PRESENTATION TO THE NUCLEAR WASTE TECHNICAL REVIEW BOARD

Subject: Physical System Functional Analysis

Battelle
. . . Putting Technology To Work

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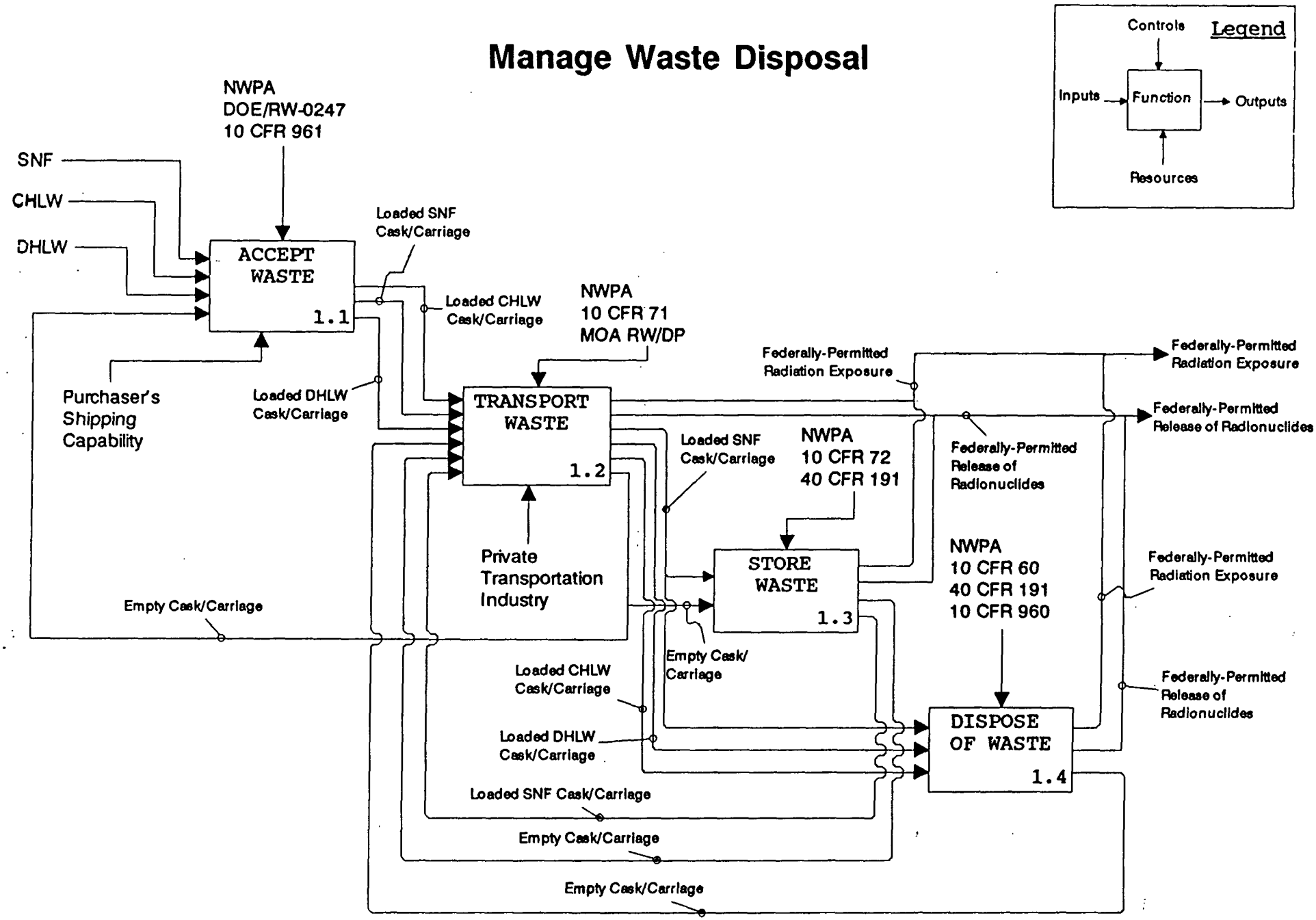
PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

Briefing Objectives

- Describe the Functional Analysis approach for specifying Physical System Requirements
- Provide an example based on the Exploratory Studies Facility

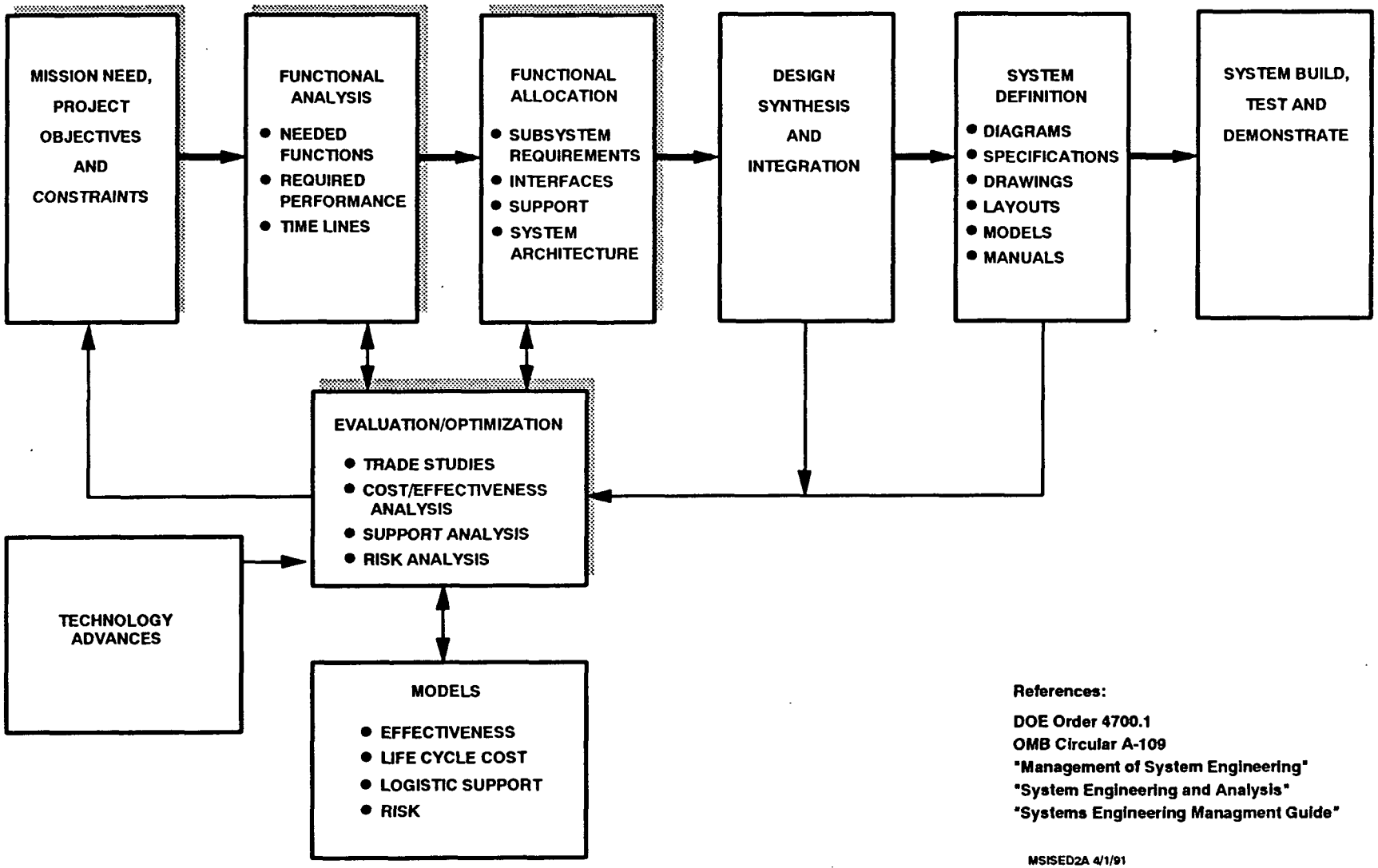
PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

Manage Waste Disposal



PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

Systems Engineering Process



References:

DOE Order 4700.1
OMB Circular A-109
"Management of System Engineering"
"System Engineering and Analysis"
"Systems Engineering Managment Guide"

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PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

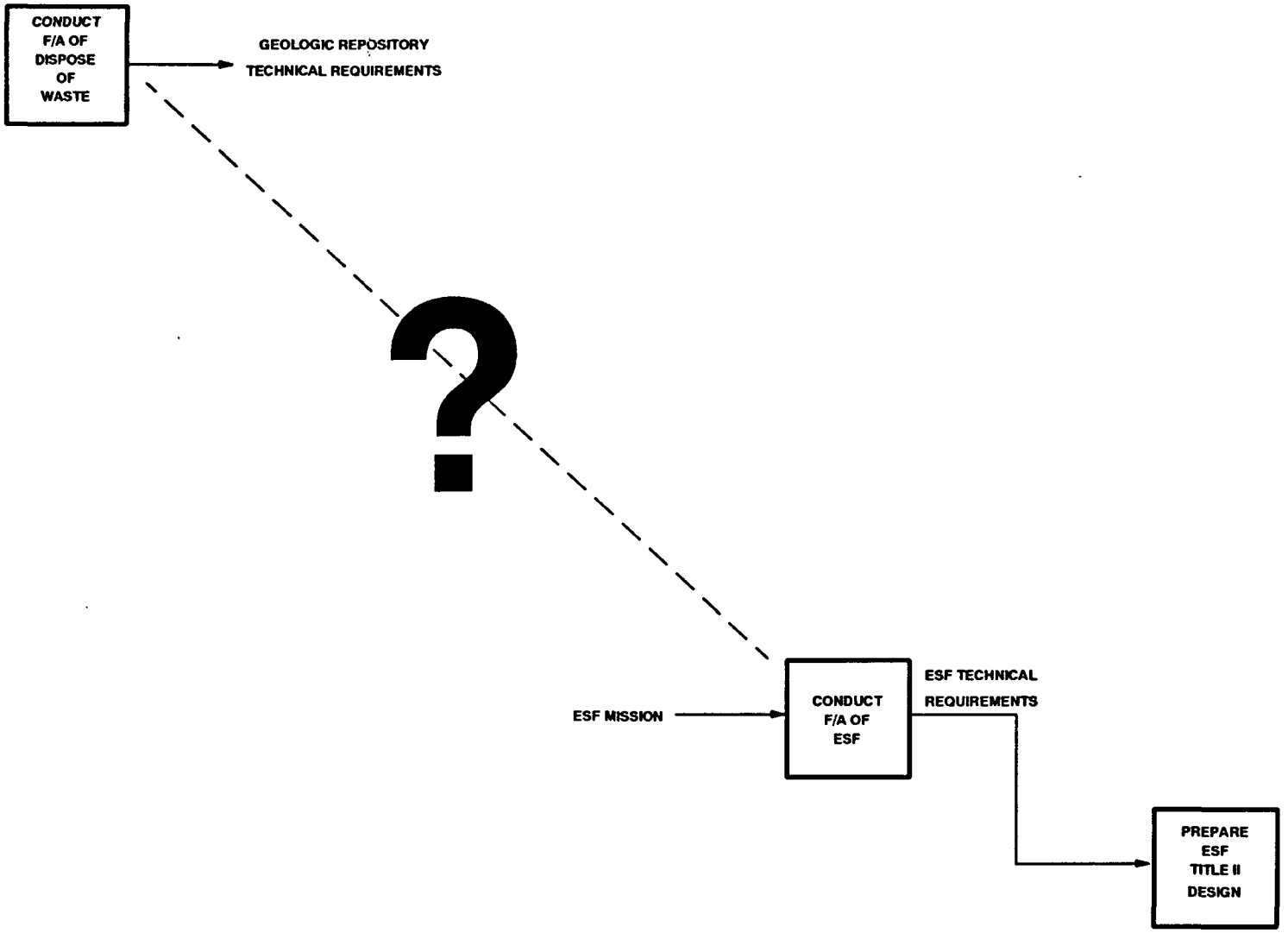
ESF Mission Statement

Based on the Nuclear Waste Policy Act, the mission of DOE's Exploratory Studies Facility can be stated succinctly as:

> To conduct subsurface exploration and testing, in support of site suitability determination and license application, in a manner that protects the environment and nuclear waste isolation capabilities of the site.

PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

Relationship of the ESF to the Geologic Repository



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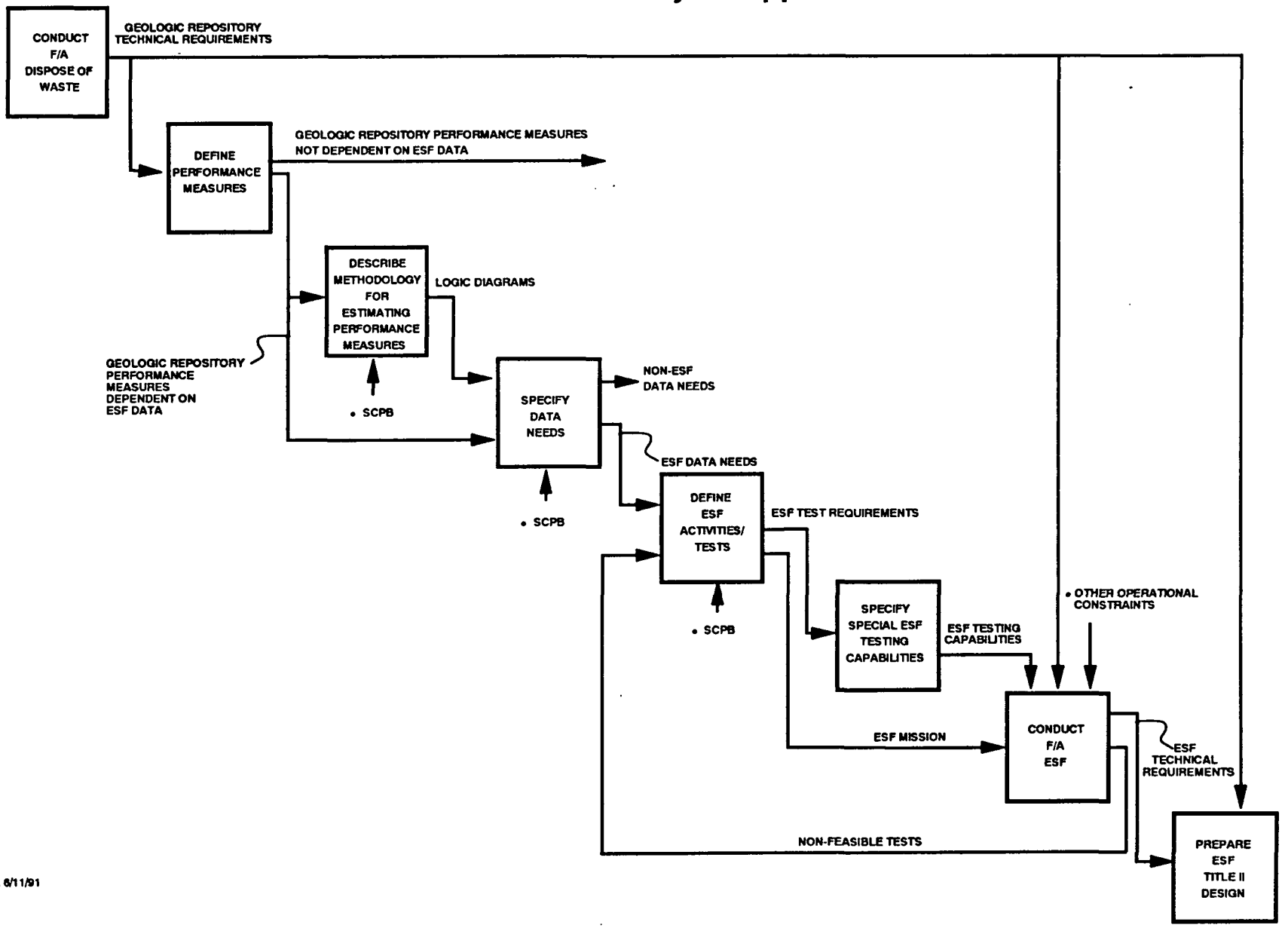
PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

ESF Mission Analysis Approach



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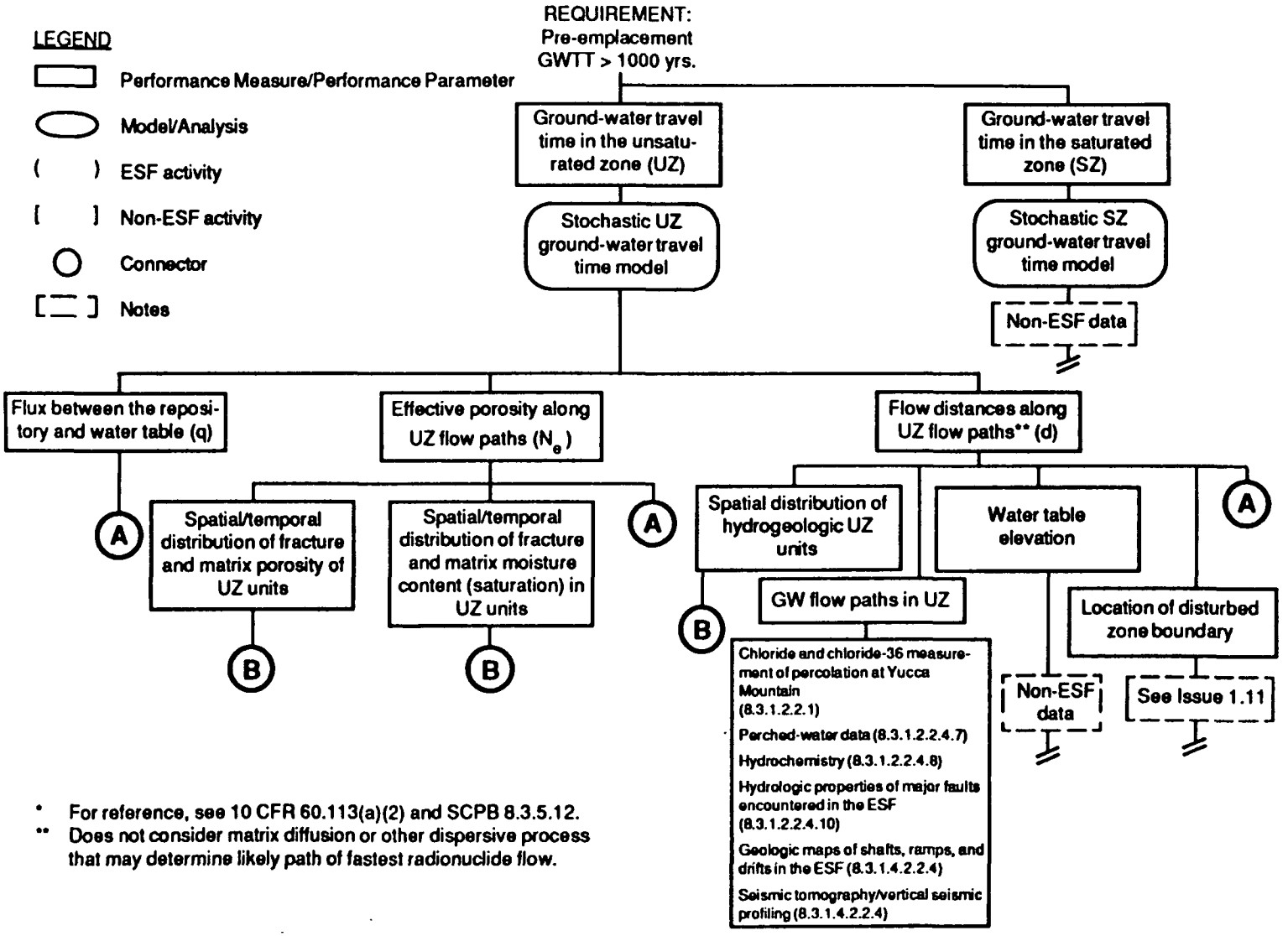
PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

ESF Mission Analysis

Issue 1.6*: Ground-Water Travel Time



* For reference, see 10 CFR 60.113(a)(2) and SCPB 8.3.5.12.

** Does not consider matrix diffusion or other dispersive process that may determine likely path of fastest radionuclide flow.

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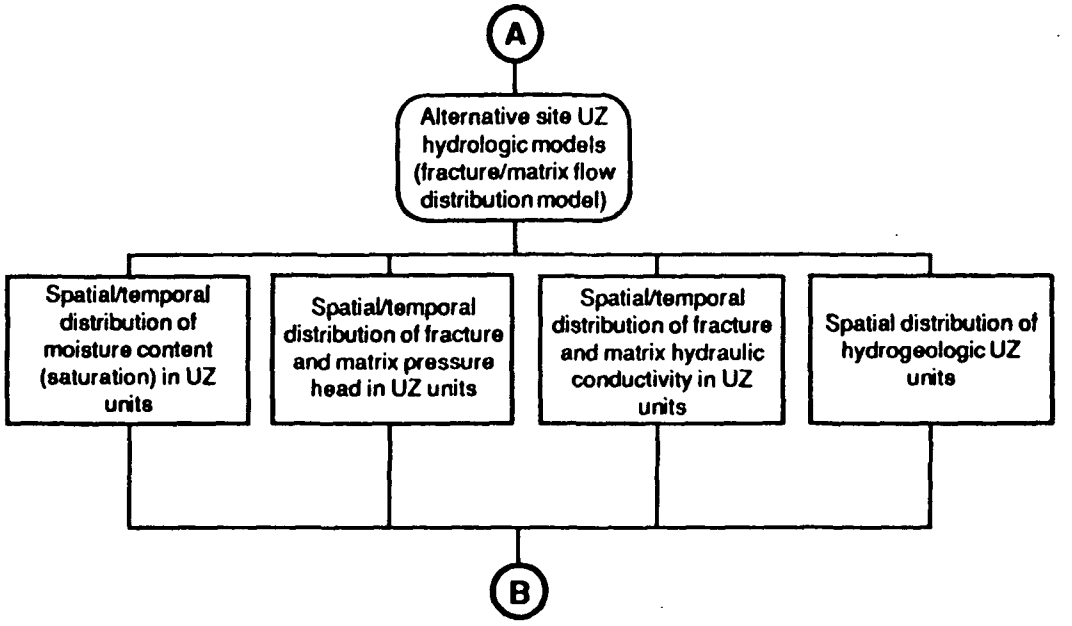
ESF Mission Analysis

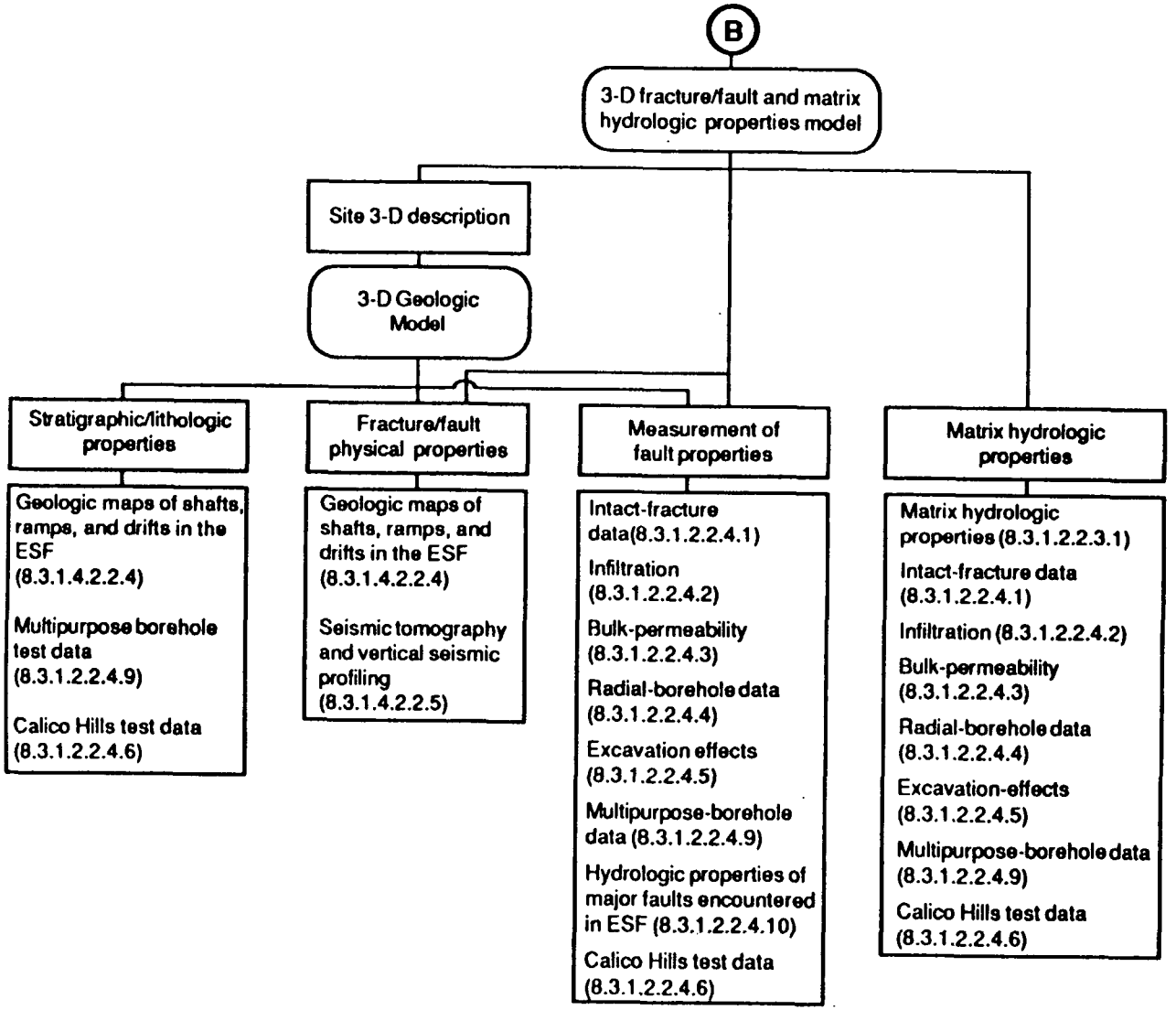
Issue 1.6*: Ground-Water Travel Time



PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

ESF Mission Analysis

Issue 1.6*: Ground-Water Travel Time



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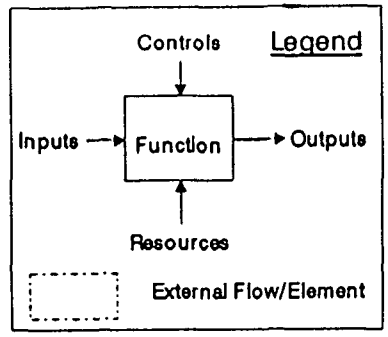
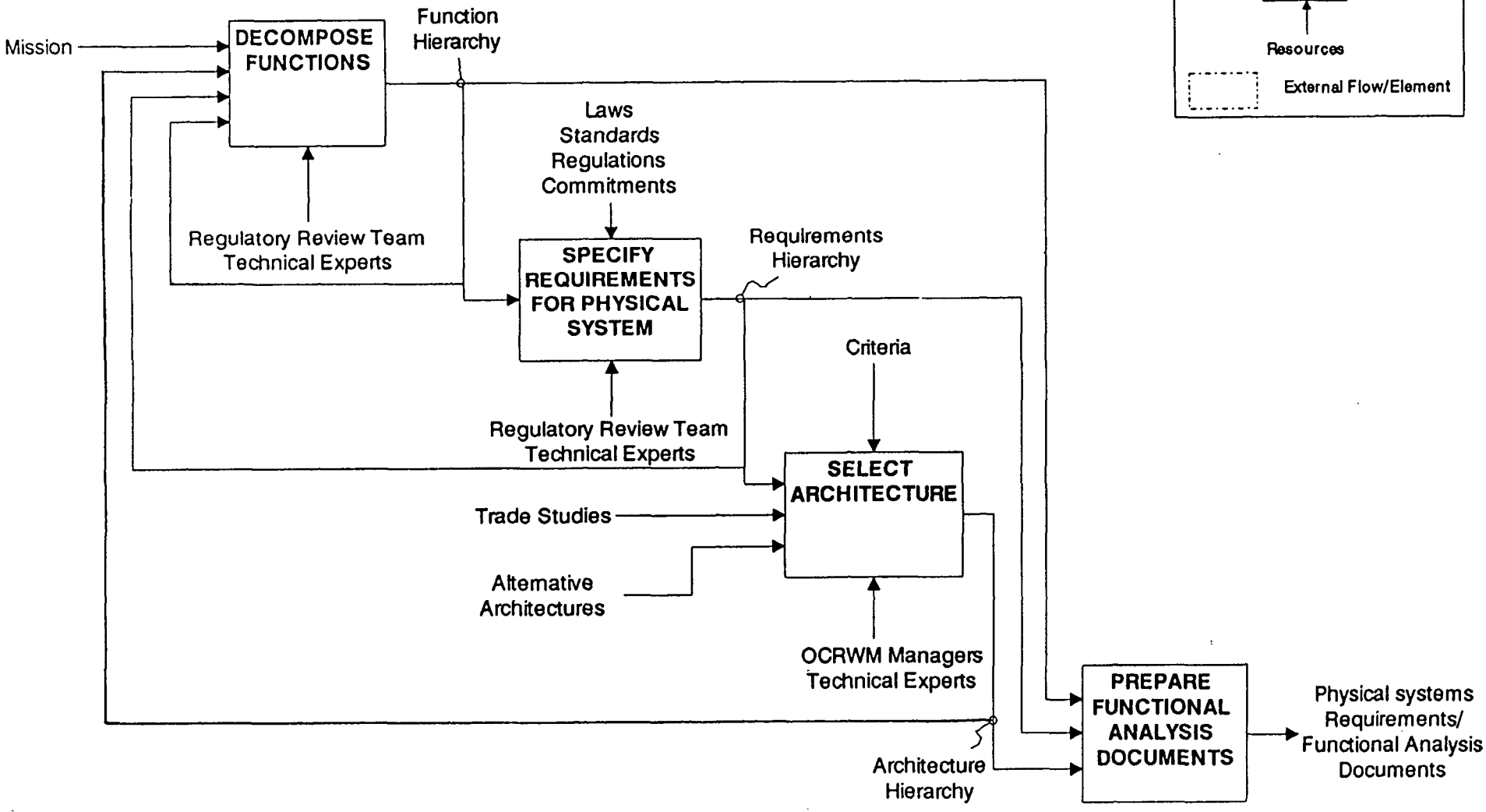
Technical Approach





PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

Constraints On The ESF

- Do not preclude possibility of ESF becoming part of GROA
- Do not adversely impact nuclear waste isolation capabilities of the site
- Do not interfere with validity of ESF tests

PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

Conduct Subsurface Based Activities Function Hierarchy

3.0 Investigate Yucca Mountain Site for a Repository

- *3.1 Conduct Environmental Investigations*
- *3.2 Conduct Geoscientific Investigations*
  - *3.2.1 Conduct Surface Based Activities*
  - **3.2.2 Conduct Subsurface Based Activities**
    - 3.2.2.1 Construct ESF
      - 3.2.2.1.1 Prepare Site
        - Survey Site
        - Construct Access Roads
        - Perform Site Grading
        - Construct Site Pads
      - 3.2.2.1.2 Construct Surface Facilities
      - 3.2.2.1.3 Excavate Subsurface
        - Excavate Accesses
        - Excavate Test Alcoves
        - Exacavate Mains
        - Excavate Subsurface Support Alcoves
        - Excavate Drifts
      - 3.2.2.1.4 Construct Subsurface Facilities
    - 3.2.2.2 Conduct ESF Tests
      - 3.2.2.2.1 Conduct Unsaturated Hydrology Investigations
        - Chloride and Chlorine - 36 Measurements of Percolation at Yucca Mountain
        - Matrix Hydrologic Properties Testing
        - Intact-Fracture Test in the ESF
        - Percolation Tests in the ESF
        - Bulk-Permeability Test in the ESF
        - Radial Borehole Tests in the ESF
        - Excavation Effects Test in the ESF
        - Calico Hills Test in the ESF
        - Perched Water Test in the ESF
        - Hydrochemistry Tests in the ESF
        - Multipurpose-Borehole Testing
        - Hydrologic Properties of Major Faults Encountered in the Main Test Level of the ESF
        - Diffusion Tests in the ESF
      - 3.2.2.2.2 Conduct Geochemistry Investigations
        - Petrologic Stratigraphy of the Topopah Spring Member
        - Mineral Distribution Between the Host Rock and the Accessible Environment
        - Fracture Mineralogy
        - History of Mineralogic and Geochemical Alteration of Yucca Mountain
        - Biological Sorption and Transport
        - Demonstration of Applicability of Laboratory Data to Repository Transport Calculations
      - 3.2.2.2.3 Characterize Structural Features Within the Site Area
        - Geologic Mapping of the ESF
        - Seismic Tomography/Vertical Seismic Profiling
      - 3.2.2.2.4 Investigate Thermal and Mechanical Rock Properties
        - Studies to Provide the Required Information for Spatial Distribution of Thermal and Mechanical Rock Properties
        - Access Convergence
        - *Demonstration Breakout Rooms*
        - Sequential Drift Mining
        - Heater Experiment in Unit TSw 1
        - Canister-Scale Heater Experiment
        - Yucca Mountain Heated Block Test
        - Thermal Stress Measurements
        - Heated Room Experiment
        - Plate Loading Tests
        - Rock-Mass Strength Experiment
        - Evaluation of Mining Methods
        - Monitoring of Ground-Support Systems
        - Monitoring of Drift Stability
        - Air Quality and Ventilation Experiment
        - Overcore Stress Experiments in the ESF
      - 3.2.2.2.5 Technologies for Repository Construction
        - Deveopment and Demonstration of Required Equipment
      - 3.2.2.2.6 Materials and Characteristics of Seals
        - In Situ Testing of Seal Components
      - 3.2.2.2.7 Post-Emplacement Near-Field Environment
        - Mechanical Attributes of the Waste Package Environment
        - Repository Horizon Near-Field Hydrologic Properties
        - Repository Horizon Rock-Water Interaction
      - 3.2.2.2.8 *Conduct Other ESF Tests, as Required*
    - 3.2.2.3 Support ESF Operations
      - 3.2.2.3.1 Provide Utility Services
        - Provide Ventilation (HVAC)
        - Provide Communications
        - Supply/Control Water
        - Provide Power
        - Provide Illumination
        - Provide On-Site Transportation
      - 3.2.2.3.2 Provide Protective Services
        - Provide Physical Security
        - Provide Inspection/Testing Services
        - Provide Emergency Medical Treatment
        - Provide Fire/Explosion Protection
        - Provide Radiological Protection
        - Provide Non-Radiological Protection
        - Provide Environmental Protection
      - 3.2.2.3.3 Administer General Support Services
        - Maintain Records
        - Provide Engineering Support
        - Provide for Human Resources
        - Provide Procurement Services
        - Provide Public Relations
        - Provide Financial Accounting
      - 3.2.2.3.4 Process Site Generated Waste (Non-Rad)
        - Process Hazardous Waste
        - Process Non-Hazardous Waste
      - 3.2.2.3.5 Maintain Operating Facilities
        - Maintain Surface Operating Facilities
        - Maintain Subsurface Test Facilities
        - Maintain Subsurface Support Facilities
      - 3.2.2.3.6 Administer QA
      - 3.2.2.3.7 Manage ESF Test Data
    - 3.2.2.4 Close ESF
      - 3.2.2.4.1 Close Subsurface Openings and Accesses
      - 3.2.2.4.2 Decommission Surface Facilities
  - *3.2.3 Conduct Lab Activities*
  - *3.2.4 Assess Data*

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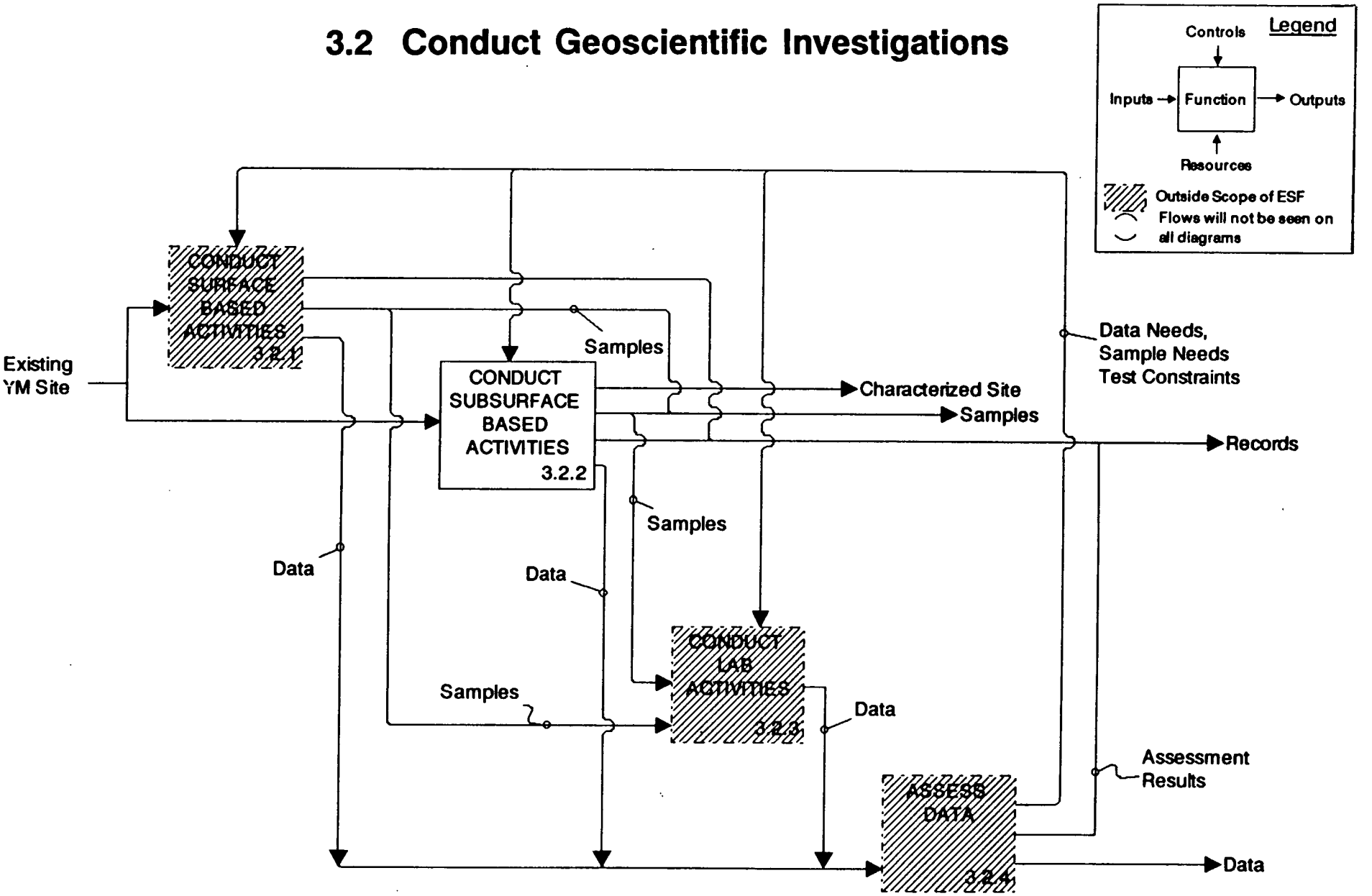
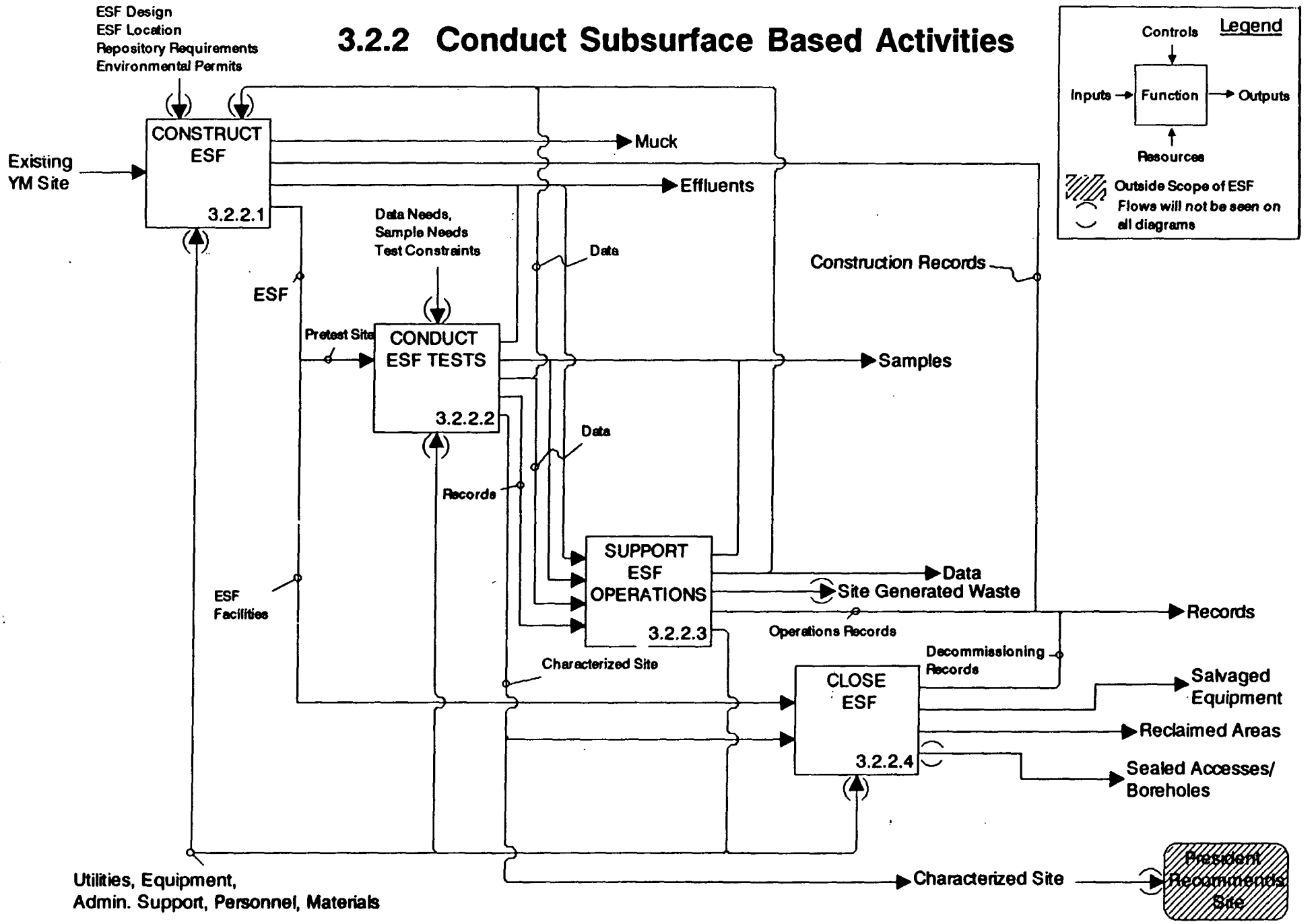
3.2 Conduct Geoscientific Investigations



PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

3.2.2 Conduct Subsurface Based Activities



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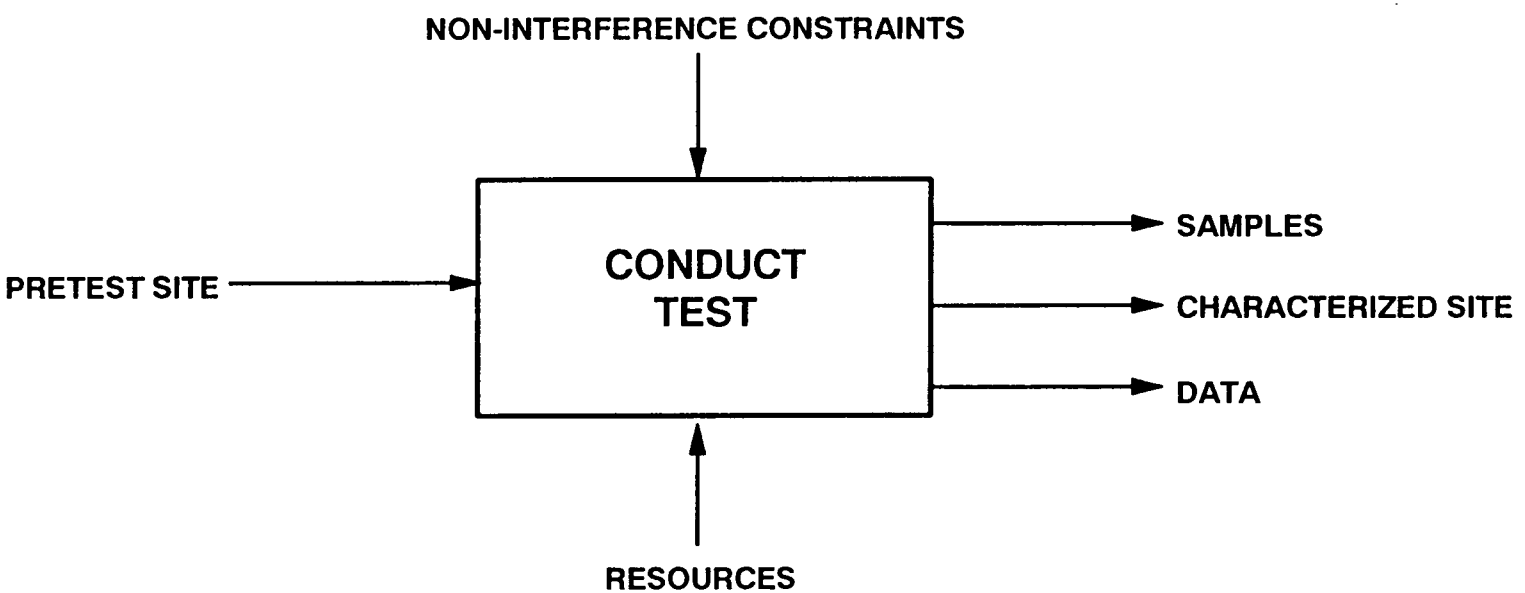
3.2.2.2 Conduct ESF Tests (Generic Example)



PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

Source Documents Containing Requirements In The Exploratory Studies Facility Document

Document Identifier	Document Description
29 USC 651 et.seq.	Occupational Safety and Health Act
30 USC 801 et.seq.	Mine Safety and Health
33 USC 1251 et.seq.	Clean Water Act
42 USC 300f et.seq.	Safe Drinking Water Act
NWPA-42 USC 10101 et.seq.	Nuclear Waste Policy Act of 1982
10 CFR 60	Disposal of High-Level Radioactive Wastes in Geologic Repositories
10 CFR 960	General Guidelines for the Recommendation of Sites for Nuclear Waste Repositories
30 CFR 57	Safety and Health Standards - Underground Metal and Nonmetal Mines*
33 CFR 322	Permits for Structures or Work in or Affecting Navigable Waters of the United States
40 CFR 191	Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (Note: Included only by implication through 10 CFR 60)
DOE/RW-0214	Quality Assurance Requirements Document
DOE ORDER 3790.1A	Federal Employee Occupational Safety and Health Program
DOE ORDER 5480.1B	Environment, Safety, and Health Program for Department of Energy Operations
DOE ORDER 5480.11	Radiation Protection for Occupational Workers
MOU Between DOE/DOL	Memorandum of Understanding Between DOE and DOL

* Not all requirements that may be applicable to an ESF have been included from 30 CFR 57.

PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

Example Function Description Table

Table F3.2.2.2.1.4 Function Description: Conduct Percolation Tests in the ESF

I. Function ID Number: 3.2.2.2.1.4

II. Function Title: Conduct Percolation Tests in the ESF

III. Function Definition:

This test will be used to observe and measure fluid flow through a network of fractures under controlled in situ conditions in order to characterize and quantify important flow processes in fractured welded tuff. The test is planned to use a large, isolated block of rock of approximately 6 ft. on a side. The block will be instrumented to detect fluid flow under physical conditions that can be mechanically controlled and systematically varied. Tracer-tagged water will be introduced from a trickle system/sand bed on the surface of the block.

This test will be performed at the Topopah Spring Member.

IV. Interfaces:

A. Inputs:

3.2.2.2.1.4I1	Pretest Site	**From:**	Function 3.2.2.1

B. Outputs:

3.2.2.2.1.4O1	Data	**To:**	Function 3.2.2.3
3.2.2.2.1.4O2	Samples	**To:**	Function 3.2.2.3
3.2.2.2.1.4O3	Records	**To:**	Function 3.2.2.3
3.2.2.2.1.4O4	Characterized Site	**To:**	Outside System Boundary

PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

Example Function Description Table (cont.)

V. Function Requirements:

A. Constraints: Requirements at this level to be specified

B. Performance:

3.2.2.2.1.4P1 Water used in this activity shall contain a tracer.

3.2.2.2.1.4P2 This activity shall be conducted in the TSw2.

3.2.2.2.1.4P3 Geologic maps, location maps, photographs, and test records shall be prepared.

C. Interface:

3.2.2.2.1.4I1a A large, isolated block of rock approximately 6 ft. on a side shall be provided in TSw2 for this activity.

3.2.2.2.1.4I1b Two parallel drifts shall be excavated so that the block can be cut from the pillar between the drifts.

3.2.2.2.1.4I1c Flexibility shall be provided for the principal investigator to locate the block.

3.2.2.2.1.4I1d Excavation methods shall not excessively damage the test block.

3.2.2.2.1.4I1e Connection to the IDS shall be provided at the test location.

3.2.2.2.1.4O1 Field measurements shall include water flow rates through the test block.

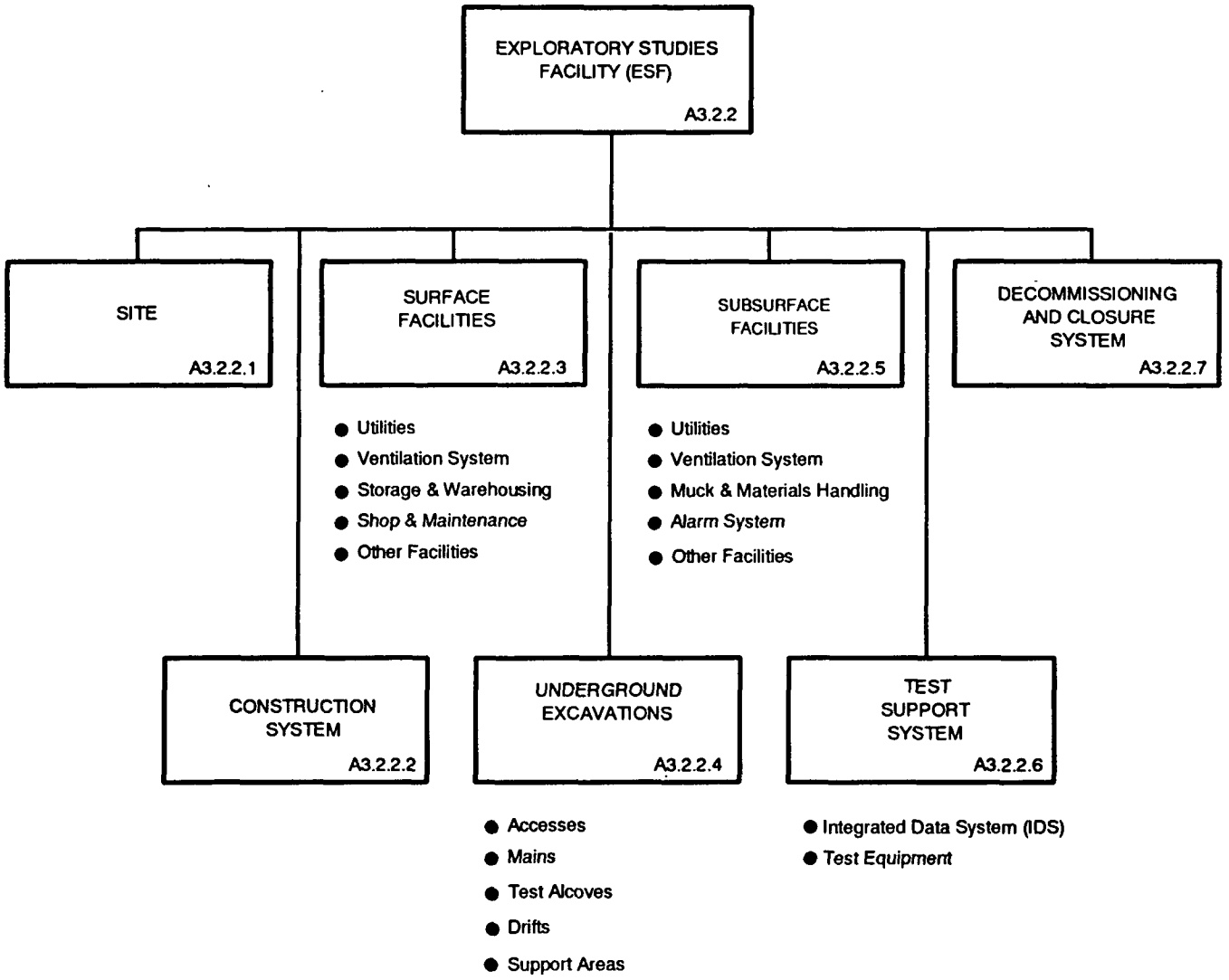
3.2.2.2.1.4O2 Samples shall be packaged, labeled, and transported to the Sample Management Facility prior to further off site analysis.

3.2.2.2.1.4O3 Records shall be provided to the appropriate records processing center.

3.2.2.2.1.4O4 The zone of hydrologic or geochemical influence shall not extend beyond the isolated test block.

PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

ESF Conceptual Architecture Hierarchy



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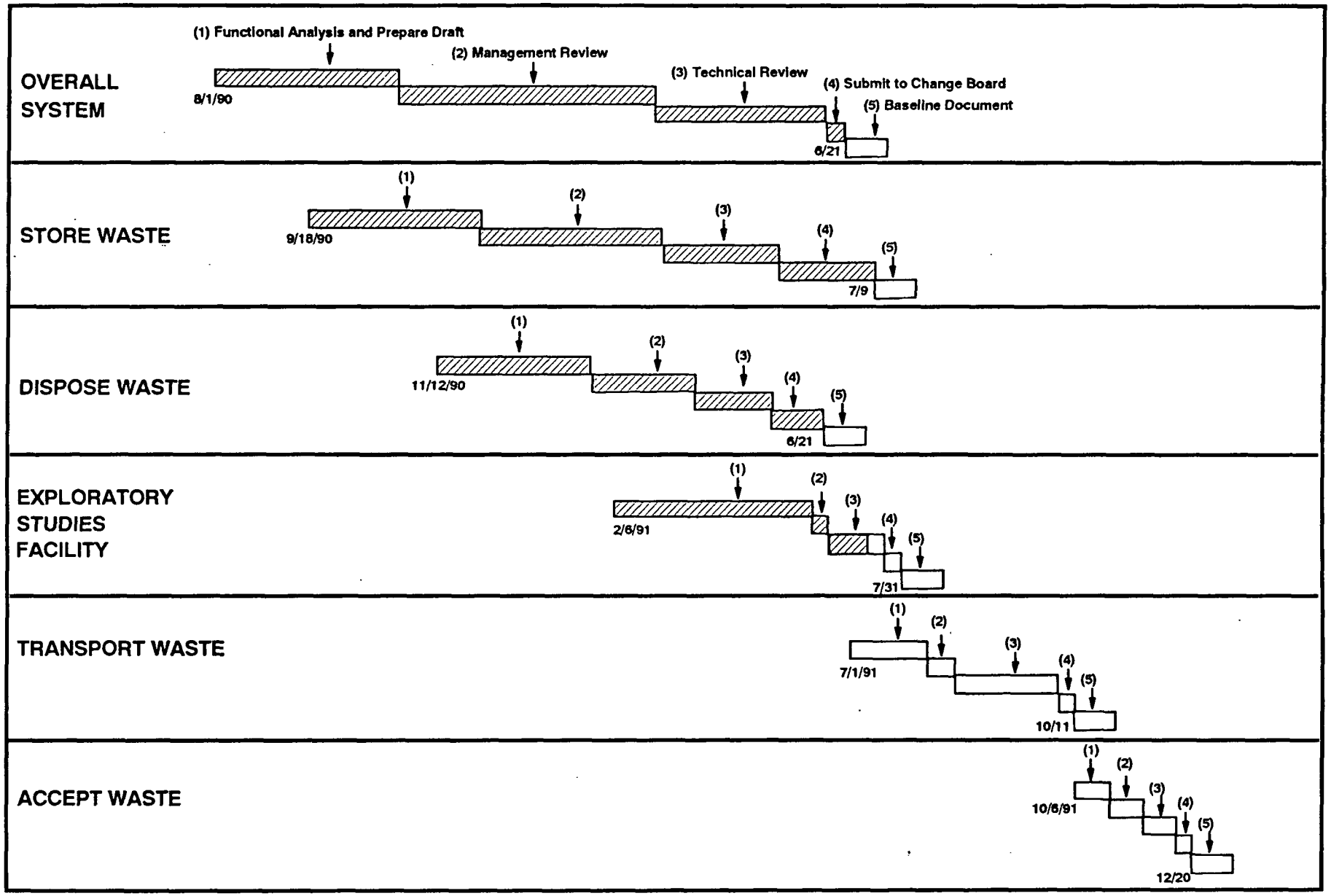
PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

Status/Schedule



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PHYSICAL SYSTEM FUNCTIONAL ANALYSIS

Summary

The Physical System Functional Analysis is an explicit, logical and orderly approach to requirements specification which

- Ensures consistency and traceability,
- Explicitly identifies key interfaces,
- Provides a framework for integrating systems analyses,
- Preserves flexibility for implementation,
- Develops program-wide technical support, and
- Leads to comprehensive requirement documents.