U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

NUCLEAR WASTE TECHNICAL REVIEW BOARD
JOINT PANELS ON HYDROGEOLOGY & GEOCHEMISTRY AND STRUCTURAL GEOLOGY & GEOENGINEERING

SUBJECT: TESTING REQUIREMENTS FOR THERMAL LOADING DECISIONS IN THE PROGRAM APPROACH

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Overview

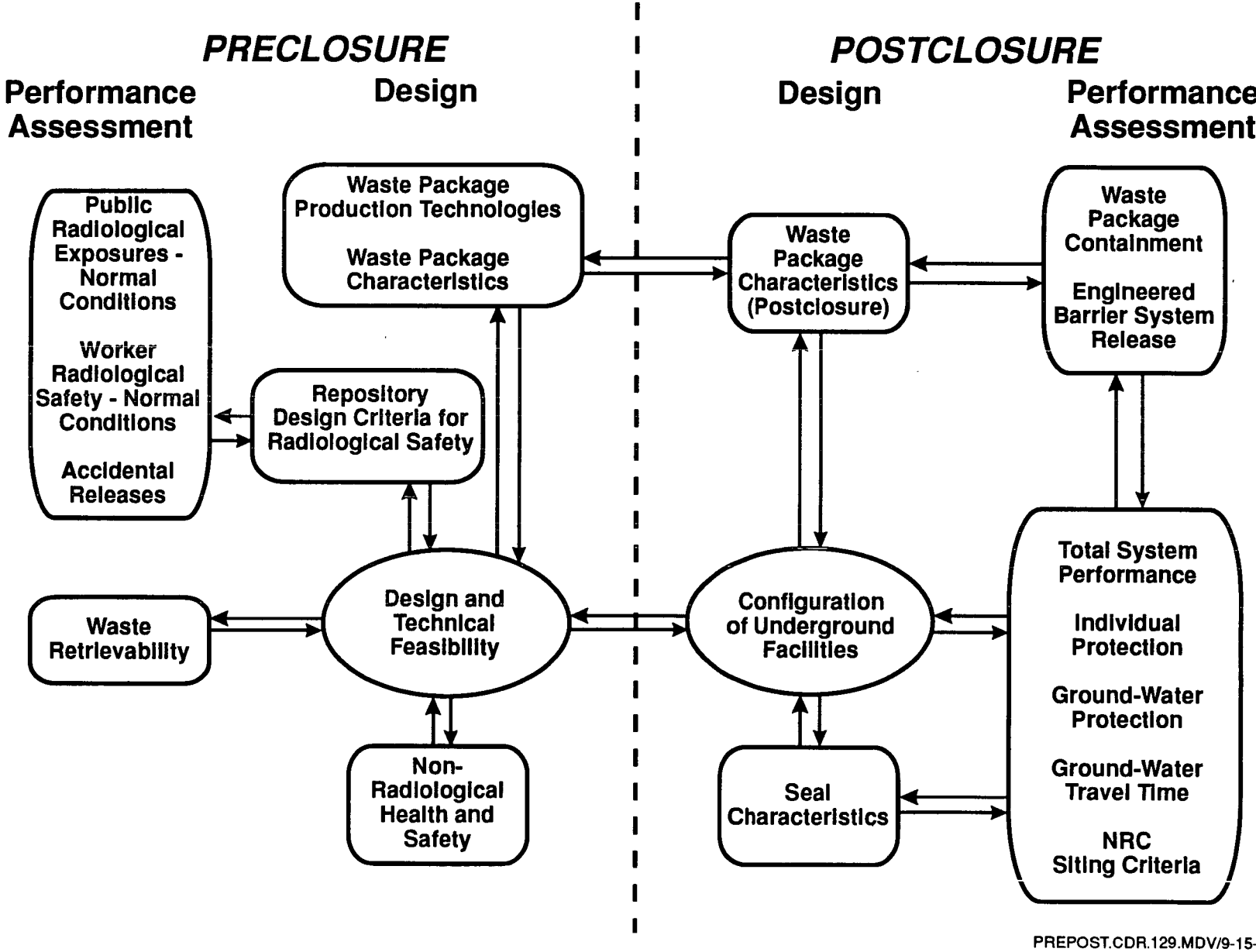
- Site Characterization Plan as the Basis
- Implementing the SCP Licensing Strategy Through the Program Approach
- Thermal Strategy Perspective
- Sequencing the Exploratory Studies Facility Testing Program

Site Characterization Plan (SCP) Examined Repository Regulatory Requirements

- Developed strategies for functional performance
- Resulted in goals for component performance including thermal goals

Thermal aspects of strategies primarily described in postclosure repository design portions of the plan

Linkages Between Preclosure and Postclosure Design



SCP Thermal Design Goals Have Been Revisited

Summary of SCP Design Goals for Thermal Loading

GOAL	POSSIBLE EFFECT ON DESIGN
T < 200°C ONE METER FROM BOREHOLE WALL	VARY PACKAGE LOADING, BOREHOLE AND DRIFT SPACING; LIMIT APD
T < 275°C AT BOREHOLE WALL AND T < 350°C AT CONTAINER CENTERLINE	VARY PACKAGE LOADING, BOREHOLE AND DRIFT SPACING; LIMIT APD
ΔT < 6°C ON SURFACE AND SURFACE UPLIFT < 0.5 cm/yr	LIMIT APD
NO INTACT ROCK FAILURE OR CONTINUOUS JOINT SLIP	LIMIT APD
LOCAL SATURATION <90%	LIMIT USABLE AREA
BOREHOLE WALLS ABOVE BOILING > 300 yrs	RAISE PACKAGE LOADING AND APD
T < 115°C IN TSw3, CHnz, AND CHnv	LIMIT APD

SCP Thermal Goals Evaluated

Process	Performance Measure	Thermal Goal
Limit temperature changes in selected barriers	Temperature	Limit temperature of CHn to < 115°C Limit temperature of TSw3 to < 115°C [illegible]
Limit deleterious rock movement or preferred pathways	Rock displacement	Relative motion < 1m at the top of TSw1 - No intact rock failure - No continuous joint slip
Limit impact on surface environment	Temperature Surface uplift	Rise in surface temperature <6°C [illegible] Surface uplift < 0.5 cm/year
~~Vary borehole and drift spacing to control thermal loading and container temperature~~ [illegible]	Thermal loading Borehole wall temperature Rock mass temperature	Design basis thermal loading less than allowable thermal loading ~~Temperature <275°C~~ ~~Borehole or emplacement drift [illegible] wall temperature <200°C~~
Limit potentia[illegible] collapse		

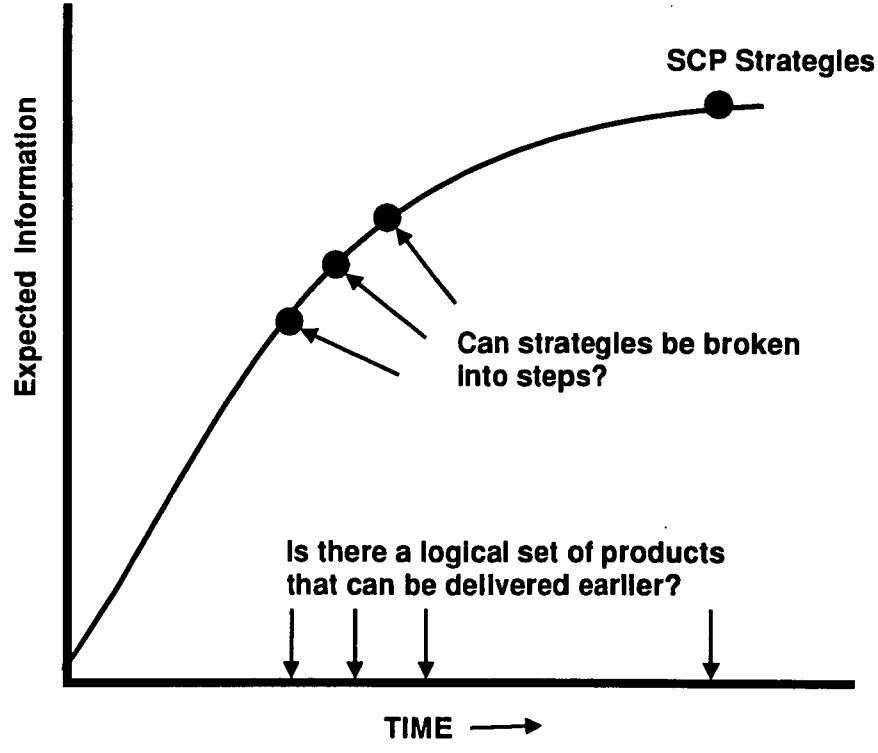
SCP Thermal Goals Evaluated (Continued)

Process	Performance Measure	Thermal Goal
Limit corrosiveness of container environment	Time container is above boiling temperature	~~Majority of borehole walls above boiling temperature of water for >300 years~~ [illegible]
Limit degradation of fuel matrix or cladding	Temperature	Fuel cladding temperature < 350°C High level waste glass temperature < 500°C
Limit access drift temperature	Temperature	Wall temperature in access drift < 50°C for first 50 years
Provide for hydrologic drainage	Temperature	~~Rock temperatures midway between emplacement drifts < 100°C~~
Limit emplacement drift temperature	Temperature	*Wall temperatures in emplacement drift < 50°C for first 50 years for horizontal borehole*

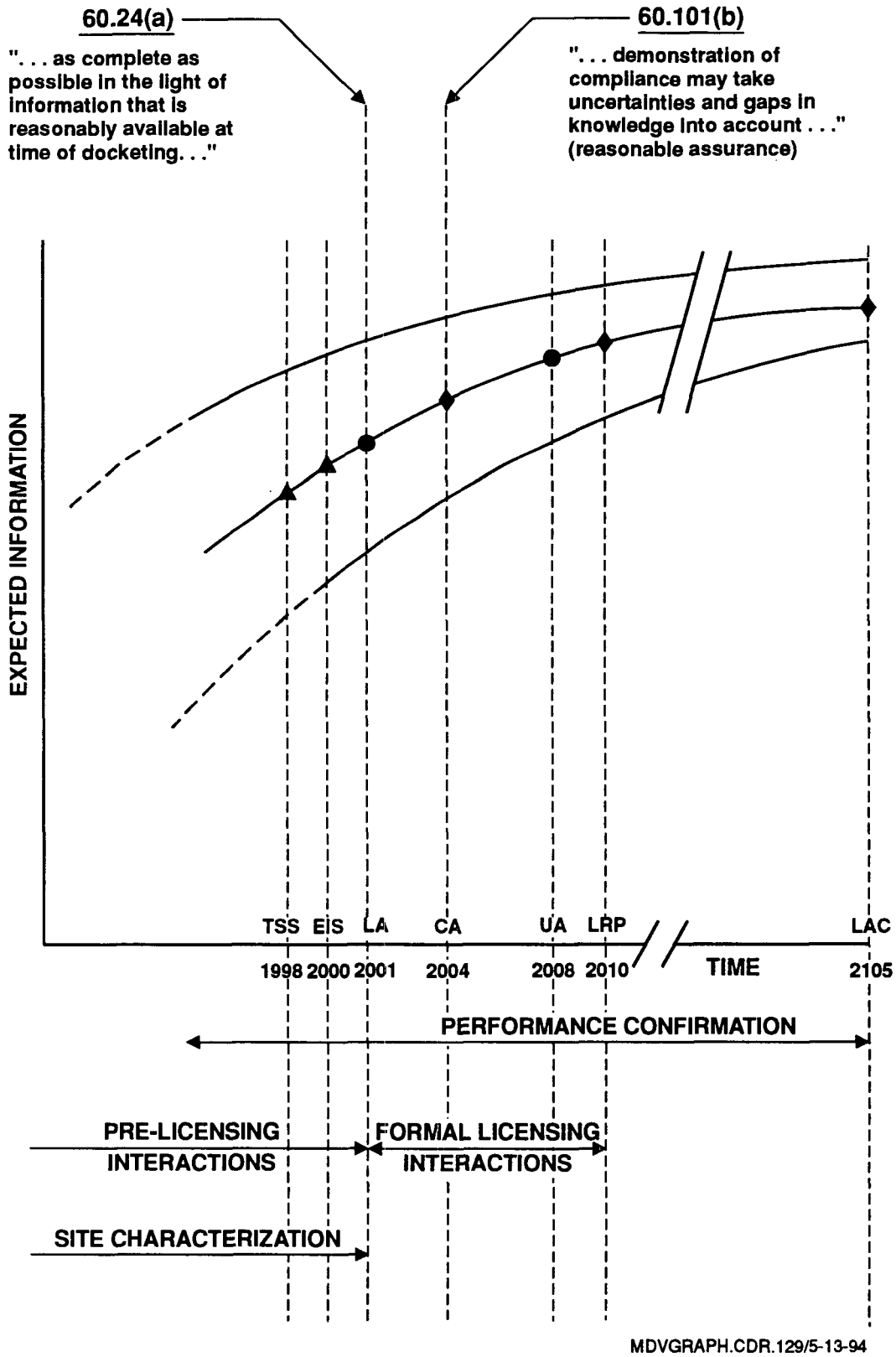
Implementing the SCP Licensing Strategy through the Program Approach

Phasing the Site Characterization Plan Strategies

1. Develop logical breakdown considering compliance arguments
2. Identify products that can be defended for suitability, EIS, and licensing
3. Ensure sufficient information at each step to demonstrate that health and safety can be protected appropriately



Phases of the Program Approach



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Develop Safety Argument in Steps

Preclosure Period: Operations

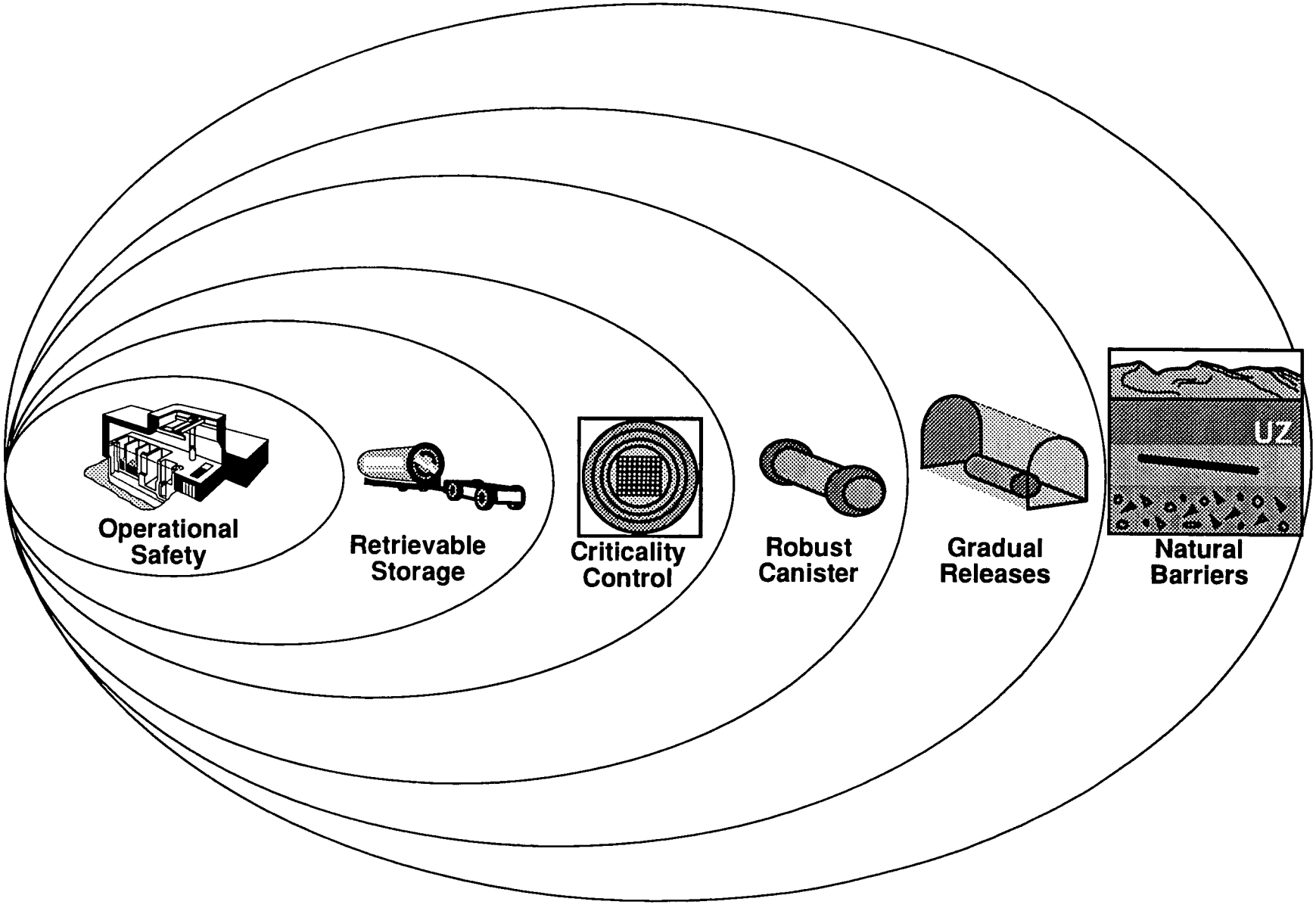
- **Build confidence in the performance of system by demonstrating the safety of engineered components**
  - **Engineered components of design that are important to safety are addressed first**
  - **Safety evaluations, including appropriate demonstrations of retrievability, criticality control, and robust canisters provide high confidence in the ability of a repository to safely function during operational time frame**
- **Reduce uncertainty during operational phases through performance-confirmation monitoring**
  - **Allow licensing decisions on configuration and final demonstrations of long-term performance to be based on many years of additional data gathered under actual conditions**

Develop Safety Argument in Steps

Postclosure Performance: Waste Isolation

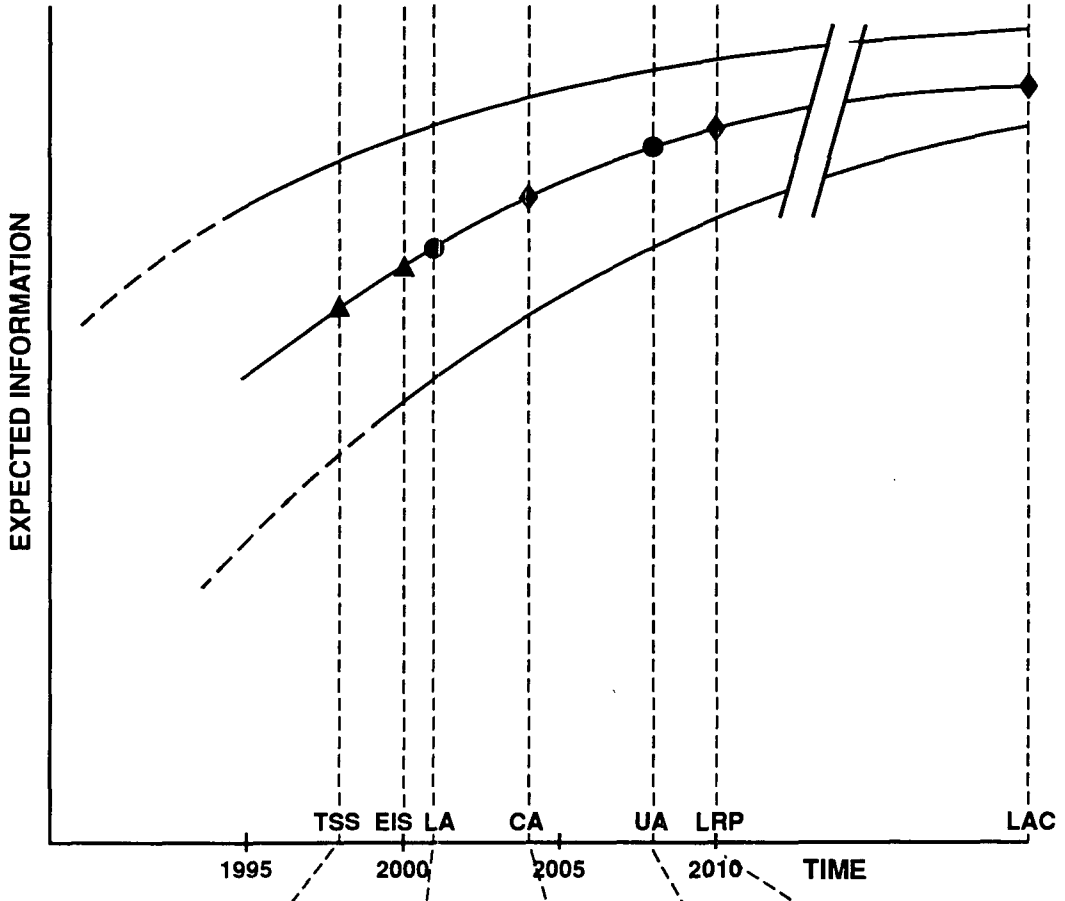
- Bound natural barrier performance through arguments with sufficient flexibility to accommodate a range of conditions
  - Goal is to provide sufficient information to docket 2001 License Application (LA)
  - Use time between License Application and Construction Authorization (~3 years) to gather additional data, strengthen safety arguments, and address specific licensing-related issues
- Increase confidence in the long-term performance of the repository through performance confirmation

Defense in Depth/Ongoing Monitoring



Increasing Long-Term Confidence

Program Approach to Increasing Confidence



	TSS/DEIS - 1998	LA/CA - 2001	CA - 2004	ULA/R&P - 2008	L/R&P - 2010	Perf. Confirm. *
NAT.BAR.EVAL						
GWTT	Bounded	Sub. Finished		Final		
Scenarios	Bounded	Bounded		Sub. Finished		Final
Subsystem Analyses	Bounded	Sub. Finished		Final		Updated
TSPA Source Term	Bounded Model	Bounded Model		Complete		Confirmed
Post CI TSPA	Bounded	Bounded		Sub Finished		Final
REPOSITORY DESIGN	ACD	Title I	Title II	Title III	Title III	Title III
Backfill/Seals		Title I (Flex)		Demonstrated		Decision
Materials Interf n	Bounded	Bounded	Matl's Sel.			
Retrievability		Title I	Proof of Princ.	Demonstrated		
Ar Pwr Den	Bounded	Bounded		APD Decision		Final APD
Emplacement Mode		Title I		Decision		
Precl P A	Bounded	Sub. Finished		Final		
Lag Storage	ACD	Title I	Title II	Title III		
Rail Spur	CD		Title I/II	Title II/III	Title III	
WASTE PKG. DESIGN	ACD/Title I	Title II (P'type)	Full Scale	P'type Tested	Title III	Oper'ns Conf.
Sub Cmp Con		Complete		Updated		
Criticality Con		Complete		Updated		
Contr Rel	Bounded	Conserv. Calcs		Complete		
Materials	Concepts	Determined		Test Complete		Model Confirmed
Waste Form		Srce Term End'd		Final Srce Term		
EBS Thermal	Concepts	Bounded				

MDVGAF1 CDR.129/4-20-94

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Synopsis of Program Approach for MGDS

	TSS/DEIS - 1998	LA/CA - 2001	CA - 2004	ULA/R&P - 2008	L/R&P - 2010	Perf. Confirm. *
NAT.BAR.EVAL.						
GWTT	Bounded	Sub. Finished		Final		
Scenarios	Bounded	Bounded		Sub. Finished		Final
Subsystem Analyses	Bounded	Sub. Finished		Final		Updated
TSPA Source Term	Bounded Model	Bounded Model		Complete		Confirmed
Post Cl. TSPA	Bounded	Bounded		Sub Finished		Final
REPOSITORY DESIGN	ACD	Title I	Title II	Title III	Title III	Title III
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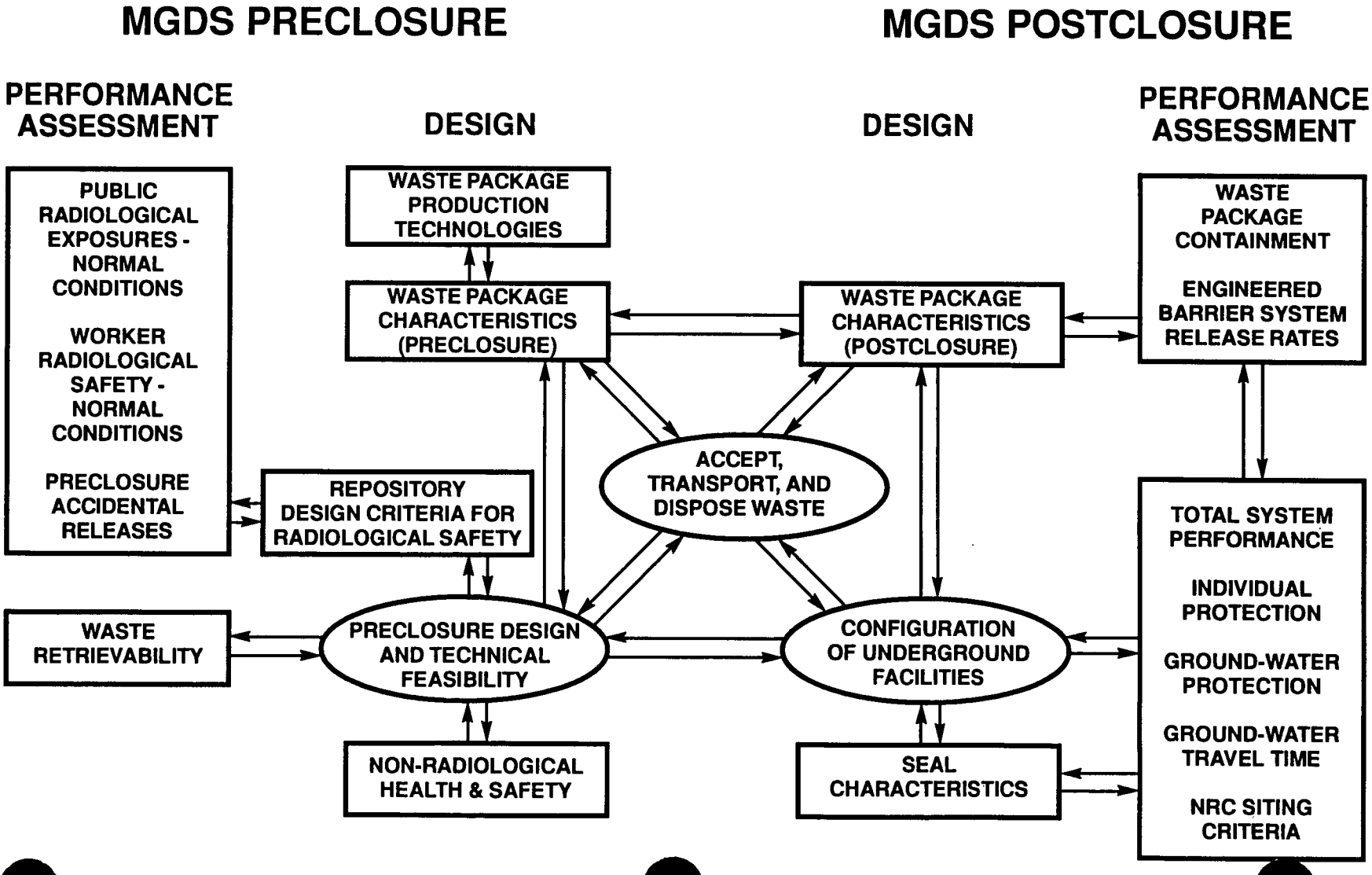
Materials Inter'n	Bounded	Bounded	Matl's Sel.			
Retrievability		Title I	Proof of Princ.	Demonstrated		
Ar. Pwr. Den.	Bounded	Bounded		APD Decision		Final APD
Emplace. Mode		Title I		Decision		
Precl. P.A.	Bounded	Sub. Finished		Final		
Lag Storage	ACD	Title I	Title II	Title III		
Rail Spur	CD		Title I/II	Title II/III	Title III	
WASTE PKG. DESIGN	ACD/Title I	Title II (P'type)	Full Scale	P'type Tested/Title III	Title III	Oper'ns Conf.
Sub Cmp Con		Complete		Updated		
Criticality Con.		Complete		Updated		
Contr. Rel.	Bounded	Conserv. Calcs		Complete		
Materials	Concepts	Determined		Test Complete		Model Confirmed
Waste Form		Srce Term Bnd'd		Final Srce Term		
EBS Thermal	Concepts	Bounded				

*** Performance confirmation program is required to start during site characterization and continue until permanent closure (10 CFR 60.140 (b))**

Thermal Strategy Perspective

Thermal Strategy Decisions and MGDS Design



Overall Thermal Strategy Perspective

Maintain flexibility in design to allow modifications that could improve system performance
- **Identify key environmental and design parameters**
- **Define envelope for key parameters**

- **Technical Site Suitability Strategy**
  - **Establish reference thermal loading (low range) based on current design concepts**
  - **Evaluate sensitivity to range of thermal loadings under consideration**

- **Licensing Strategy**
  - **Determine range of conditions over which designs work**
  - **Use performance confirmation to show we are within those conditions**
  - **Modify strategy as needed to improve performance**

Overall Thermal Strategy Perspective

(Continued)

- **Program Approach did not fundamentally change SCP Approach to Safety/Compliance Strategies**
  - **It did change DOE's plans for getting information in front of NRC**

Current Design and Performance Assessment understanding suggests different thermal loadings enhance different components of safety argument

Thermal Strategy--Different Perspectives

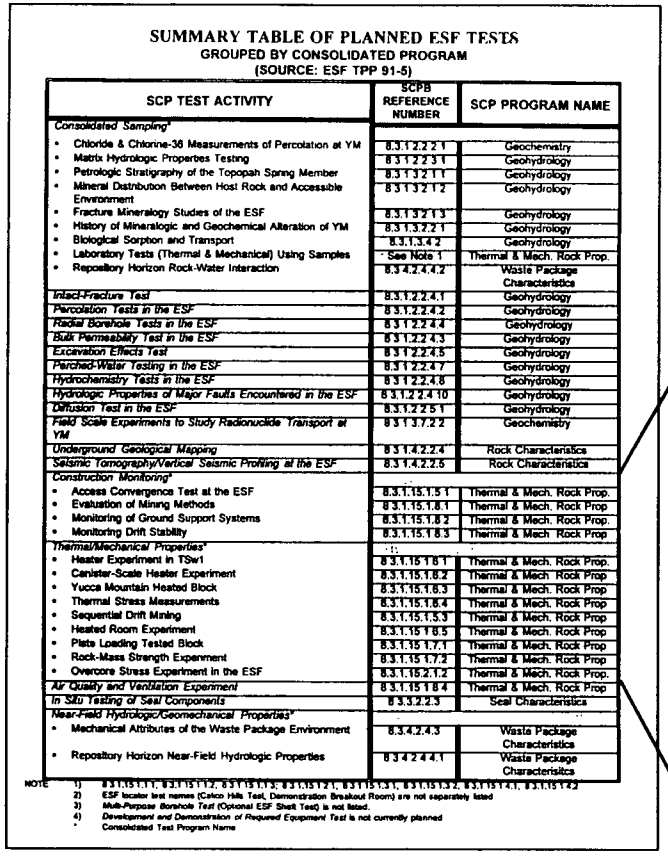
- **Performance Assessment Perspective**
  - Minimal disturbance to existing site conditions for 1998 Technical Site Suitability (TSS) and 2001 License Application may reduce uncertainties
  - This could provide a stronger technical basis for 1998 TSS determination
- **Waste Package Design Perspective**
  - Higher thermal loads may drive off water and reduce corrosion
  - Leads to increased confidence in robust long-lived waste package
- **Repository Design Perspective**
  - Assuming performance meets requirements, cost and efficiency may favor higher thermal loadings
  - Operational considerations could favor lower thermal loads

Sequencing the ESF Testing Program

Testing Perspective

- Use data from test programs to reach consensus on appropriate thermal loads for key decision points
- Redirect test program, as needed, to acquire additional information
- Use appropriate bounding calculations and ranges of data to develop performance and safety evaluations

ESF Activities--Test Planning Package 91-5



SUMMARY TABLE OF PLANNED ESF TESTS
GROUPED BY CONSOLIDATED PROGRAM
(SOURCE: ESF TPP 91-5)

SCP TEST ACTIVITY	SCPB REFERENCE NUMBER	SCP PROGRAM NAME
*Consolidated Sampling**		
• Chloride & Chlorine-36 Measurements of Percolation at YM	8.3.1.2.2.2.1	Geochemistry
• Matrix Hydrologic Properties Testing	8.3.1.2.2.3.1	Geohydrology
• Petrologic Stratigraphy of the Topopah Spring Member	8.3.1.3.2.1.1	Geohydrology
• Mineral Distribution Between Host Rock and Accessible Environment	8.3.1.3.2.1.2	Geohydrology
• Fracture Mineralogy Studies of the ESF	8.3.1.3.2.1.3	Geohydrology
• History of Mineralogic and Geochemical Alteration of YM	8.3.1.3.2.2.1	Geohydrology
• Biological Sorption and Transport	8.3.1.3.4.2	Geohydrology
• Laboratory Tests (Thermal & Mechanical) Using Samples	See Note 1	Thermal & Mech. Rock Prop.
• Repository Horizon Rock-Water Interaction	8.3.4.2.4.4.2	Waste Package Characteristics
Intact-Fracture Test	8.3.1.2.2.4.1	Geohydrology
Percolation Tests in the ESF	8.3.1.2.2.4.2	Geohydrology
Radial Borehole Tests in the ESF	8.3.1.2.2.4.4	Geohydrology
Bulk Permeability Test in the ESF	8.3.1.2.2.4.3	Geohydrology
Excavation Effects Test	8.3.1.2.2.4.5	Geohydrology
Perched-Water Testing in the ESF	8.3.1.2.2.4.7	Geohydrology
Hydrochemistry Tests in the ESF	8.3.1.2.2.4.8	Geohydrology
Hydrologic Properties of Major Faults Encountered in the ESF	8.3.1.2.2.4.10	Geohydrology
Diffusion Test in the ESF	8.3.1.2.2.5.1	Geohydrology
Field Scale Experiments to Study Radionuclide Transport at YM	8.3.1.3.7.2.2	Geochemistry
Underground Geological Mapping	8.3.1.4.2.2.4	Rock Characteristics
Seismic Tomography/Vertical Seismic Profiling at the ESF	8.3.1.4.2.2.5	Rock Characteristics
*Construction Monitoring**		
• Access Convergence Test at the ESF	8.3.1.15.1.5.1	Thermal & Mech. Rock Prop.
• Evaluation of Mining Methods	8.3.1.15.1.8.1	Thermal & Mech. Rock Prop.
• Monitoring of Ground Support Systems	8.3.1.15.1.8.2	Thermal & Mech. Rock Prop.
• Monitoring Drift Stability	8.3.1.15.1.8.3	Thermal & Mech. Rock Prop.
*Thermal/Mechanical Properties**		
• Heater Experiment in TSw1	8.3.1.15.1.6.1	Thermal & Mech. Rock Prop.
• Canister-Scale Heater Experiment	8.3.1.15.1.6.2	Thermal & Mech. Rock Prop.
• Yucca Mountain Heated Block	8.3.1.15.1.6.3	Thermal & Mech. Rock Prop.
• Thermal Stress Measurements	8.3.1.15.1.6.4	Thermal & Mech. Rock Prop.
• Sequential Drift Mining	8.3.1.15.1.5.3	Thermal & Mech. Rock Prop.
• Heated Room Experiment	8.3.1.15.1.6.5	Thermal & Mech. Rock Prop.
• Plate Loading Tested Block	8.3.1.15.1.7.1	Thermal & Mech. Rock Prop.
• Rock-Mass Strength Experiment	8.3.1.15.1.7.2	Thermal & Mech. Rock Prop.
• Overcore Stress Experiment in the ESF	8.3.1.15.2.1.2	Thermal & Mech. Rock Prop.
Air Quality and Ventilation Experiment	8.3.1.15.1.8.4	Thermal & Mech. Rock Prop.
In Situ Testing of Seal Components	8.3.3.2.2.3	Seal Characteristics
*Near-Field Hydrologic/Geomechanical Properties**		
• Mechanical Attributes of the Waste Package Environment	8.3.4.2.4.3	Waste Package Characteristics
• Repository Horizon Near-Field Hydrologic Properties	8.3.4.2.4.4.1	Waste Package Characterisitcs

NOTE
1) 8.3.1.15.1.1.1, 8.3.1.15.1.1.2, 8.3.1.15.1.1.3, 8.3.1.15.1.2.1, 8.3.1.15.1.3.1, 8.3.1.15.1.3.2, 8.3.1.15.1.4.1, 8.3.1.15.1.4.2
2) ESF locator test names (Calico Hills Test, Demonstration Breakout Room) are not separately listed
3) *Multi-Purpose Borehole Test* (Optional ESF Short Test) is not listed.
4) *Development and Demonstration of Requered Equipment Test* is not currently planned
* Consolidated Test Program Name

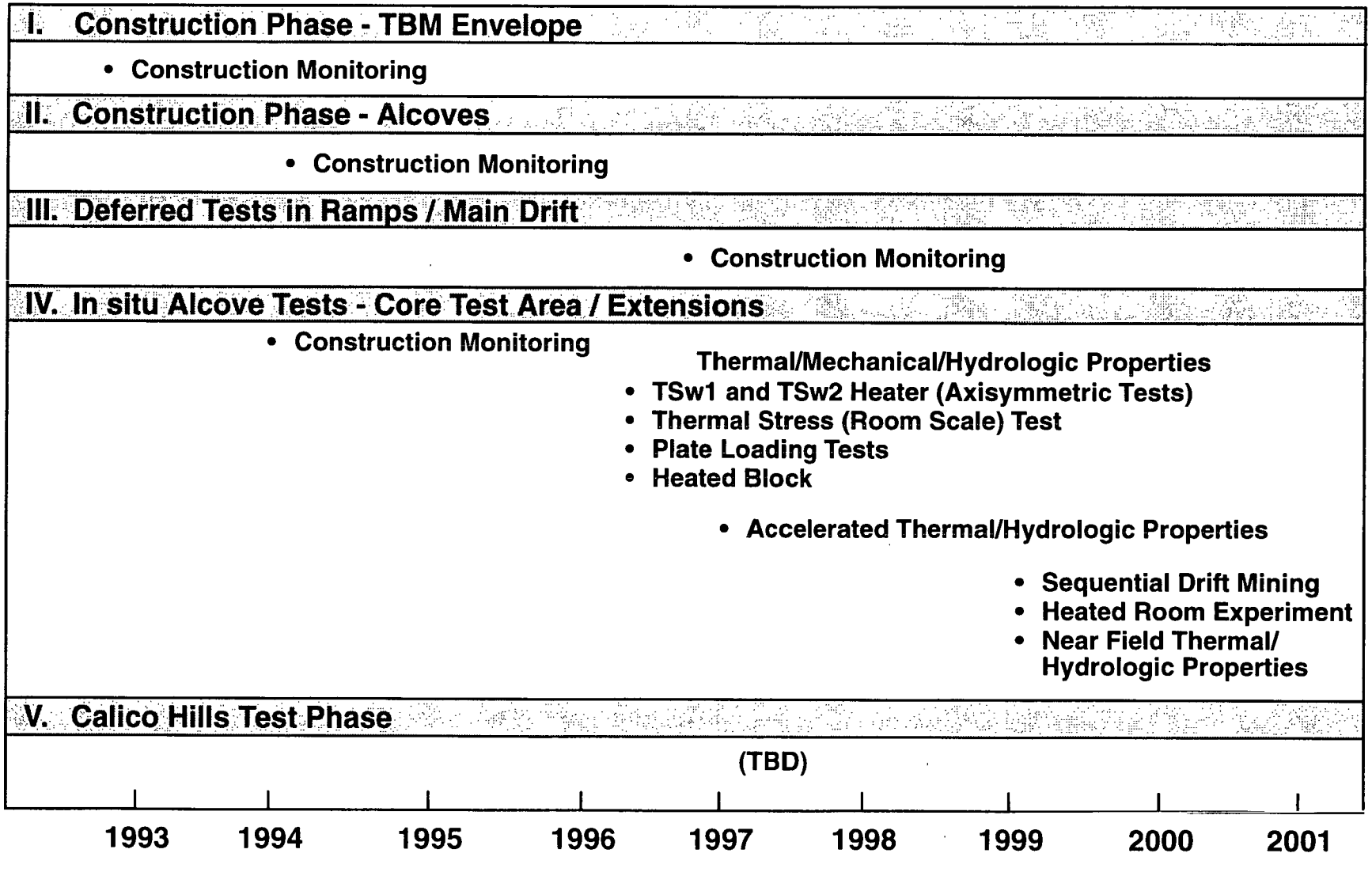
Construction Monitoring

- Access Convergence Test at the ESF
- Evaluation of Mining Methods
- Monitoring Ground Support Systems
- Monitoring Drift Stability

Thermal/Mechanical Properties

- Heater Experiment in TSw1
- Canister-Scale Heater Experiment
- YM Heated Block
- Thermal Stress Measurements
- Sequential Drift Mining
- Heated Room Experiment
- Plate Loading Tested Block
- Rock Mass Strength Experiment
- Overcore Stress Experiment in ESF

Thermal-Mechanical Testing in the Exploratory Studies Facility



Thermal-Mechanical Testing in the ESF Program Approach Decisions