U.S. Department of Energy
Office of Civilian Radioactive Waste Management

DOE's Repository Safety Strategy Revision 4--Postclosure Safety Strategy

Presented to:

DOE/NRC Technical Exchange on Total System Performance Assessment (TSPA) for Yucca Mountain
San Antonio, Texas

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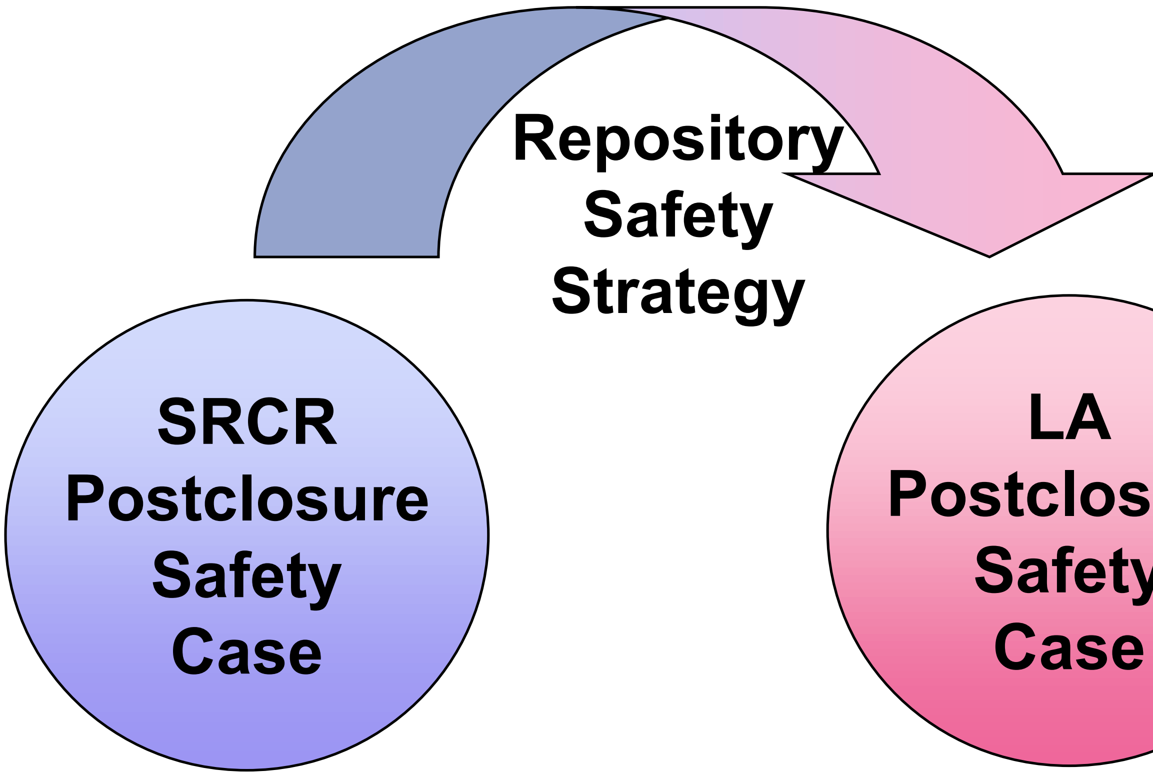
YUCCA MOUNTAIN PROJECT

Repository Safety Strategy is a Plan



This plan is determined by management after technical input

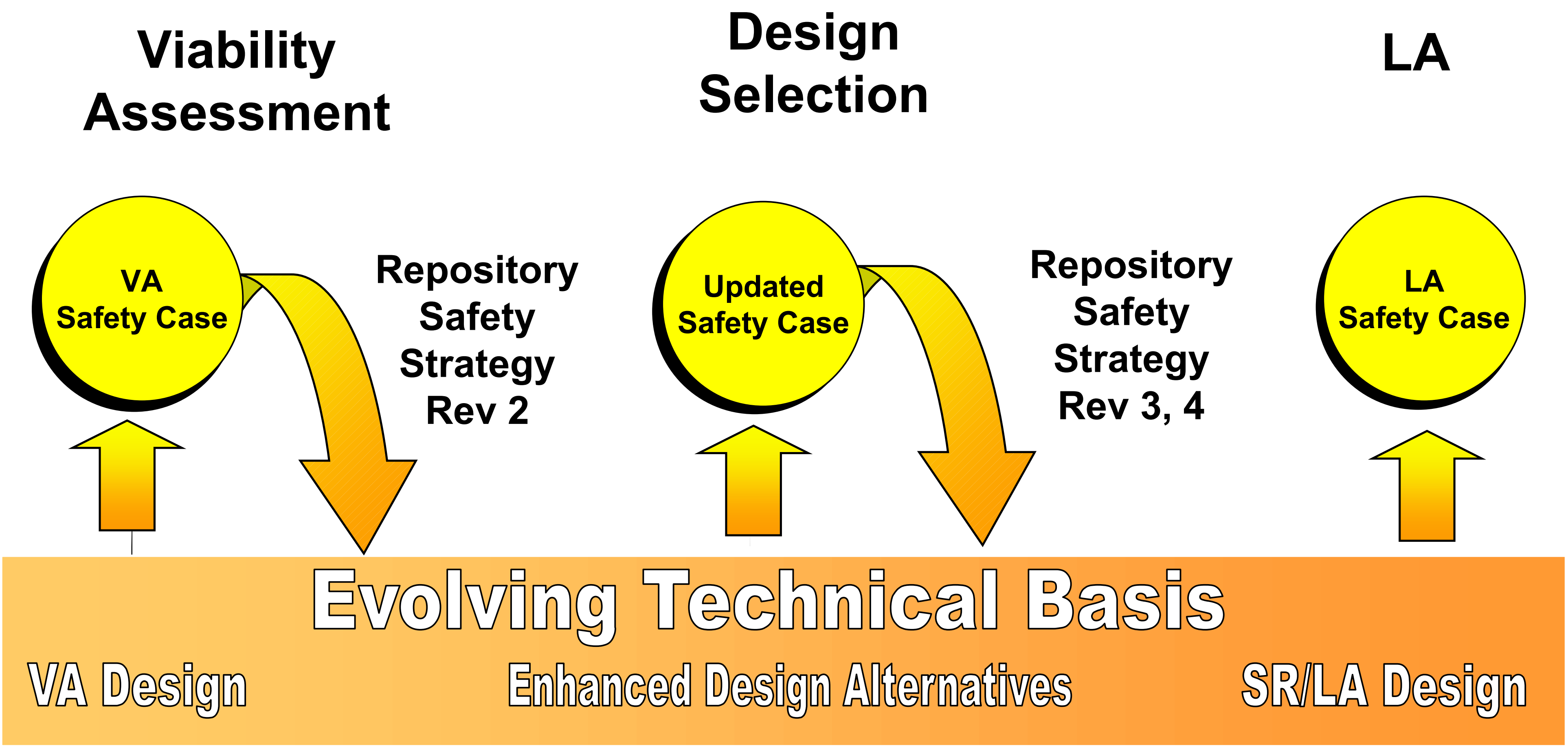
Development of Strategy Involves a Sequence of Assessments

- **Quantitative assessments performed within context of TSPA-SR**
  - Based upon information in AMRs and PMRs
  - Analysis of expected performance
  - Uncertainty, sensitivity, and barrier importance analyses
- **Qualitative assessment of confidence and unquantified uncertainty determined from numerous workshops with AMR and PMR leads**
- **Additional judgment will be applied in scientific reviews of SR products**

Focus of the Assessments for the Repository Safety Strategy

- **Principal factors--factors of the multiple barrier system that are necessary and sufficient to determine postclosure safety**
- **Performance assessment--analyses and supporting technical information to show whether regulatory postclosure performance objective is met**
- **Measures to provide additional assurance of postclosure safety**

Revising the Repository Safety Strategy



Revision 3 of the Repository Safety Strategy

- **Principal Factors**
  - Subjective judgements about factors expected to be important to performance
  - Judgements supported by “barrier neutralization” analyses
  - No consideration of disruptive FEPs
- **Performance Assessment**
  - VA models
- **Measures to Increase Assurance of Safety**
  - Preliminary consideration of safety margins and defense-in-depth
  - Initial plans for safety assurance, performance confirmation

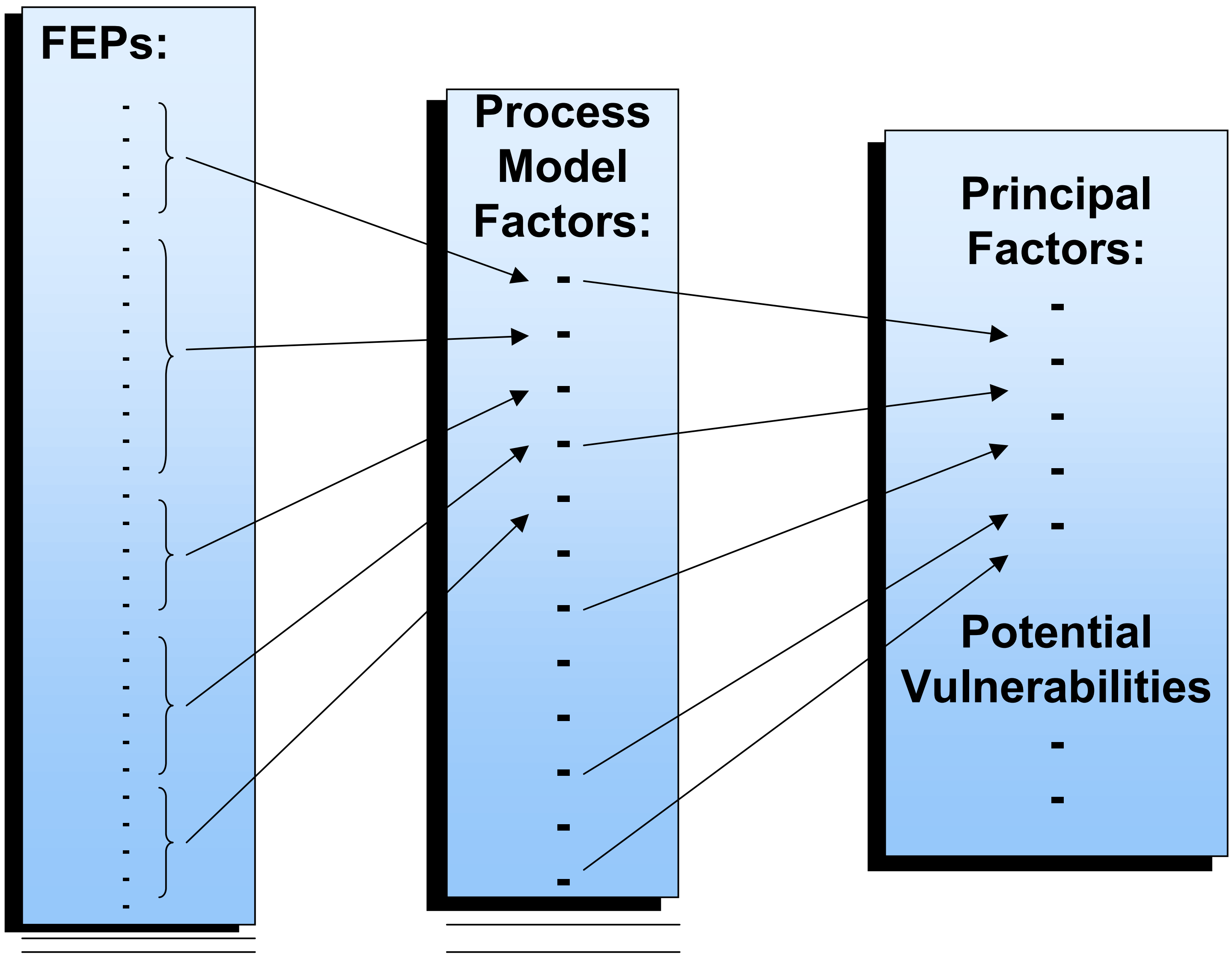
Revision 4 of the Repository Safety Strategy

- **Principal Factors**
  - Based on extensive TSPA analyses and barrier importance analyses
  - TSPA includes both nominal and igneous activity scenarios
- **Performance Assessment**
  - Updated models fully documented in PMRs and AMRs
  - Analyses fully probabilistic to address range of uncertainties
- **Measures to Increase Assurance of Safety**
  - Full evaluation of safety margins and defense-in-depth
  - Full documentation of potentially disruptive FEPs
  - Rev 1 of Performance Confirmation Plan

Status of Repository Safety Strategy for SRCR

Assess Information Needs	Completed in FY 00 Plan
Update Information - Design	Completed System Design Descriptions
Update Information - Improve models	Completed 122 AMRs, 9 PMRs
Update Information - Improve Scientific Basis	Completed/ongoing tests: ESF niches, Nye Co. drilling, Busted Butte, Drift Scale Test, EBS tests, materials tests
Assess performance	Completed TSPA-SR model Ongoing uncertainty, sensitivity and barrier importance analyses
Update Safety Case	Completed identification of process model factors and barriers Ongoing analysis to identify principal factors
Assess Information Needs	Ongoing in FY 01 Planning

Concept



FEPs:
Process Model Factors:
Principal Factors:
Potential Vulnerabilities

Example of Relationship Between FEPs and Process Model Factors

Table B-7. Features, Events, and Processes Considered for Waste Package Degradation Model

PMR	FEP Number	FEP Title	Process Model Factor
Waste Package (FEPs analyzed in ANL-EBS-PA-000002 Rev 00)	2.1.03.01.00	Corrosion of waste containers	Waste Package Degradation and Performance
	2.1.03.02.00	Stress corrosion cracking of waste containers	
	2.1.03.03.00	Pitting of waste containers	
	2.1.03.05.00	Microbially-mediated corrosion of waste container	
	2.1.03.11.00	Container form	
	2.1.03.12.00	Container failure (long-term)	
	2.1.10.01.00	Biological activity in waste and EBS	
	2.1.11.06.00	Thermal sensitization of waste containers increases fragility	
	2.1.06.06.00	Effects and degradation of drip shield (general corrosion, localized corrosion, microbial effects)	Drip Shield Degradation and Performance
	1.2.02.03.00	Fault movement shears waste container	Excluded from TSPA
	1.2.03.02.00	Seismic vibration causes container failure (effects on either waste package or drip shield excluded by design)	
	2.1.03.04.00	Hydride cracking of waste containers	
	2.1.03.06.00	Internal corrosion of waste container	
	2.1.03.07.00	Mechanical impact on waste container (effects of rockfall on drip shield or on waste package—even if drip shield is not present—excluded by design)	
	2.1.03.08.00	Juvenile and early failure of waste containers (initial defects of waste packages or drip shields sufficient to result in juvenile failure excluded)	
	2.1.03.09.00	Copper corrosion	
	2.1.03.10.00	Container healing	
	2.1.06.07.00	Effects at material interfaces	
	2.1.07.01.00	Rockfall (large block)	
	2.1.07.05.00	Creeping of metallic materials in the EBS	
	2.1.09.03.00	Volume increase of corrosion products	
	2.1.09.09.00	Electrochemical effects (electrophoresis, galvanic coupling) in waste and EBS	
	2.1.11.05.00	Differing thermal expansion of repository components	
	2.1.12.03.00	Gas generation (H2) from metal corrosion	
	2.1.13.01.00	Radiolysis	

Selected Process Model Factors

Climate	In-drift moisture distribution (and removal)	DHLW degradation and performance	EBS (invert) degradation and performance
Net infiltration	Waste package degradation and performance	DSNF degradation and performance	UZ radionuclide transport
UZ flow	Drip shield degradation and perfomance	Dissolved radionuclide concentrations	Coupled effects on UZ radionuclide transport
Coupled effects on UZ flow	Radionuclide distribution in repository	Colloid associated radionuclide concentrations	SZ flow
Seepage into emplacement drifts	In-package environments	Gaseous radionuclide source term	Changes in SZ flow
Coupled effects on seepage	Cladding degradation and performance	Seismic effects on source term	SZ radionuclide transport
In-drift physical and chemical environments	CSNF degradation and performance	In-package radionuclide transport	Biosphere dose conversion factors

TSPA Sensitivity/Importance Studies

- **Fully probabilistic base case up to 100,000 years**
  - Nominal + igneous activity scenarios
  - Human intrusion scenario
- **Numerous sensitivity and uncertainty analyses to assess uncertainties captured in TSPA and support FEP screening**
- **Barriers importance analyses to identify principal factors and address defense-in-depth issues**
  - Degraded barrier analyses
  - Neutralized barriers analyses

Preliminary Principal Factors

- Critical to Performance
  - Waste package performance (nominal scenario)
  - Probability of igneous intrusion (igneous activity scenario)
  - Repository response to igneous intrusion (igneous activity scenario)
- Assurance factors
  - Drip shield performance
  - Seepage
  - Radionuclide concentrations at the source
  - Radionuclide travel time in UZ and SZ
  - Biosphere dose conversion factors

Preliminary Principal Factors

Factors	RSS3 Principal Factors	RSS4	
		RSS4 Principal Factors	Rationale
Waste Package Performance	✔	✔	Waste packages expected to remain intact for >>10,000 years and prevent any release well beyond regulatory period.
Seepage into Emplacement Drifts	✔	✔	Invoked for defense-in-depth. Affects release of solubility-limited radionuclides after waste packages have breached.
Drip Shield Performance	✔	✔	Invoked for defense-in-depth. Redundant barrier to prevent exposure of waste to water.
Dissolved Radionuclide Concentrations	✔	✔	Invoked for defense-in-depth. Affects release of radionuclides after waste packages have breached
Colloid-Associated Radionuclide Concentrations		✔	Invoked for defense-in-depth. Affects release of radionuclides after waste packages have breached
UZ Radionuclide Travel Time	✔	✔	Invoked for defense-in-depth. Affects release of radionuclides after waste packages have breached
SZ Radionuclide Travel Time	✔	✔	Invoked for defense-in-depth. Affects release of radionuclides after waste packages have breached
Wellhead Dilution	✔		No longer considered as Principal Factor because dilution factors will be determined by regulation
Igneous Activity--Probability		✔	Release possible in less than 10,000 years. Risk depends on probability of occurrence
Igneous Activity—Repository Effects		✔	Release possible in less than 10,000 years. Risk depends on damage to waste packages and drip shields
Biosphere Dose Conversion Factors		✔	Release possible in less than 10,000 years. Risk depends on biosphere transport and uptake

Barriers Potentially Important to Waste Isolation

- Overlying rock (including capillary effects)
- Drip shield
- Waste package
- UZ radionuclide transport barrier
- SZ radionuclide transport barrier
- Other barriers
  - Spent fuel cladding
  - Waste canister
  - Drift invert
  - Inner waste package barrier

Additional Work Needed to Complete the Postclosure Safety Case

Measures to Increase Assurance	Applicability to Potential Vulnerabilities	Other Applicability	Adequacy of Current Information
Quality of the Performance Assessment	Addresses issue of uncertainty	• Standard approach to assurance of safety in licensing • Recommended by NEA	• Models will be traceable to FEPs • Comprehensive analysis of parameter uncertainty will be conducted • Extensive sensitivity and importance analyses to identify areas where uncertainty may be important • May be some over-conservatisms that obscure understanding
Safety Margins and Defense-in-Depth	Addresses issue of uncertainty, reliability of individual barriers	• Standard approach to assurance of safety in licensing • Recommended by NEA	• System contains substantial margin in 1st 20,000 year • System may not have adequate defense-in-depth with respect to the performance objective of the proposed rule
Explicit Consideration of Potentially Disruptive Processes and Events	Directly addresses potential for igneous activity	• Recommended by NEA	• Traceability of FEPs screening to process models is incomplete • Basis for excluding nuclear criticality, seismic activity, water table rise is incomplete but proceeding • Analyses of igneous activity and human intrusion is incomplete but proceeding
Insights from Natural Analogues	Could increase confidence in long-term behavior of metal passive layers, transport models, effects of heat on host rock	• Recommended by NWTRB, NEA	• Some information is available • Additional information could be obtained during performance confirmation period
Safety Assurance • **Performance Confirmation Testing** • **Retrievability** • **Closure decisions** • **Postclosure montoring**	Do not directly address identified vulnerabilities	• Required by Act and Proposed rule • Address broader confidence issue	• Plans not completely developed at present

Work to Address Specific Vulnerabilities

Potential Vulnerabilities	Recommended Approaches
1. Adequacy of treatment of model uncertainty	• Mitigate uncertainties through defense-in-depth • Ensure effects of rockfall analyzed
2. Over-conservatism in some models	• Conduct studies to determine appropriateness of reducing over-conservatism in key models
3. Thermal loading issues	• Improve basis for selecting a thermal design by LA • Utilize flexible design that permits a decision after performance confirmation testing • Maintain options until thermal design can be selected before emplacement
4. Potential for igneous activity at this site	• Demonstrate low probability of occurrence • Demonstrate low risk and substantial margin
5. Reliability of complex metal barriers	• Mitigate uncertainties through defense-in-depth • Utilize alternative engineered barrier concepts
6. Possibility of peak dose rate exceeding 100 mrem/year	• Reduce conservatism in key models – Solubilities of neptunium and plutonium – UZ flow and transport – SZ flow and transport

Steps to Complete the Repository Safety Strategy

Complete uncertainty, sensitivity and barrier importance analyses for nominal and disruptive event scenarios	June -July
Complete documentation of TSPA-SR	July - August
Complete RSS Rev 4	July - August
Complete reviews of TSPA-SR and RSS Rev 4	August - September
Complete SRCR reviews	September - November