

Spent Fuel and Waste Science and Technology

DR Integration and R&D Prioritization

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SFWST Annual Working Group Meeting
Las Vegas, Nevada
May 22-24, 2018

Some Overarching Goals

- 1. Improved integration among DR work packages**
- 2. Continued integration with and support of performance assessment (GDSA) and safety case**
- 3. Summary of what has been accomplished since 2012 UFD Roadmap vis-à-vis Roadmap priorities**
- 4. Identify potential gaps in R&D activities vis-à-vis Roadmap priorities, e.g., criticality effects**
- 5. Possible adjustments of R&D priorities and activities based on**
 - a. Accomplishments since 2012
 - b. Current state of the art (or knowledge readiness level - KRL)
- 6. Initial preparation for 1st-quarter FY19 integration and R&D prioritization workshops**
 - Workshops to produce summary documents of accomplishments and potential gaps
 - Workshops to further model integration efforts with GDSA and among WPs

Tuesday: Objectives

8:00-8:30am	Obtain nametag, sign in
8:30-9:30 am	Welcome & SFWST Campaign Updates <ul style="list-style-type: none"> • DR & ST High Level Updates • Ram Murthy: QA Update
9:30-9:50 am	Break
9:50 – 10:20 am	DR NEUP Topical Session (Ruth Tinnacher, California State University East Bay).
10:20-12:00	DPC Session (Hardin, Banerjee)
Noon-1:30 pm	Lunch (on your own)
1:30-2:15 pm	International Session (Birkholzer)
2:15-2:45 pm	DR Integration Intro – Objectives, Goals (MacKinnon/McMahon)
2:45-3:05 pm	Break
3:05-5:00 pm	DR Integration (Sevougian) DR Roadmap (Sassani) GDSA Status (Mariner)
5:00-5:30 pm	Online Waste Library (OWL) demo (Sassani)

■ **These four talks describe how to achieve the overall goals discussed on previous slide, i.e.:**

1. Improved integration
2. Support for GDSA and safety case
3. Accomplishments vis-à-vis 2012 Roadmap
4. Potential gaps vis-à-vis 2012 Roadmap
5. Possible adjustments to R&D priorities
6. Preparation for FY19 workshops

Wednesday: Objectives

WEDNESDAY, MAY 23, 2018	
8:00-10:00 am	Argillite Disposal R&D (Includes EBS R&D) Jove-Colon/Matteo
10:00-10:20 am	Break
10:20-12:20 pm	Crystalline Disposal R&D (includes EBS R&D) Wang/Matteo
12:20-1:50 pm	Lunch on your own
1:50-3:50 pm	Salt Disposal R&D (Includes EBS R&D) Kuhlman/Matteo
3:50-4:10 pm	Break
4:10-5:40 pm	PRIORITIZE & SCOPE FY19 DR ACTIVITIES: Crystalline Breakout Session (Mariner) Salt Breakout Session (Kuhlman) DPC Breakout Session (Hardin) Argillite Breakout Session (Sassani)

■ **These three sequential host-rock-oriented sessions provide:**

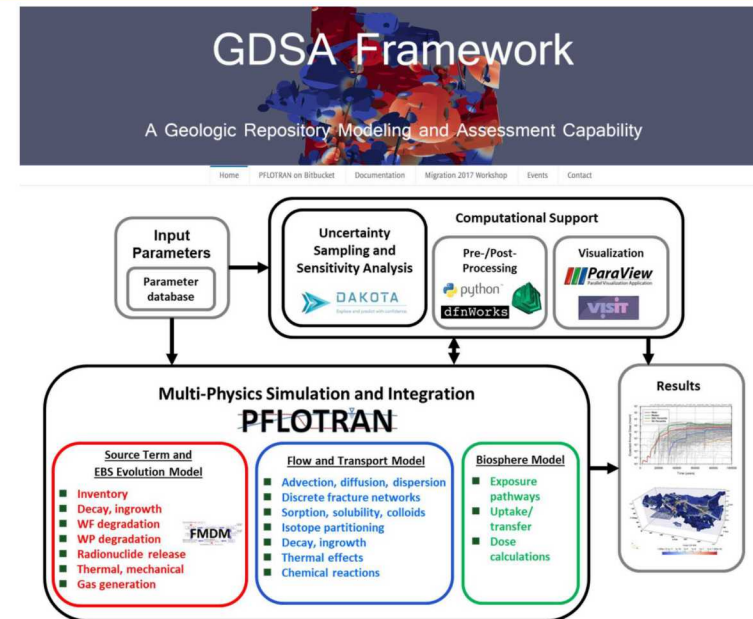
1. Technical Lead (TL) overview talks, describing accomplishments, integration, and potential R&D gaps
2. PI lightning talks describing SFWST R&D for the specific host rock, as well as related International work
3. Integration with EBS and DPC work packages

■ **These four breakout sessions (to be completed on Thursday morning) initiate:**

1. Prioritization of FY19 (and outyear) R&D activities based on priority scores and state of the art
2. Scoping or potential re-scoping of FY19 (and outyear) activities
3. “Warm-up” for FY19 integration/prioritization workshops
4. Brainstorming on process model integration with *GDSA Framework* → see next slide

Integration with *GDSA Framework* (and/or the Generic Safety Case)

- Define one or two “capability points,” as requested by DOE, e.g.,
 - Near-term (2021) “baseline” capability:
 - Process models and their implementation in *GDSA Framework* will have a certain “fidelity” that allows for a full PA calculation
 - Farther-term (2025) “enhanced” capability:
 - Process models and their implementation in *GDSA Framework* will have a higher fidelity that brings higher confidence to the generic safety case



- Year-by-year work scopes and activities should be designed and integrated to support either or both of the “capability points”
- Integration with GDSA/PA is a high ranking cross-cutting issue in the 2012 Roadmap
- We are host-rock & concept neutral, but...
 - An implied trade-off always exists between Issue/FEP importance and R&D cost, when considering planning priorities—see later slide

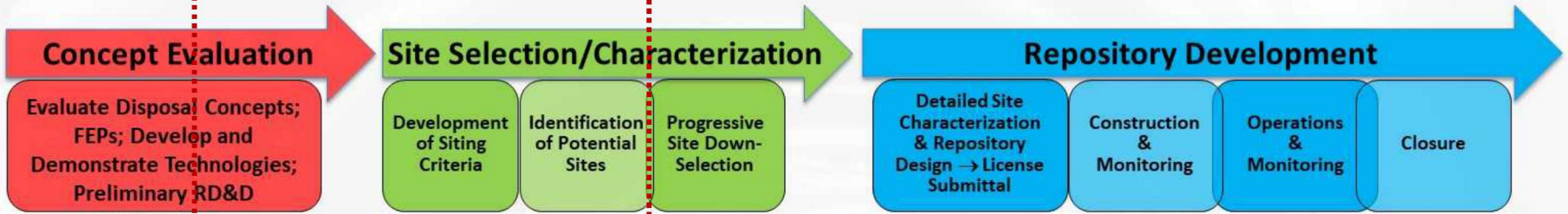
Schematic Repository Project Timeline (and maturation of safety case)

U.S. Program currently:

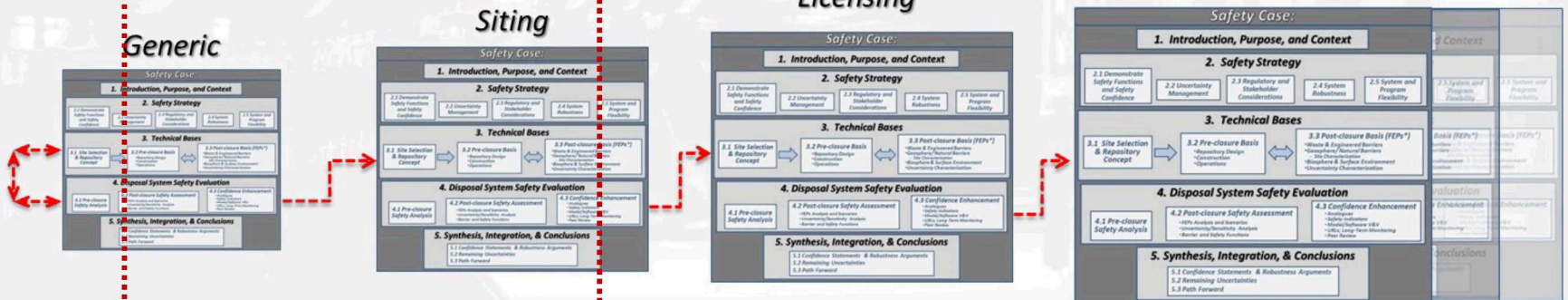
- Concept Evaluation stage
- "Generic" stage

- Baseline models
- Before site-selection
- "Pre- CD-0"

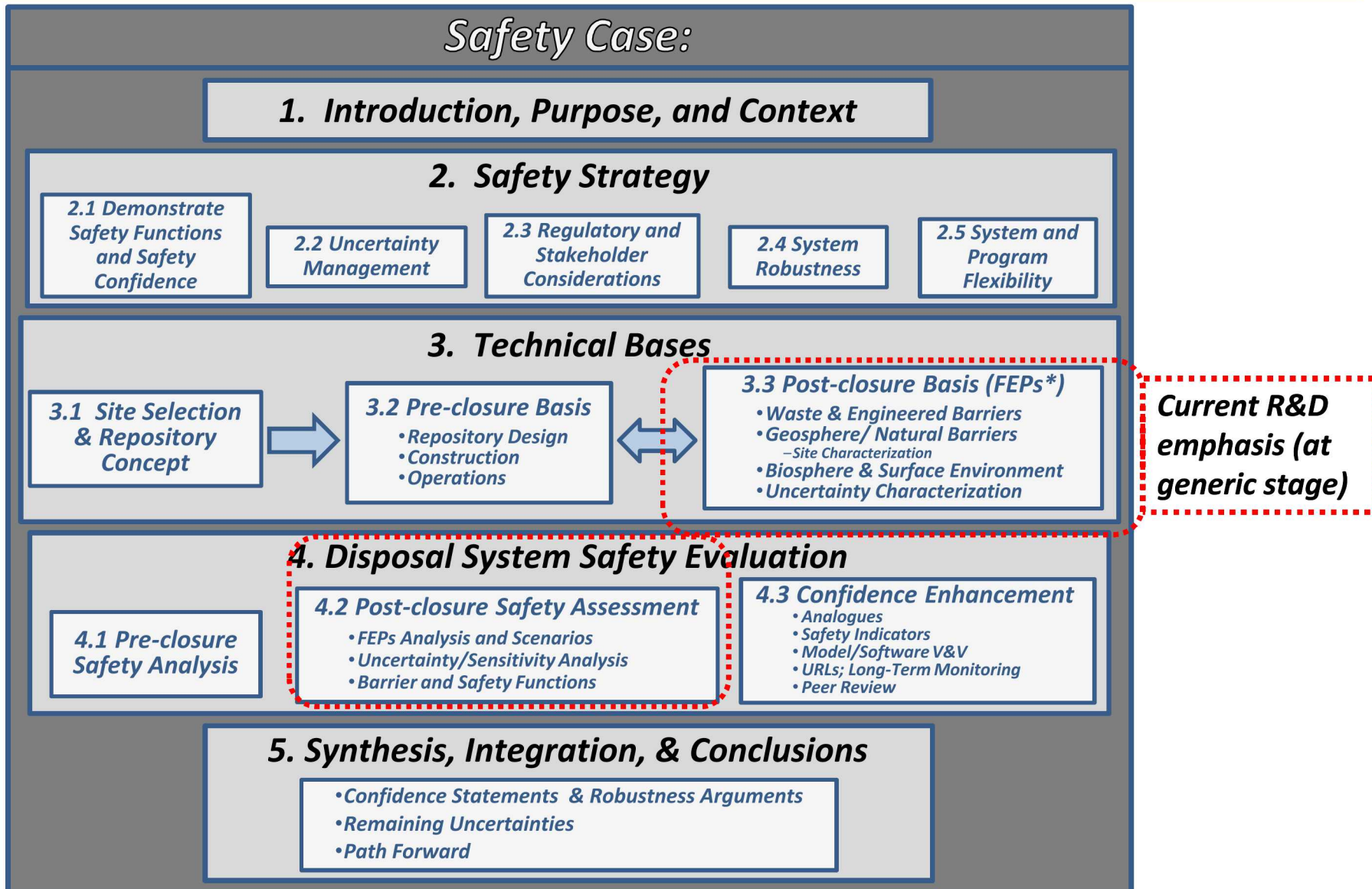
20??



Construction → Operations → Closure



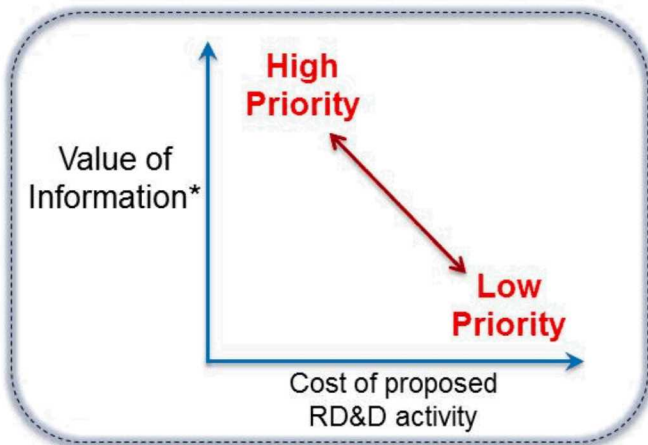
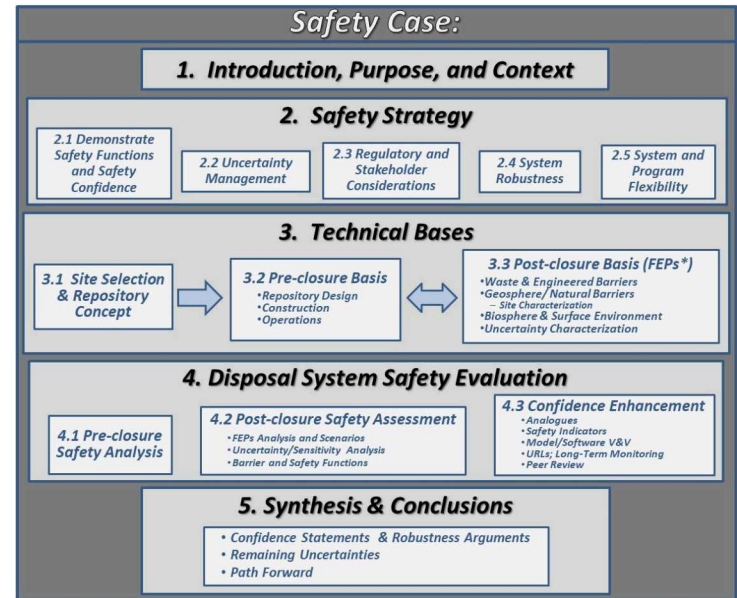
Components of Safety Case



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, i.e., increase the TRL (or KRL)
3. Other factors, e.g., cost, redundancies, synergies



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

Prioritization process can be formalized (as in 2012 UFD Roadmap)

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, to give an overall numerical score
4. Compare utilities (“rankings”) of the activities

Previous Prioritization – Roadmap

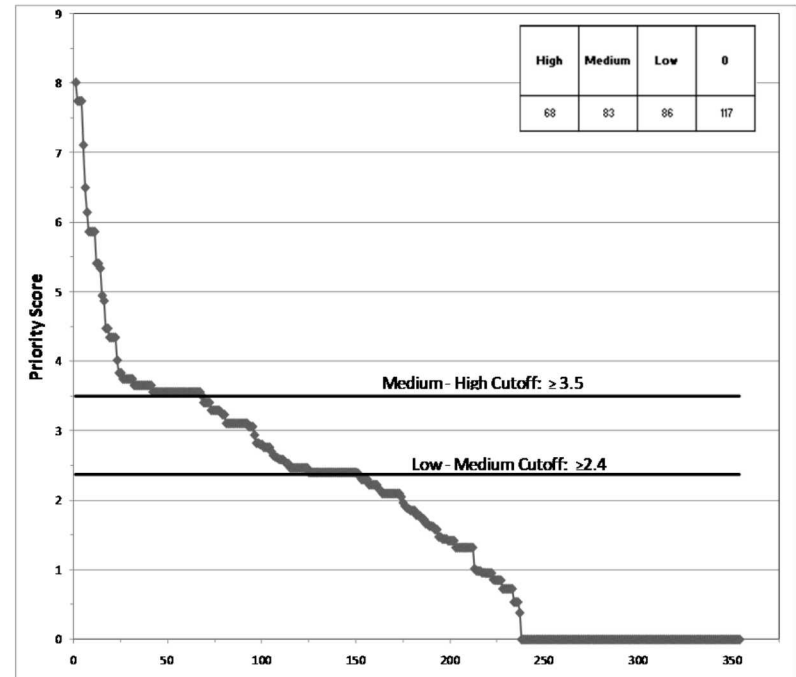
FEPs or “R&D Activities”:

“utility score”

Excerpt
(from Roadmap App. B)

UFD FEP ID No., Title, and Media	Overall Priority Score
2.2.01.01 - Evolution of EDZ - Clay/Shale	8.00
2.2.08.01 - Flow Through the Host Rock - Salt	7.73
2.2.08.02 - Flow Through the Other Geologic Units - Confining units - Aquifers - Salt	7.73
2.2.08.06 - Flow Through EDZ - Salt	7.73
2.2.08.04 - Effects of Repository Excavation on Flow Through the Host Rock - Salt	7.10
2.2.08.07 - Mineralogic Dehydration - Salt	6.49
2.2.01.01 - Evolution of EDZ - Deep Boreholes	6.13
2.2.09.01 - Chemical Characteristics of Groundwater in Host Rock - Deep Boreholes	5.86
2.2.09.02 - Chemical Characteristics of Groundwater in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers - Deep Boreholes	5.86
2.2.09.05 - Radionuclide Speciation and Solubility in Host Rock - Deep Boreholes	5.86
2.2.09.06 - Radionuclide Speciation and Solubility in Other Geologic Units (Non-Host-Rock) - Deep Boreholes	5.86
2.2.09.03 - Chemical Interactions and Evolution of Groundwater in Host Rock - Deep Boreholes	5.40
2.2.09.04 - Chemical Interactions and Evolution of Groundwater in Other Geologic Units (Non-Host-Rock) - Confining units - Aquifers - Deep Boreholes	5.40
1.2.03.01 - Seismic Activity Impacts EBS and/or EBS Components -	4.94
2.1.09.13 - Radionuclide Speciation and Solubility in EBS - In Waste Form - In Waste Package - In Backfill - In Tunnel -	4.86
2.1.03.02 - General Corrosion of Waste Packages -	4.34
2.1.03.03 - Stress Corrosion Cracking (SCC) of Waste Packages -	4.34
2.1.03.04 - Localized Corrosion of Waste Packages -	4.34
2.1.03.05 - Hydride Cracking of Waste Packages -	4.34
2.1.02.01 - SNF (Commercial, DOE) Degradation - Alteration / Phase Separation - Dissolution / Leaching - Radionuclide Release -	4.01
2.2.07.01 - Mechanical Effects on Host Rock - Salt	3.83
2.2.07.01 - Mechanical Effects on Host Rock - Clay/Shale	3.83
2.2.02.01 - Stratigraphy and Properties of Host Rock - Granite/Crystalline	3.74
2.2.02.01 - Stratigraphy and Properties of Host Rock - Deep Boreholes	3.74
2.2.02.01 - Stratigraphy and Properties of Host Rock - Salt	3.74
2.2.02.01 - Stratigraphy and Properties of Host Rock - Clay/Shale	3.74

Quantitative → qualitative score”



Objectives of Wed-Thu Breakouts

WEDNESDAY, MAY 23, 2018	
8:00-10:00 am	Argillite Disposal R&D (Includes EBS R&D) Jove-Colon/Matteo
10:00-10:20 am	Break
10:20-12:20 pm	Crystalline Disposal R&D (includes EBS R&D) Wang/Matteo
12:20-1:50 pm	Lunch on your own
1:50-3:50 pm	Salt Disposal R&D (Includes EBS R&D) Kuhlman/Matteo
3:50-4:10 pm	Break
4:10-5:40 pm	PRIORITIZE & SCOPE FY19 DR ACTIVITIES: Crystalline Breakout Session (Mariner) Salt Breakout Session (Kuhlman) DPC Breakout Session (Hardin) Argillite Breakout Session (Sassani)

THURSDAY, MAY 24, 2018	
8:00-9:15 am	PRIORITIZE & SCOPE FY19 DR ACTIVITIES (cont'd): Crystalline Breakout Session (Mariner) Salt Breakout Session (Kuhlman) DPC Breakout Session (Hardin) Argillite Breakout Session (Sassani)

NOTE: Preliminary priority scores, “gap” activities, and work scope should already have been developed prior to the May meeting and included in the updated [R&D Activities worksheet](#)

- 1. Review the priority score (PS) of each current activity (H, M, L)**
 - If R&D activities have not yet been scored, please do so
 - Map activity to an element of the Safety Case
- 2. Review/brainstorm a list of possible “gap” activities:**
 - Based on their importance to the safety case and their current state-of-the-art
 - Consider integration with other WBS elements and with GDSA
- 3. Discuss major process models: type of integration with GDSA and timeframe**
- 4. Draft a brief, preliminary, technical R&D work scope for each priority activity to be funded in FY19 and/or in outyears:**
 - Begin with highest priority FEPs/activities
 - Consider integration with other WBS elements and with GDSA

R&D Activity Priority Score – for this Workshop

- **Two prioritization methods used (but are likely to evolve/change for the FY19 DR Integration Workshops):**
 1. **2012 UFD Roadmap Score for the highest scoring related FEP(s)**
 - Use FEP (“R&D Issue) scores from App. B of Roadmap – see previous Roadmap slide
 - Does not work for certain FEPs, such as criticality – which was scored low in 2012 because of assumption of PWR waste packages instead of DPCs
 2. **Priority scoring matrix: combination of ISC (importance to safety case) and SAL (state of the art level) → see next slide**
 - ISC is determined with a simpler “utility function” than in the Roadmap – may evolve to more granularity for FY19
 - SAL is independent of the ISC score (unlike in the Roadmap)
 - Cost of activity not quantitatively factored into Priority Score

- **Use Baseline GDSA-PA Model (2021) to prioritize R&D activities with respect to system post-closure performance (effect on dose)**

R&D Activity Priority Score (using $ISC \times SAL$ product)

SAL (state of the art) value

ISC (importance to safety case) value:

ISC score	ISC Definition	Description: Max rating of (a) Safety Analysis; (b) Design, Construction, Operations; or (c) Overall Confidence	Alternative Description (see Safety Case Elements figure below)
High	High Importance to SC	If maximum rating is "High" in at least one of the three elements of the safety case (for the highest scoring related FEP in App. A of UFD Roadmap)	Knowledge gained by proposed R&D strongly affects one of the three elements of "Disposal System Safety Evaluation" in the Safety Case (pre-closure safety analysis, post-closure safety assessment, confidence enhancement)
Medium	Medium Importance to SC	If maximum rating is "Medium" in at least one of the three elements of the safety case (for the highest scoring related FEP in App. A of UFD Roadmap)	Knowledge gained strongly affects one of the Technical Bases elements of the Safety Case but the Technical Basis element itself only weakly or moderately influences a safety assessment metric
Low	Low Importance to SC	If maximum rating is "Low" in at least one of the three elements of the safety case (for the highest scoring related FEP in App. A of UFD Roadmap)	Knowledge gained is only of a supporting nature and does not strongly affect the associated process model or model inputs

State of the Art Level (SAL)	SAL Definition (use highest scoring related FEP in UFD Roadmap)	Description
5	Fundamental Gaps in Method or Fundamental Data Needs, or Both	The representation of an issue (conceptual and/or mathematical, experimental) is lacking, or the data or parameters in the representation of an issue (process) is lacking
4	Improved Representation	The representation of an issue may be technically defensible, but improved representation would be beneficial (i.e., lead to more realistic representation).
3	Improved Confidence	Methods and data exist, and the representation is technically defensible but there is not widely-agreed upon confidence in the representation (scientific community and other stakeholders).
2	Improved Defensibility	Related to confidence, but focuses on improving the technical basis, and defensibility, of how an issue (process) is represented
1	Well Understood	The representation of an issue (process) is well developed, has a strong technical basis, and is defensible. Additional R&D would add little to the current understanding

SAL:	1	2	3	4	5
ISC:					
High	L	M	M	M	H
Medium	L	M	M	M	M
Low	L	L	L	L	L

Final R&D Priority Score

R&D Integration Table (excerpt) – thanks to all who contributed!

Task #	Task Name/ (and Work Package number -- if needed or helpful for more specificity)	Brief Task Description including Relevance (and/or input) to PA/GDSA (nPA = not direct input to PA)	Code (if applicable)	<u>ISC:</u> Importance to Safety Case (ISC) (H, M, or L -- see ISC table definitions) (Identify applicable Safety Case element from the provided figure)	<u>SAL:</u> Current "State of the Art" Level (SAL = 1, 2, 3, 4, or 5 -- see SAL table definitions) (Give brief <u>update</u> to applicable state-of-the-art "discussion(s)" shown in UFD Roadmap App. A, i.e., those discussion(s) for the highest scoring related FEPs)	<u>Priority scores and draft workscope:</u> <u>Short-term (1 yr) R&D Priority Scores & Brief FY19 Work Scope Proposal</u> (Priority Score = H, M, or L, based on combined ISC and SAL -- see PS table definitions) (Also give Roadmap Score for related FEP)	Related UFD Roadmap Issue(s)/FEP(s), and associated UFD Roadmap priority scores* (Find highest scoring related FEP in App. B of UFD Roadmap)
Ongoing Crystalline/Argillite/Salt/EBS/DPC Activities							
4	SNF Degradation	<ul style="list-style-type: none"> • Implementation mixed potential model of spent fuel matrix degradation (including possible effect of Fe corrosion) • Radiolysis • Thermodynamics & stability of UO₂ degradation phases (dehyd. schoepite, studtite, metastudtite) • Alternate electrochemical modeling for UO₂ degradation 	PFLOTRAN/FMDM VASP (DFT calcs) Zuzax/Cantera	ISC = High SC element 3.3.1b	SAL = 5 <u>From Roadmap:</u> U.S. program evaluated the long-term behavior of LWR UOX in oxidizing environments. Other programs have evaluated and are modeling the degradation of UOX and MOX in reducing environments. Little information is available regarding the degradation/alteration of other UNF types.	PS Matrix Score = H; Roadmap Score = H For FY19 continue work on FMDM model development and code optimization	<ul style="list-style-type: none"> • Primary FEP is 2.1.02.01; score = 4.01 • Other related FEPs have lower scores
4a	SNF Degradation testing activities	<ul style="list-style-type: none"> • Degradation testing and integration of testing results into mixed potential model of spent fuel matrix degradation 	PFLOTRAN et al.		SAL = 5 . Little information is available regarding the degradation/alteration of other UNF types.		
5	(Pseudo) Colloid-Facilitated Transport Model	<ul style="list-style-type: none"> • Formation, stability, and transport of pseudocolloids in the near field and far field 	PFLOTRAN	ISC = High SC element 3.3.2b	SAL = 5 <u>From Roadmap:</u> Significant work has been done. But the puzzle is yet to be put together. Evidence suggests that Pu travels further than Kd models would predict.....	PS Matrix Score = H; Roadmap Score = M For FY19 begin coupling LANL colloid model to GDSA Framework	<ul style="list-style-type: none"> • FEP 2.2.09.59 and 2.2.09.60; scores = 3.29
7	Discrete Fracture Network (DFN) Model	<ul style="list-style-type: none"> • Generation and representation of realistic fracture networks • Fluid flow & transport in fracture networks • Mapping tools (dfnWorks to PFLOTRAN) • Dual continuum; matrix diffusion 	DFNWorks, PFLOTRAN, mapDFN.py, FracMan	ISC = High SC element 4.2e	SAL = 4 <u>From Roadmap:</u> The effects of geologic formation heterogeneity and their scale dependence is not fully understood. Need to consider/characterize scale dependence of properties for all physical transport processes.....	PS Matrix Score = M; Roadmap Score = H FY19 Workslope.....	<ul style="list-style-type: none"> • Primary FEP is 2.2.09.51 (crystalline); score = 3.74 • Other related FEPs also have relatively high scores: 2.2.08.01, 2.2.02.01, 2.2.05.01, 2.2.08.02
10	Salt Coupled THM processes	<ul style="list-style-type: none"> • Coupled thermal-hydrological-mechanical processes in salt EBS and EDZ 	TOUGH-FLAC	ISC = High SC elements 3.3 & 4.2	SAL = 5 <u>From Roadmap (for FEP 2.2.01.01):</u> Need to know the evolution of the characteristics of the EDZ under the thermal-mechanical and wetting changes (clay and salt). Need to understand the coupled evolution of near-field host rock (EDZ) and backfill.	PS Matrix Score = H; Roadmap Score = H FY19 workslope:	<ul style="list-style-type: none"> • Primary FEP is 2.2.08.06 (salt); score = 7.73 • Other related FEPs include 2.1.08.03 and 2.2.01.01
11	Coupled THC processes in Salt	<ul style="list-style-type: none"> • Coupled thermal-hydrologic-chemical processes in a salt repository 	FEHM, PFLOTRAN	ISC = High SC elements 3.3 & 4.2	SAL = 5 <u>From Roadmap (for FEP 2.2.08.01):</u> Need to develop improved modeling tools to represent fractures/fracture sets as discrete features in crystalline. Need information to characterize/model connectivity, channelization (e.g., tracer tests). Need to understand fracturation and healing in clays and salt. Water migration in salt is a unique process that needs to be better understood. Need to understand thermal and pressure gradients and gas generation and migration. Need to capture and validate uncertainty.		<ul style="list-style-type: none"> • Primary FEP is 2.2.08.06 (salt); score = 7.73 • Another high-score FEP is 2.2.08.04; score = 7.10

Points to be Considered During Breakout Sessions

Consider these points with the corresponding 4 objectives on Slide 10:

- 1. Rank the suite of host-rock R&D activities in order of importance to post-closure system performance and the safety case, considering state of the art and possibly cost:**
 - If the neither of the two priority scoring methods provide enough scoring granularity, brainstorm a method and/or criteria that might
- 2. When considering potential “gap” activities, i.e., new high priority activities, identify how much R&D needs to be performed “in-house” vs. how much can be leveraged internationally**
- 3. What considering integration with GDSA, identify the type of coupling that is appropriate at the first 2021 “capability point”**
- 4. Compare current PICS-NE work scope (if applicable) with draft scope in the R&D Activities Table**

Objectives of Thu Cross-Cutting Sessions

THURSDAY, MAY 24, 2018	
9:15-10:00 am	Cross-cutting activities <ul style="list-style-type: none"> • International (Birkholzer) • EBS (Matteo)
10:00-10:20 am	Break
10:20-11:30 am	DR Summary Integration & Planning Session – overall prioritization and review of cross-cutting R&D issues; review FY19 and out-year scope (Sevougian, Mariner, Sassani, Kuhlman, Hardin)
11:30-Noon	Working Group Debrief and Closing

- Breakout session leads (Mariner, Kuhlman, Hardin, Sassani) present international and EBS related activities
 - Birkholzer reviews international activity priorities
 - Matteo reviews EBS activity priorities
 - Try to integrate international and EBS activities across host rocks, as appropriate

- Review and integrate R&D activities and their priorities across all host rocks:
- Review **cross-cutting** issues
- Review contentious work scopes (if there are any)

Cross-cutting Roadmap Issues (Sassani)

- Design Concept Development (**High**)
- Generic Disposal System Modeling (**High**)
- Operations Related Research and Technology Development (**Low**)
- Knowledge Management (**Medium**)
- Site Screening and Selection Tools (**Medium**)
- Experimental and Analytical Techniques for Site Characterization (**Medium**)
- Underground Research Laboratories (**Medium**)
- *Model basis, International R&D and validation exercises, e.g., URLs and DECOVALEX* (**High**) (Prasad)

Back-Up Slides

Safety Case:

1. Introduction, Purpose, and Context

2. Safety Strategy

2.1 Management Strategy

- a. Organizational/mgmt. structure
- b. Safety culture & QA
- c. Planning and Work Control
- d. Knowledge management
- e. Oversight groups

2.2 Siting & Design Strategy

- a. National laws
- b. Site selection basis & robustness
- c. Design requirements
- d. Disposal concepts
- e. Intergenerational equity

2.3 Assessment Strategy

- a. Regulations and rules
- b. Performance goals/safety criteria
- c. Safety functions/multiple barriers
- d. Uncertainty characterization
- e. RD&D prioritization guidance

3. Technical Bases

3.1 Site Selection

- a. Consent-based siting methodology
- b. Repository concept selection
- c. FEPs Identification
- d. Technology development
- e. Transportation considerations
- f. Integration with storage facilities

3.2 Pre-closure Basis

- a. Repository design & layout
- b. Waste package design
- c. Construction requirements & schedule
- d. Operations & surface facility
- e. Waste acceptance criteria
- f. Impact of pre-closure activities on post-closure

3.3 Post-closure Bases (FEPs)

3.3.1 Waste & Engineered Barriers Technical Basis

- a. Inventory characterization
- b. WF/WP technical basis
- c. Buffer/backfill technical basis
- d. Shafts/seals technical basis
- e. UQ (aleatory, epistemic)

3.3.2 Geosphere/Natural Barriers Technical Basis

- a. Site characterization
- b. Host rock/DRZ technical basis
- c. Aquifer/other geologic units technical basis
- d. UQ (aleatory, epistemic)

3.3.3 Biosphere Technical Basis

- a. Biosphere & surface environment:
 - Surface environment
 - Flora & fauna
 - Human behavior

4. Disposal System Safety Evaluation

4.1 Pre-closure Safety Analysis

- a. Surface facilities and packaging
- b. Mining and drilling
- c. Underground transfer and handling
- d. Emplacement operations
- e. Design basis events & probabilities
- f. Pre-closure model/software validation
- g. Criticality analyses
- h. Dose/consequence analyses

4.2 Post-closure Safety Assessment

- a. FEPs analysis/screening
- b. Scenario construction/screening
- c. PA model/software validation
- d. Barrier/safety function analyses and subsystem analyses
- e. PA Model Analyses/Results
- f. Uncertainty characterization and analysis
- g. Sensitivity analyses

4.3 Confidence Enhancement

- a. R&D prioritization
- b. Natural/anthropogenic analogues
- c. URL & large-scale demonstrations
- d. Monitoring and performance confirmation
- e. International collaboration & peer review
- f. Verification, validation, transparency
- g. Qualitative and robustness arguments

5. Synthesis & Conclusions

- a. Key findings and statement(s) of confidence
- b. Discussion/disposition of remaining uncertainties
- c. Path forward

Questions to Consider When Prioritizing an R&D Activity

- **Will the associated FEP(s) affect repository performance in a meaningful way (e.g., the regulatory metric)?**
- **How far advanced is the current “state of the art” knowledge (KRL) regarding the associated FEP(s) and how/why does this particular activity best advance the state of the art?**
- **Time scale of associated transient processes within a performance assessment (10 years, 100 years.... 1,000,000 years)?**
- **Key environmental inputs required for this activity and key outputs, parameters, models supported or produced—i.e., integration with data, process models, and GDSA?**
- **Real-time integration horizon: estimate how long before the output of the proposed activity is ready for integration with GDSA and/or the Safety Case?**

GDSA Integration Tasks (excerpt)

- Two time frames: ~ 2021 and ~ 2025
- Two model fidelities: lower and higher (or “baseline” and “enhanced”)

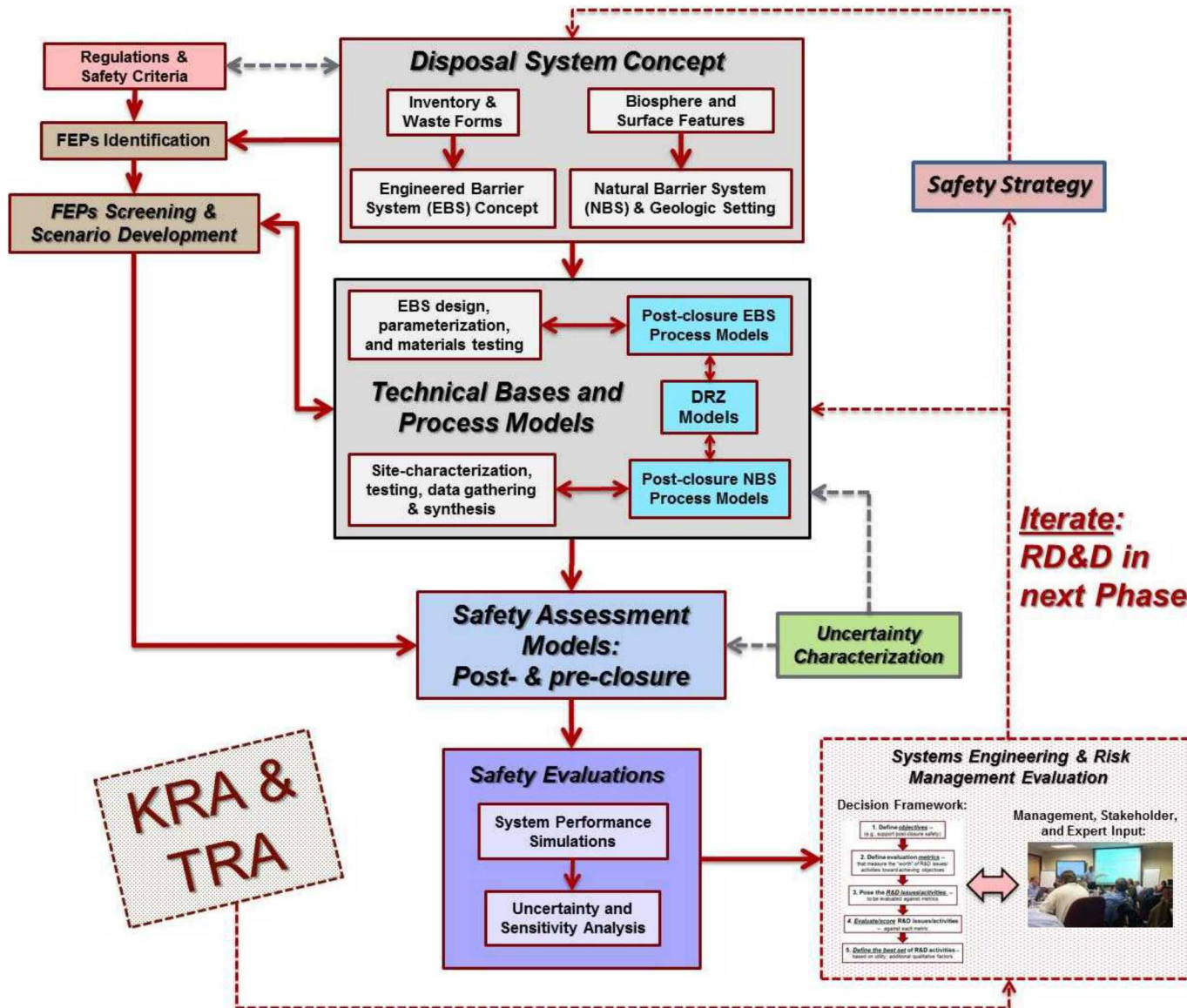
		This sheet is linked to the R&D Activities sheet...														
		C = complete; LF = lower fidelity (or what needs to be done for candidate sites evaluation); HF = higher fidelity (to support confidence in final site selection); ? = uncertain														
		By 2021 (? e.g., candidate sites selected for evaluation ?)							By 2025 (? e.g., final site selected ?)							
Priority	Task #	Process Model	Argillite	Crystalline	Salt	DBH (Cs/Sr)	2021 GDSA LOE	Notes	Status	Argillite	Crystalline	Salt	DBH (Cs/Sr)	2025 GDSA LOE	Notes	Status
N/A	A	Hydrology (H)	HF	HF	HF	HF			done	HF	HF	HF	HF			done
N/A	B	Thermal (T)	HF	HF	HF	HF			done	HF	HF	HF	HF			done
1	C	Radionuclide Transport & Chemistry	LF -> HF?	LF -> HF?	LF -> HF?	LF -> HF?		LF = Kds	done	HF	HF	HF	HF	H	HF = full reactive transport	available
2	83	Waste Form-Canister-Buffer Discretization (1D -> 3D)	LF	LF	LF	LF	M			HF?	HF?	HF?	HF?	H	see Task #65	
3	63	Basic biosphere model	LF	LF	LF	LF	L									
4	4	SNF Degradation	LF -> HF?	LF -> HF?	LF -> HF?		M	LF = Arrhenius law		HF	HF	HF			HF = FMDM	
N/A	84	HLW WF degradation (simplified)	LF	LF	LF		C		done	HF	HF	HF				
5	8	HLW WF degradation (process model)								HF	HF	HF		H		
6	68	Simplified Representation of Mechanical processes in PA			LF (IC)	?	M	Initial condition at closure				HF	?	H		
7	5	(Pseudo) Colloid-Facilitated Transport Model	HF	HF		HF	M			HF	HF		HF		Assume complete by 2020	
8	6	Intrinsic Colloids	HF	HF	?	HF	M			HF	HF	HF	HF		Assume complete by 2020	
9	13	Simplified Representation of THMC processes in EBS (clay illitization)	LF	LF	LF	?	M	LF = response surface by 2020		LF	LF	LF	?	H	Probably not complete at HF level even in 2024	
9	14	Simplified Representation of THM (BBM) model of buffer materials (unsaturated)	LF	LF	LF	?	M	LF = response surface by 2020		LF	LF	LF	?	H	Probably not complete at HF level even in 2024	
9	15	Simplified Representation of Rigid-Body-Spring-Network (RBSN)	LF	LF	LF	?	M	LF = response surface by 2020		LF	LF	LF	?	M - H	Probably not complete at HF level even in 2024	
10	7	Discrete Fracture Network (DFN) Model		LF		LF	M - H				HF		HF	H		
N/A	85	WP Degradation Model Framework	?	LF	?	LF	C									
11	9	Waste Package Degradation Model (mechanistic)	?	LF	?	LF	L - M	Some additional effort to include all mechanisms		?	HF	?	HF	H		
12	69	Full Representation of Chemical processes in PA	LF -> HF?	LF -> HF?	LF -> HF?	LF -> HF?	M	part of Task #83		HF	HF	HF	HF	H		
13	70	Pitzer model			HF	HF	M - H			HF	HF	HF	HF	M - H		
14	52	In-Package Flow	LF	LF	LF		M			LF	LF	LF		H	Probably not implemented even for 2024 (so maybe only M)	
14	53	In-Package Chemistry	LF	LF	LF	LF	M	Assume some LF version of Task 53		HF	HF	HF	HF	H		
15	51	Cladding Degradation	LF	LF	LF		M	Assume some LF version of Task 51		HF	HF	HF		H		

Working Integration Timeline – 2020?

- This is a snapshot of the current working file in Excel – will be revised in preparation for FY19 Integration Workshops....

This sheet is linked to the GDSA Tasks sheet...		GDSA LOE	Fraction of task	GDSA Priority	Status/ Notes			GDSA LOE	Fraction of task	GDSA Priority	Status/ Notes			GDSA LOE	Fraction of task	GDSA Priority	Status/ Notes
2018						2019						2020					
5	(Pseudo) Colloid-Facilitated Transport Model	M	/2	H	start this year	6	Intrinsic Colloids	M			combine with pseudo-colloids	7	Discrete Fracture Network (DFN) Model	M - H	/3	H	real DFN w/ matrix diffusion & thermal
13	Simplified Representation of THMC processes in EBS (clay illitization)	M	/2	H	use GDSA reference case; LF = response surf	5	(Pseudo) Colloid-Facilitated Transport Model	M	/2	H	finish this year	53	In-Package Chemistry	M	/2		Jerden's work?
14	Simplified Representation of THM (BBM) model of buffer materials (unsaturated)	M	/2	H	use GDSA reference case; LF = response surf	13	Simplified Representation of THMC processes in EBS (clay illitization)	M	/2	H	use GDSA reference case; LF = response surf	52	In-Package Flow	M			
10	Salt Coupled THM processes	H	/2	H	use GDSA reference case; LF = response surf	14	Simplified Representation of THM (BBM) model of buffer materials (unsaturated)	M	/2	H	use GDSA reference case; LF = response surf	69	Full Representation of Chemical processes in PA	M	/2		Carlos' model? Also, HeeHo
7	Discrete Fracture Network (DFN) Model	M - H	/3	H	real DFN w/ matrix diffusion & heat	10	Salt Coupled THM processes	H	/2	H	use GDSA reference case; LF = response surf	51	Cladding Degradation	M			
68	Simplified Representation of Mechanical processes in PA	M		H	LF = response surf	15	Simplified Representation of Rigid-Body-Spring-Network (RBSN)	M			DRZ fractures (not needed in Pierre shale?) LF = response surf	73	Other missing FEPs (processes) SF-17SN01030401 SF-17SN01050402	M - H	/2		Funding dependent
83	Waste Form-Canister-Buffer Discretization (1D -> 3D)	M		M	ongoing; integrate with Carlos	7	Discrete Fracture Network (DFN) Model	M - H	/3	H	real DFN w/ matrix diffusion & heat	79	Disruptive events SF-17SN01030401 SF-17SN01050402	H+	/2		Funding dependent
78	PFLOTTRAN improvements	L		M	Checkpoint/restart capability for new process models	53	In-Package Chemistry	M	/2		Jerden's work?	72	Surface processes and features	M			
80	Species and element properties	L		M	temp-dependent solubilities	69	Full Representation of Chemical processes in PA	M	/2		Carlos' model? Also, HeeHo	64	Grid refinement	M	/2	L	
80	Species and element properties	L		M	Species-specific diffusivities	70	Pitzer model	M - H	/2	L	Wolery version - do we have enough staff to do?	62	QA, V&V (documentation and tests)	H			ongoing, partly funded by WIPP
9	Waste Package Degradation Model (mechanistic)	L - M	/2	M	Start in 2018 for LC (include breach area)	9	Waste Package Degradation Model (mechanistic)	L - M	/2	M	Start in 2018 for LC (include breach area)						
70	Pitzer model	M - H	/2	L	Wolery version - do we have enough staff to do?	73	Other missing FEPs (processes) SF-17SN01030401 SF-17SN01050402	M - H	/2		Funding dependent						
74	Implicit solution for decay and ingrowth	M		L	lower priority for 2018	79	Disruptive events SF-17SN01030401 SF-17SN01050402	H+	/2		Funding dependent						
62	QA, V&V (documentation and tests)	H		H	ongoing, partly funded by WIPP	66	Operator splitting for reactive transport	L - M		L	low priority						
						86	Multi-Component Gas Transport	L - M		L	low priority						
						64	Grid refinement	M	/2	L	low priority						
						62	QA, V&V (documentation and tests)	H		H	ongoing, partly funded by WIPP						

Evolution and Iteration of Technical Bases and Safety Assessment



Technical Elements of an Alternative Safety Strategy

1. Demonstrate Safety Functions and Safety Confidence

- R&D, testing, and design are formulated around major safety functions, barrier capabilities, and regulatory requirements
- Safety assessments and safety case arguments are made periodically to show the operation of the safety functions
- Safety case is updated periodically and informs R&D program
- Multiple lines of evidence are formulated (e.g., natural and man-made analogues)
- Robust and transparent QA program

2. Uncertainty Management

- Reduce uncertainties through testing, characterization, and R&D
- Avoid uncertainties through siting and design
- Acknowledge remaining uncertainties in the Safety Case
- Develop stylized human intrusion scenario

3. Regulatory and Stakeholder Considerations

- National regulations and performance objectives inform siting, design, uncertainty management, and safety assessments
- Credibility is maintained:
 - Openness regarding any unresolved issues
 - Transparency in project operations and documentation
 - Traceability of assumptions, data, and records
 - Periodic peer reviews

4. System Robustness

- Select a robust site:
 - stable geologic, geochemical, and mechanical characteristics
 - unlikely external events (tectonism, volcanism)
 - minimal nearby mineral resources
- Select/design engineered materials to be robust and to mitigate uncertainties in the given host rock environment
- Multiple and complementary barriers:
 - Both engineered and natural
 - Uncertainties in one barrier/component offset by performance of another
- Ensure that the delay/retardation safety function will operate after failure of containment function (e.g., with an appropriate buffer)
- Safety assessments show that few processes/parameters control system performance

5. System and Program Flexibility

- Design can be modified based on unexpected technical difficulties or uncertainties
- Design, tests, and models can adapt to scientific and engineering advances (over decades)
- The design can adapt to major project decision points
- Peer review recommendations can be accommodated
- Safety assessment results can be accommodated in repository design and can alter R&D directions