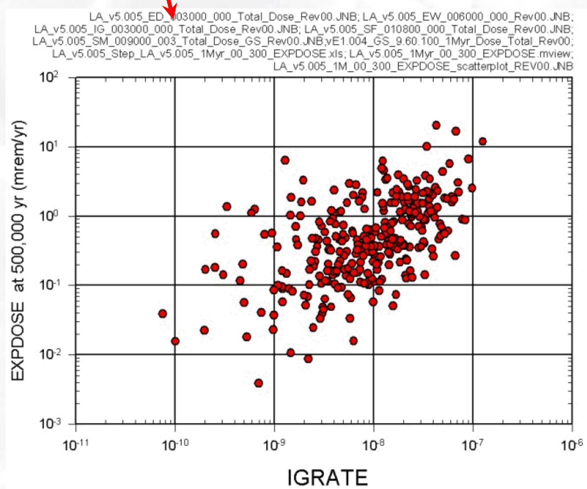
WDGCA22 – Temperature dependence in A22 corrosion rate

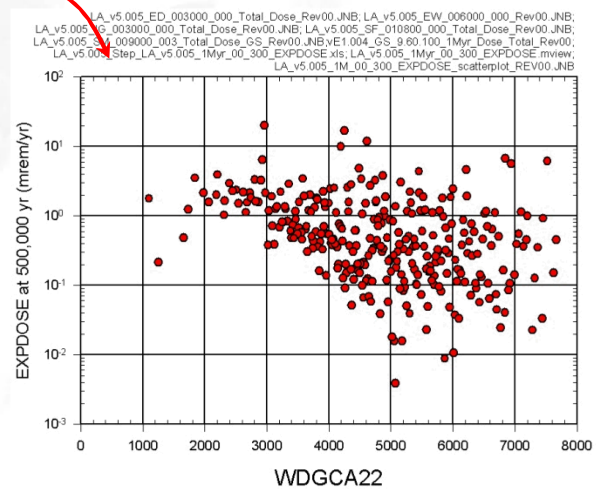
SZGWSPDM – Uncert factor for groundwater specific discharge rate



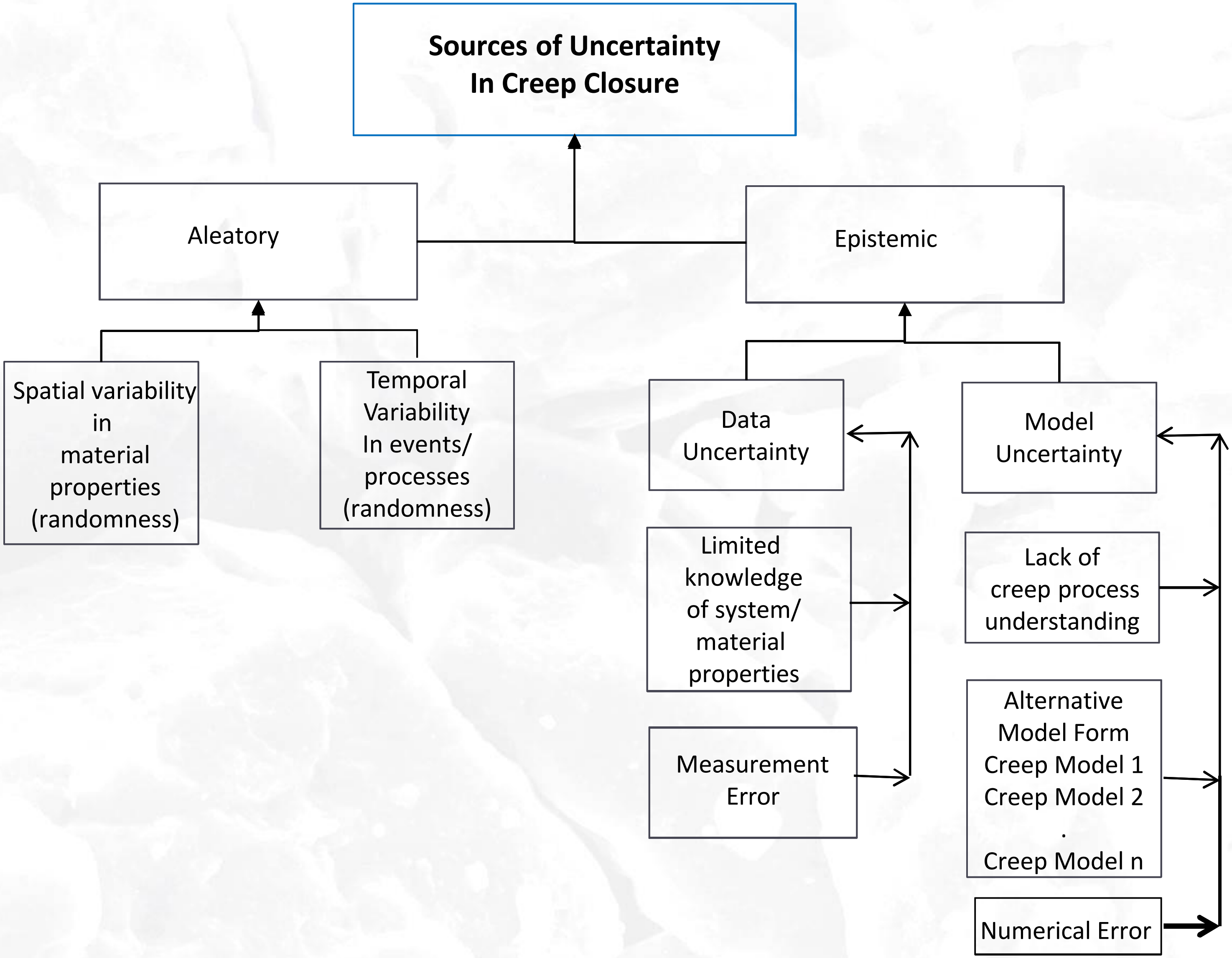


EXPDOSE: 500,000 Years		
Variable	R^2	SRRC
IGRATE	0.29	0.54
WDGCA22	0.46	−0.38
SZGWSPDM	0.53	0.24
EP1LOWNU	0.56	0.19
MICNP237	0.59	0.16
EP1L0WPU	0.61	0.17
SZCONCOL	0.64	0.15
SZFISPVO	0.66	0.15
INFIL	0.67	0.11
GOESITED	0.68	−0.10
SZKDCSVO	0.69	−0.10
HFOSITED	0.69	−0.09
SZDIFCVO	0.70	−0.09





Uncertainty in Creep Closure of Emplacement Drifts in Salt



Some Aspects of Uncertainty Characterization

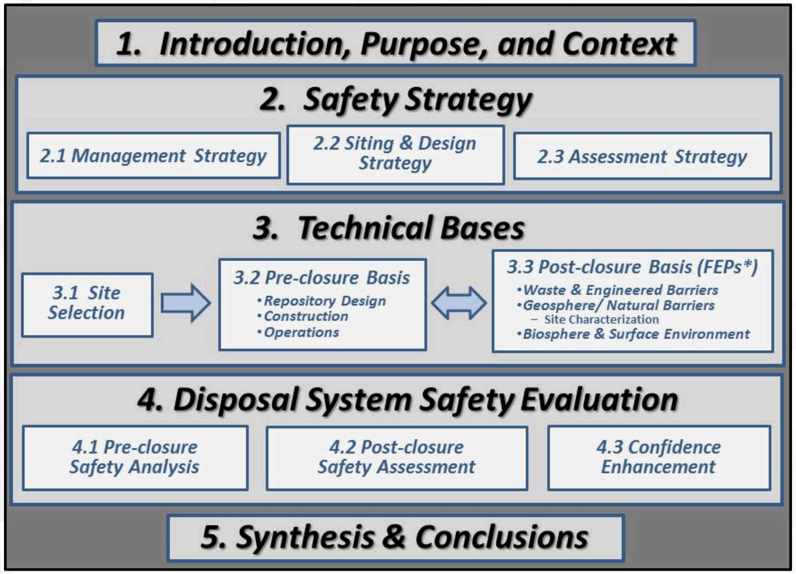
- **Nature of uncertainty: aleatory (inherent randomness) vs. epistemic (lack of knowledge)**
- **Sources of model and prediction uncertainty, e.g.:**
  - Parameter (input) uncertainty (epistemic)
  - Model structural uncertainty (epistemic—lack of knowledge of true physics)
  - Experiment or data measurement uncertainty (aleatory or variability)
  - Numerical approximation uncertainties, arising from spatial-temporal discretization error, statistical sampling error, iterative convergence error
- **How to upscale data (from lab to field; from core data to numerical grid blocks)—how to handle associated variance reduction**
- **Methods to fit uncertainty distributions to dense data sets**
  - Mechanistic considerations when choosing probability distribution type
- **How to fit uncertainty distributions to sparse data sets**
  - Maximum entropy
  - How/when to use expert elicitation (i.e., subjective uncertainty assessment)?

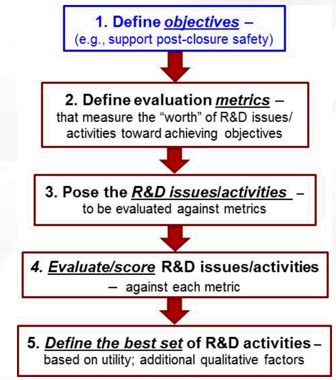
Open Discussion

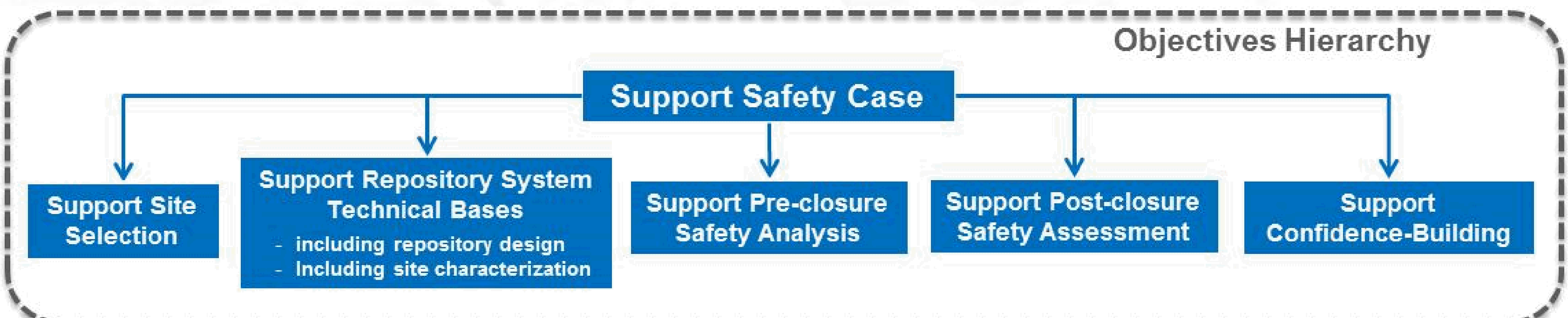
Backup Slides

Step 1. Define Objectives Hierarchy
(to Evaluate R&D Issues/Activities)

- **Use key elements of the *safety case* as high-level objectives for evaluating RD&D activities:**

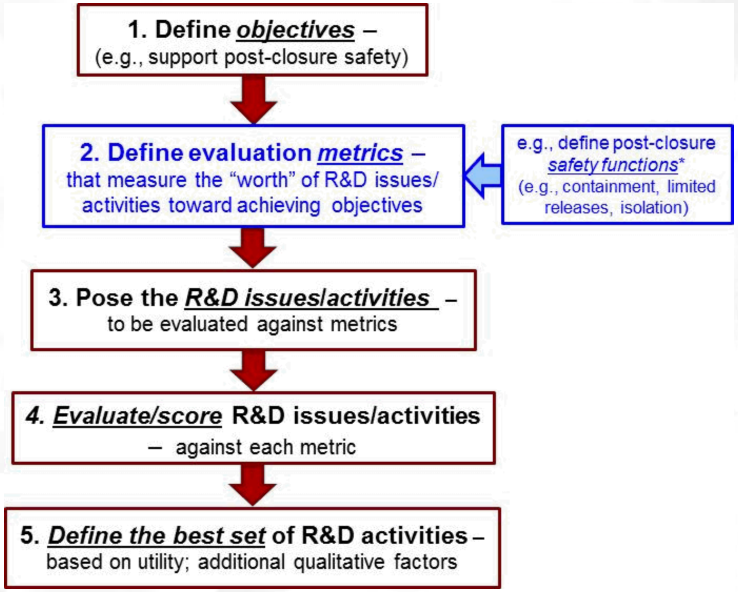






Step 2. Define a Metric for each Objective
(Example for Post-closure Safety Objective)

- For generic repository investigations, the importance of R&D issues (particularly FEPs issues) might *primarily* be determined by their importance to the post-closure safety objective:
  - Design a metric "**Importance to Postclosure Safety**" (*see backup slides*)
  - Decompose "Importance to Postclosure Safety" into "Important to Postclosure **Safety Function A**," "Importance to Postclosure **Safety Function B**," etc.
    - What functions the system must perform to successfully achieve post-closure safety
  - Evaluate R&D issues against the post-closure *safety functions:*



max {*Importance to Safety Function A*; *Importance to Safety Function B*; etc.**}**

= *Importance to Postclosure Safety*

Define System Safety Functions

- ***Post-closure safety functions**** identify key attributes of material barriers that are relied upon to prevent or limit contact of waste with the biosphere:
  - ***Isolation/Stability Safety Function***— Aspects of the repository and geologic environment that isolate the waste from external changes or events, and therefore help maintain the integrity and longevity of the barriers
  - ***Containment***—Aspects of the repository that prevent fluid contact with the waste:
    - If groundwater does not contact the waste there is, in general, no release mechanism to transport radionuclides
    - {Note: An alternative definition of containment is provided at 10 CFR 60.2: "Containment means the confinement of radioactive waste within a designated boundary."}
  - ***Limited or Delayed Releases***— Aspects of the repository that delay or reduce the transfer of radionuclides to the accessible environment after the *containment* function is compromised

*Definitions from Bailey, L., et al. 2011. *PAMINA*: *European Handbook of the state-of-the-art of safety assessments of geological repositories—Part 1.* European Commission. January 31, 2011.

Define Post-closure Safety Metric

- Define importance of an R&D issue to post-closure safety based on a *safety function metric*:

<u>*Importance*</u> of R&D Issue = **<u>*Impact*</u> of R&D Issue on a Safety Function** ∪ **<u>*Function Level*</u> of the Safety Function**

- "<u>*Function level*</u>" for any safety function is defined as either *primary* or *secondary:*
  - A *primary* safety function operates from the time of closure to prevent transfer of radionuclides to the biosphere
  - A *secondary* safety function is only operative if a primary function fails, for whatever reason

Function	Type	Function Level	Definition	Examples of Key Associated Parameter(s) or Characteristic(s)
Isolation/stability	Safety	Primary (P)	Aspects of the repository and geologic environment that isolate the waste from external events or changes, and therefore help maintain the integrity and longevity of the barriers.	• (high) seal integrity • (thick) host rock zone • (non-) communication between salt beds and interbeds
Containment	Safety	Primary (P)	Aspects of the repository that prevent fluid contact with the waste.	• (very low or zero) permeability
Limited or delayed releases	Safety	Secondary (S)	Aspects of the repository that delay or 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

"Design" function →

Define Post-closure Metric – (cont.)

Importance **of R&D Issue** = ***Impact*** **of R&D Issue on a Safety Function** ∪ ***Function Level**** **of the Safety Function**

* Also called the "significance level"

- ***"Impact"*** of an R&D Issue on *performance* of a safety/design function (for process/ parameter issues), or on confidence in the *demonstration of performance* of a safety/design function (for modeling or *in situ* testing issues):

Impact of an R&D Issue	
D	Direct and potentially significant impact on the success of a safety or design function
I	Indirect but potentially significant impact on the success of a safety or design function
W	Weak impact (whether direct or indirect) on the success of a safety or design function

Define Post-closure Metric – (cont.)

***Importance* of R&D Issue** = ***Impact* of R&D Issue on a Safety Function** $\cup$ ***Function Level* of the Safety Function**

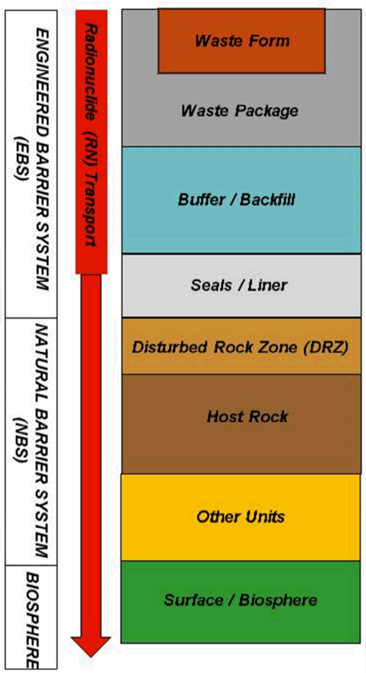
- *"Importance"* value ratings (High, Medium, or Low) for R&D issues (based on impact and function level):

Importance Value Rating	= Impact Level	+ Function Level
High: H=(D,P)	Direct (D)	Primary (P)
Medium: M=(I,P)	Indirect (I)	Primary (P)
Low: L=(W,P)	Weak (W)	Primary (P)
Low: L=(D,S)	Direct (D)	Secondary (S)
Low: L=(I,S)	Indirect (I)	Secondary (S)
Low: L=(W,S)	Weak (W)	Secondary (S)

(Note: An R&D Issue receives a rating according to its highest function-impact combination, i.e., it may receive an L rating for one function/impact but if it gets an H for another function/impact, it inherits that highest rating.)

Post-closure Technical Bases
(Organized according to the FEPs Matrix* structure)

*from Freeze et al. 2014



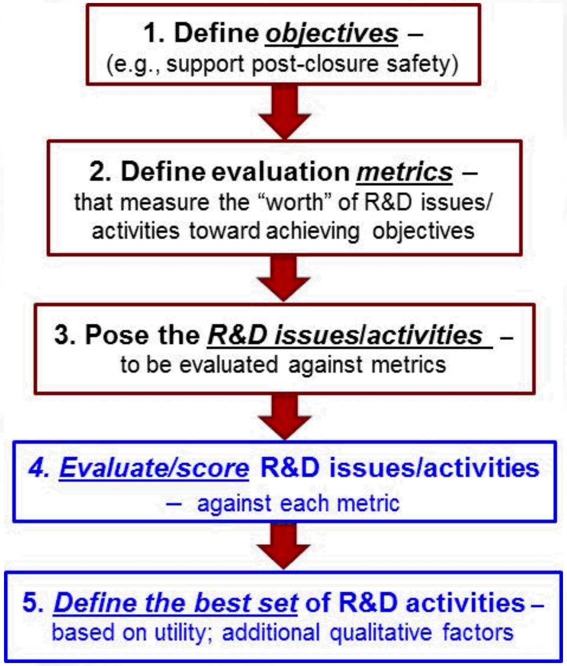
Characteristics, Processes, and Events / Features		Processes											Events					
	Characteristics	Mechanical and Thermal-Mechanical	Hydrological and Thermal-Hydrologic	Chemical and Thermal-Chemical	Biological and Thermal-Biological	Transport and Thermal-Transport	Thermal	Radiological	Long-Term Geologic	Climatic	Human Activities (Long Timescale)	Other	Nuclear Criticality	Early Failure	Seismic	Igneous	Human Activities (Short Timescale)	Other
Waste and Engineered Features																		
Waste Form and Cladding																		
Waste Package and Internals																		
Buffer/Backfill																		
Emplacement Tunnels/Drifts and Mine Workings																		
Seals/Plugs																		
Geosphere Features																		
Host Rock (Repository Horizon)																		
Other Geologic Units (non-Repository Horizon)																		
Surface Features																		
Biosphere																		
System Features																		
Repository System																		

Modeling, Testing, Confidence-Building Issues

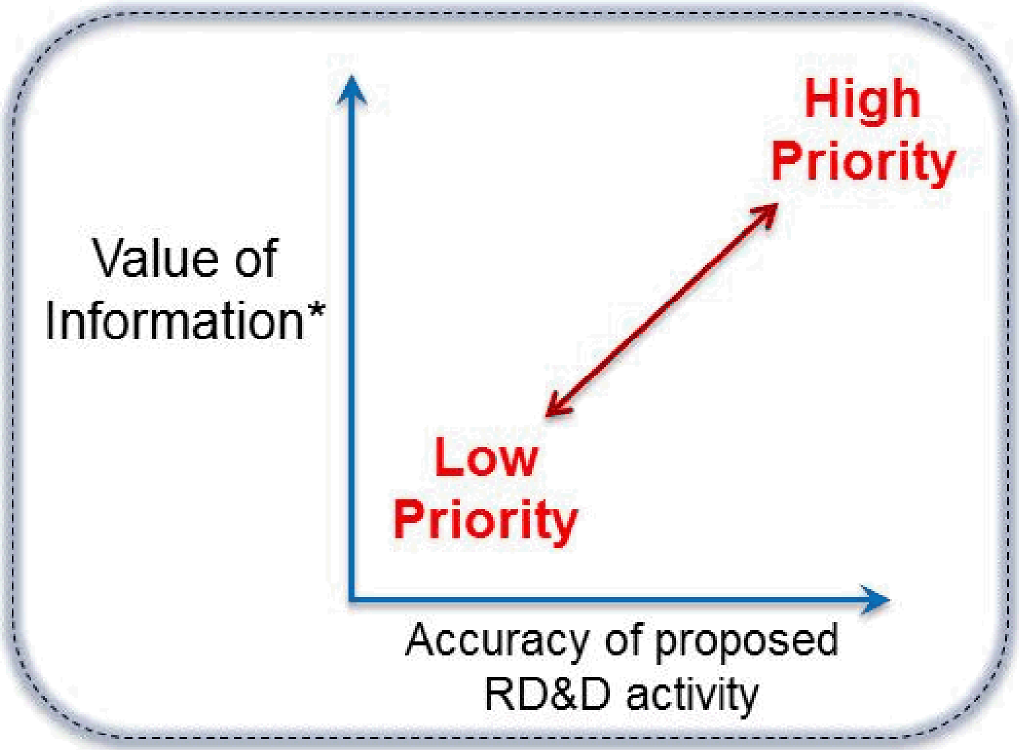
Salt RD&D Technical Issue	Issue Importance Rating	Explanation of Issue Importance Rating
Modeling Issues		
31. Appropriate constitutive models (e.g., Darcy flow; effective stress)	H (= D,P)	Direct impact on the confidence in the demonstration (modeling) of performance of primary safety functions
32. Appropriate representation of coupled processes in process models	H (= D,P)	Direct impact on the confidence in the demonstration (modeling) of performance of primary safety functions
33. Appropriate representation of coupled processes in TSPA model	H (= D,P)	Direct impact on the confidence in the demonstration (modeling) of performance of primary safety functions
34. Appropriate inclusion and scaling/representation of spatially and temporally varying processes and features in process and TSPA models	H (= D,P)	Direct impact on the confidence in the demonstration (modeling) of performance of primary safety functions
35. Efficient and high performance computing of three-dimensional, spatially and temporally varying processes	M (= I,P)	Indirect impact on demonstrating the importance of primary safety functions
36. Efficient uncertainty quantification and sensitivity analysis methods	M (= I,P)	Indirect impact on demonstrating the importance of primary safety functions
37. Verification and validation	H (= D,P)	Direct impact on the confidence in the demonstration (modeling) of performance of primary safety functions
38. Data and results management	H (= D,P)	Direct impact on confidence (QA)
In-Situ **Testing/Design/Operations Issues**		
39. Development of accurate instrumentation and methods for *in situ* testing and characterization	H (= D,P)	Direct impact on the confidence in the demonstration (modeling) of performance of the containment safety function, through measurements of *in situ* stresses and rock movement (H) and brine and vapor/gas movement (M)
40. *In situ* demonstration and verification of repository design, with respect to its impact on the host rock and the ability to comply with preclosure and postclosure safety requirements.	H (= D,P)	Direct impact on the confidence in the demonstration of performance of the containment safety function
41. Demonstrate under representative conditions the integrated design functions of the waste package, backfill, host rock, and ventilation.	H (= D,P)	May not be possible in the time frame of an *in situ* test. Direct impact on the confidence in the demonstration of performance of the containment safety function
42. Provide a full-scale benchmark for understanding coupled THMC processes and comparing measured system responses with model predictions and assumptions	H (= D,P)	Similar to Issue 37, Verification and Validation. Direct impact on the confidence in the demonstration (modeling) of performance of primary safety functions
Confidence-Building Issues		
43. Develop generic safety case	H	This is the fundamental documentation structure for demonstrating repository safety
44. Comparisons to natural and anthropogenic analogs	H	It is the best way to validate long time-scale processes
45. International peer review and collaboration	M	Adds credibility with the scientific community
46. In-situ testing and demonstrations	H	Adds credibility with the political and scientific communities. Was rated H in Items 39-42
47. Verification, validation, transparency, and traceability	H	Essential for all nuclear waste programs
48. Qualitative arguments about the intrinsic robustness of site and design	M	Helpful for understanding and transparency

Steps 4 & 5. Evaluate the Issues and Recommend R&D

- **Overall goal**: Identify best set of R&D activities (including *in situ* URL activities) that have the greatest potential to further understanding and safety confidence
- **Method**: Workshop(s) comprised of subject matter experts, safety assessment experts, and decision analysts. Recent example:
  - Joint DOE-NE/EM workshop, March 2013, in Albuquerque, NM: "Advancing the Science and Engineering Supporting Deep Geologic Disposal of Nuclear Waste in Salt", whose major tasks included
    - Review/revise pre-workshop R&D issue list and the associated importance ratings
    - For high importance ("H") issues that are not being addressed by current fiscal year tasks, define specific activities needed to advance the state of the art (lab, modeling, *in situ*)
    - Fill-out test questionnaire for each newly proposed test/activity (*see backup slides*)



Expected Accuracy of RD&D Activity



* = ***Func*** {sensitivity of performance to the information obtained; uncertainty reduction potential (TRL)}

Test Questionnaire

1) Name of test:
2) Test objectives, description, and type (lab, field, etc.):
3) R&D issue(s) addressed by test (field tests should include one or more “H”-rated issues):
4) Safety case objectives addressed by test (e.g., post-closure safety; pre-closure safety; confidence building) and why the test is important to the safety case:
   - List objectives in order of applicability (e.g., 1. Post-closure safety, 2. Confidence-building, etc.)
5) For the proposed test describe the current “state of the art” knowledge regarding the issue(s) it addresses; in other words, why is this data necessary?
6) Define the data that will be collected/measured (e.g., name and description of process(es)/parameter(s), time duration, spatial scale, frequency, accuracy):
   - Describe how the data will be collected
7) Define the instrumentation that will be used to measure process(es)/ parameter(s) and define the instrumentation placement or layout:

Test Questionnaire (cont.)

8) Define the pre-and post-test modeling/simulation needs for the activity, including:

   - Description and type of model addressed by test (constitutive; process; coupled process; N/A if testing for constructability)

9) List system features involved in test (e.g., waste package; backfill; seal system; DRZ; pristine host rock; etc.):

10) Time period of applicability for data gathered: pre-emplacement; pre-closure, post-closure:

    - E.g., data gathered applies to processes occurring during first 300 years after closure; data gathered applies to processes that occur over 10,000 years after closure; etc.

11) For field tests define additional lab tests or other separate activities/data needed to support this test:

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