Department of Energy
Washington, DC 20585

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DNF SAFETY BOARD

JUN 2 8 1995

Mr. John T. Conway
Chairman
Defense Nuclear Facilities Safety Board
625 Indiana Avenue, N.W., Suite 700
Washington, D.C. 20004

Dear Mr. Conway:

In the "Defense Nuclear Facilities Safety Board Recommendation 94-2 Implementation Plan," (March 31, 1995) the Department of Energy (DOE) committed to utilizing a systems engineering approach for low-level (LLW) waste management. Our aim is to provide a technical basis with clearly identified interfaces for the management of LLW.

The Implementation Plan describes four integrated program planning documents to be developed under the systems engineering task. Enclosed is the first of these documents, the LLW Systems Engineering Evaluation Report. This report identifies the key programmatic functions of the LLW program and describes the input/output and requirements/constraints for these functions.

This report addresses the initial functional analysis we conducted as a first step in the systems engineering approach for LLW management. We envision systems engineering as an ongoing effort, and this report will be updated accordingly to reflect new knowledge. As part of this continuous improvement process, we are planning workshops involving DOE field elements and site representatives.

We will keep you advised of progress in our LLW systems engineering work through contact with your staff and our formal semi-annual reports to the Board.

Sincerely,

Jill E. Lytle
Deputy Assistant Secretary
   for Waste Management
Environmental Management

Enclosure

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LOW-LEVEL WASTE MANAGEMENT SYSTEM
ENGINEERING EVALUATION REPORT

INTRODUCTION

The Low-level Waste (LLW) Program is utilizing Systems Engineering (SE) to provide a sound basis for program definition. Systems Engineering provides a logical, disciplined process that will ensure that the functions necessary to accomplish the LLW mission are identified, and that the programmatic drivers, constraints, enabling assumptions, and performance requirements are identified and satisfied. The SE process will enable managers to focus on strategic and programmatic issues, identify technical and management interfaces to examine the linkage and interactive aspects of activities, and provide a technical basis for deriving functional requirements from top level program requirements.

Three major elements of the Systems Engineering process are technical functions, programmatic functions and management. The technical functions consist of the products and functions that are necessary and sufficient to accomplish the mission. The programmatic functions provide the requirements, constraints and resources needed to implement the Technical Functions.

Management is responsible for managing all technical and programmatic functions and for implementing and complying with DOE orders and policies. The three elements (technical, programmatic and management) are closely related, but must be kept separate to insure that each of the elements are completely defined and that the interfaces between the three elements are accurately identified and managed. The relationship between technical, programmatic, and line management functions is show graphically in figure 1.
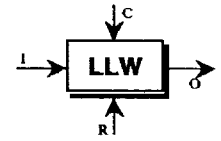
Systems Engineering is an iterative process that is applied hierarchically (top down) to: determine the functions at each level; specify how well they must be performed (requirements), develop a set of alternatives that will satisfy the functions and requirements; and evaluate the performance of the alternatives. The selection of the most desirable alternative, based upon a value system, establishes the functional requirements for the next functional level. The process is iterative because the solutions from one level may affect higher or lower levels and require reconsideration of previous decisions.

The process can be thought of as a series of tasks in which the functions, requirements, and alternatives are determined and analyzed. The resultant solution is then tested to ensure it satisfies the functions and requirements.
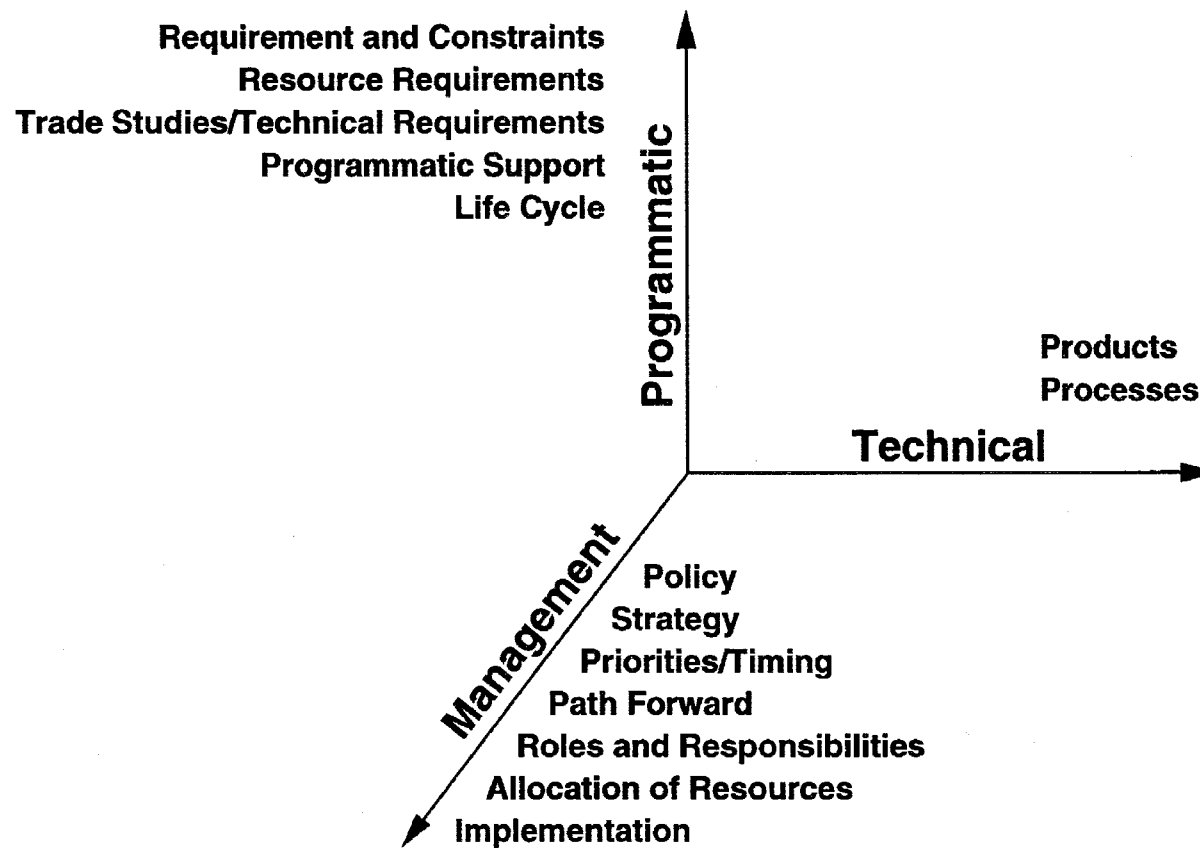
LLW PROGRAM

ELEMENTS OF THE SYSTEMS ENGINEERING PROCESS

Requirement and Constraints
Resource Requirements
Trade Studies/Technical Requirements
Programmatic Support
Life Cycle

Programmatic

Products
Processes

Technical

Management

Policy
Strategy
Priorities/Timing
Path Forward
Roles and Responsibilities
Allocation of Resources
Implementation

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Figure 1

The Systems Engineering "Process Flow" for analyzing system to accomplish a Mission is comprised of the following tasks graphically presented in Figure 2:

• Mission Analysis/Problem Definition (Define Mission Needs)

• Functional Analysis (Define Functions That Meet Needs)

• Determine Value System (Develop Decision Criteria)

• Requirements Analysis (Develop Requirements)

• Alternative and Risk Analysis (Select Solution Loop)

• Decision Analysis

• Test

• Decision (Recommendation)

The top three levels of the LLW Program Functional decomposition are pure functions that cannot be addressed by physical architectures. The SE process, at this level is limited to defining a complete set of functions that will satisfy the Program Mission, encompass all site functions, and provide a clear unambiguous set of functional definitions and requirements. The "Functional Value System" devised to evaluate the selected functions for this process is subjective in nature because physical architectures are not available to provide an objective basis of comparison. The Functional Value System used is comprised of:
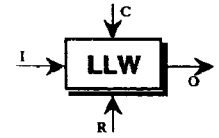
Defining the functions:

• at high enough level to provide a clear hierarchy

• to establish clear programmatic interfaces, and

• to simplify or minimize the interfaces between technical functions

• to derive the requirements that the technical functions must satisfy.
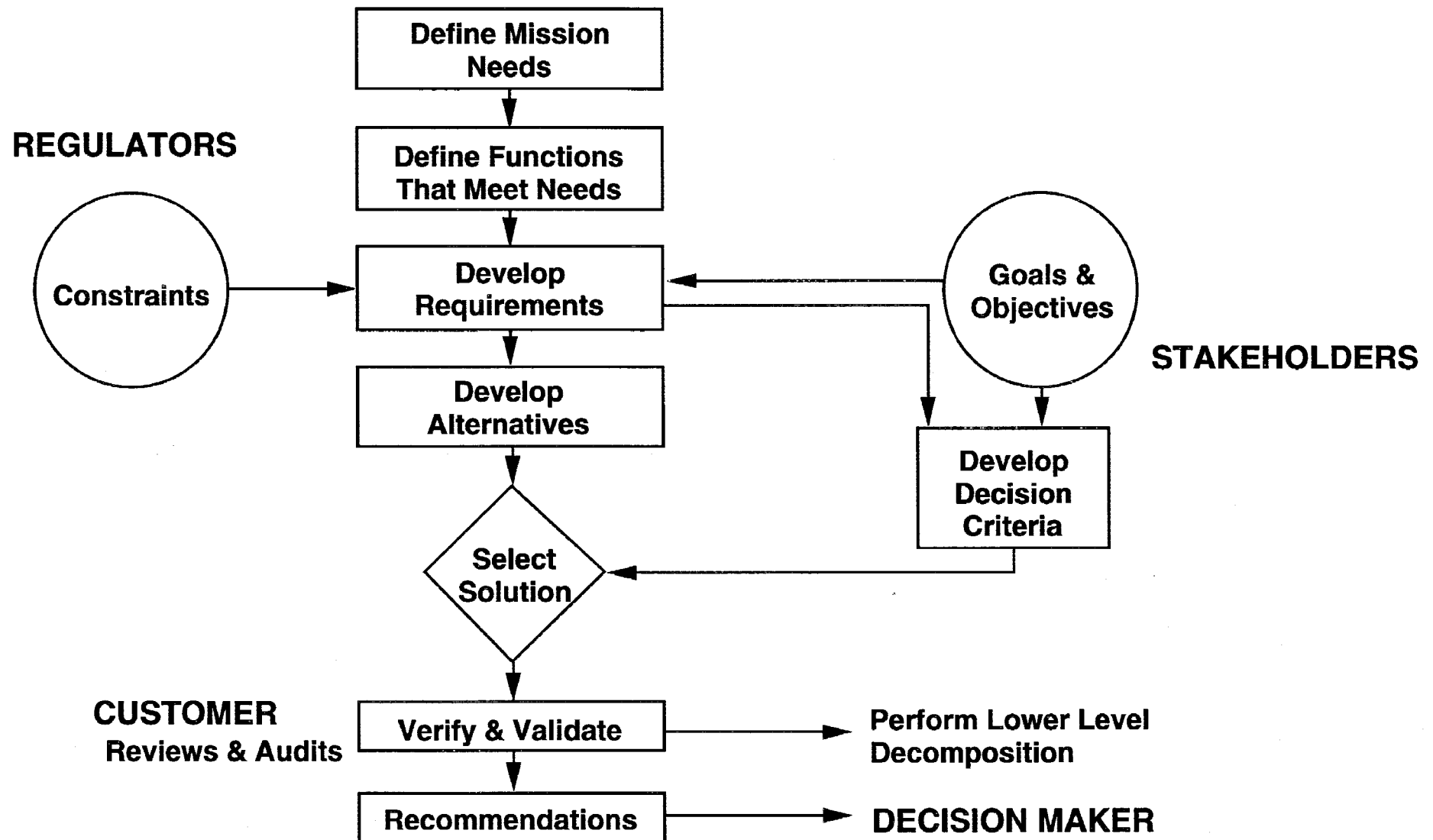
LLW ENGINEERING EVALUATION

The Engineering Evaluation for the Low-Level Waste Program, reported in this document, was to conduct a preliminary Systems Engineering decomposition of the LLW mission to provide a basis for understanding the technical and programmatic functions that must be managed.

LLW PROGRAM

SYSTEMS ENGINEERING PROCESS FLOW CHART

REGULATORS

STAKEHOLDERS

Define Mission Needs

↓

Define Functions That Meet Needs

↓

Constraints → Develop Requirements ← Goals & Objectives

↓

Develop Alternatives

Develop Decision Criteria

↓

Select Solution ←

↓

CUSTOMER
Reviews & Audits   Verify & Validate → **Perform Lower Level Decomposition**

↓

Recommendations → **DECISION MAKER**

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Figure 2

The LLW mission was decomposed into a set of functions that are necessary and sufficient to accomplish the mission. These functions were evaluated to determine an appropriate functional level for each function based upon the "functional value system" described above. The functional decomposition was performed by a team of Headquarters and Field Office Staff on a very accelerated schedule and must be considered conceptual in nature.

To aid in the evaluation the following steps were taken:

- Input and Output diagrams (See Figure 4) were prepared for each selected function (Level 0, Level 1, and Level 2).

- An LLW Functional Logic Network (Functional Process Flow) was developed (see figure 5) to define a top level process flow and to help identify major interfaces.

- N^2 diagrams (see figure 6) were developed to relate the functions, interfaces, and the inputs and outputs.

- The selected functions were evaluated, with the aid of the above SE tools and the selected functional value system, to identify appropriate level 1 and level 2 functions.

The preliminary LLW Program level 0, 1, and 2 functions are given in figure 7. The input output diagrams that include the functional definition, inputs and outputs, and the known requirements are given in figures 8-21. There are many requirements yet to be determined. Programmatic functions will be identified to define the missing requirements and constraints. The required resources will also be developed in a similar fashion. The N^2 diagrams for the selected functions are given in figures 22-24.

NEXT STEP

The SE process will be performed in detail with a team selected on a basis of their LLW and SE expertise. This task will include the identification and definition of the programmatic functions that are needed to implement the technical functions. The task will use an approach that proved successful, at the program level, with DOE owned Spent Nuclear Fuel. It is proposed that INEL LLW staff be utilized, in a similar fashion to what they provided for SNF, to develop a "strawman" to serve as a starting point (example) for the DOE LLW Program. The, Program level, Systems Engineering effort would include Headquarters, field elements, and Site, representatives to participate in the process and to concur with the results. Working groups would be formed to identify top level requirements and constraints for the DOE LLW Program considering DOE, NRC and Commercial requirements. The requirements and constraints will be concurred to and approved by DOE management.
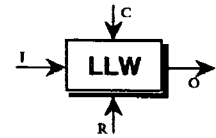
Lower level, site specific requirements and constraints for low level waste, storage and disposal facilities, transportation, etc. will be derived from the approved DOE LLW Program level requirements and constraints.

The Integrated Program Planning Documents associated with this Systems Engineering approach for LLW include the Program Strategic Plan, Requirements Document, and Management Plan. The Systems Engineering process and the Program Strategic Plan are closely related and are frequently developed in an iterative process. The relationship between Systems Engineering, the Strategic Plan, and other Integrated Program Planning Documents is given in figure 3.
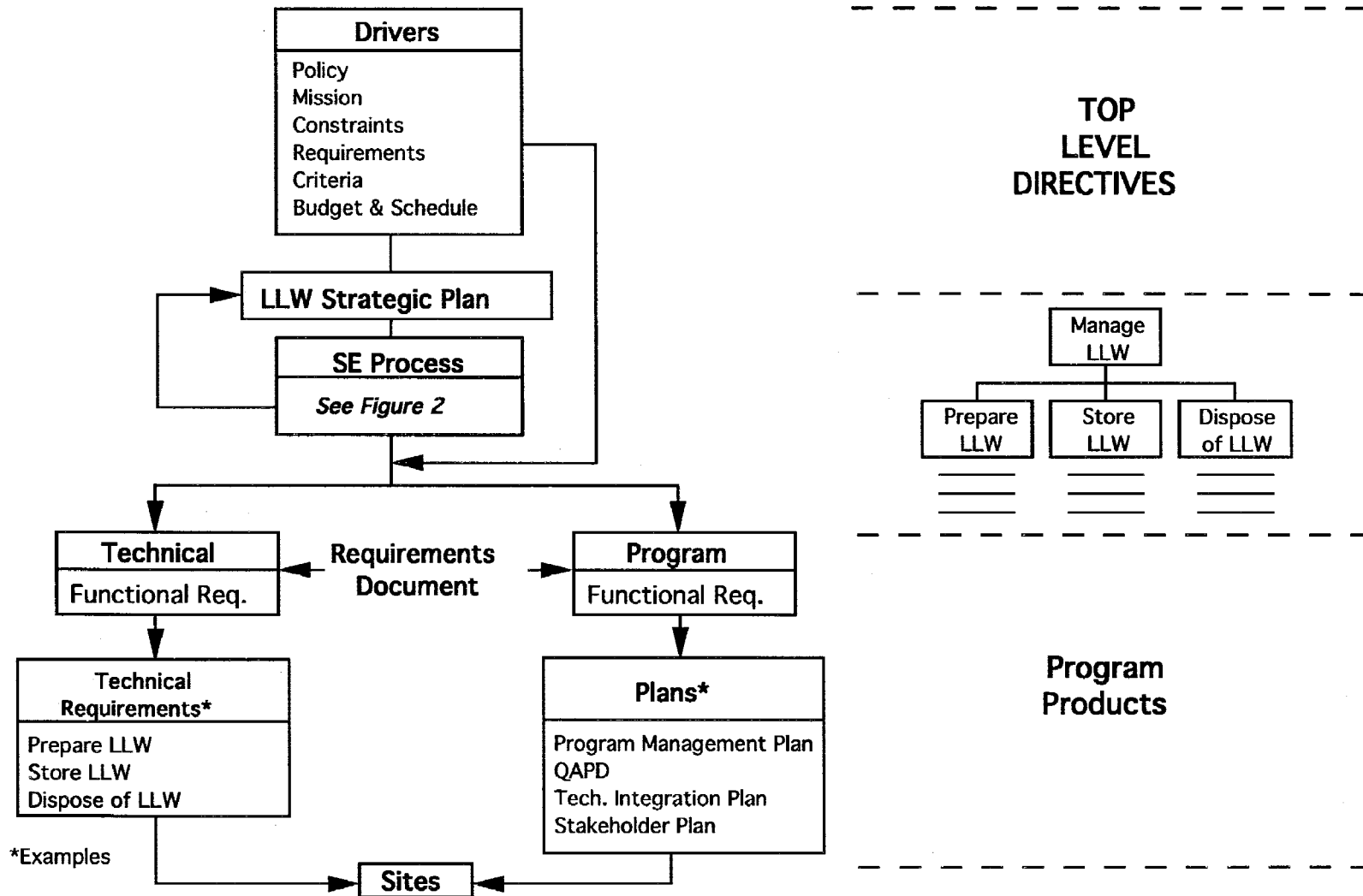
The Program Requirements Document is based upon the direction given in the Strategic Plan and the technical and programmatic functions and requirements developed by the Systems Engineering process. The Program Management Plan describes how the technical and programmatic functions will be implemented to accomplish the mission and satisfy the requirements and constraints defined in the Requirements Document. The Systems Engineering process and these program documents will form the foundation for the development of a LLW management plan for a newly integrated LLW management program.

LLW PROGRAM

LLW SYSTEMS ENGINEERING APPROACH
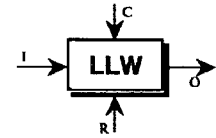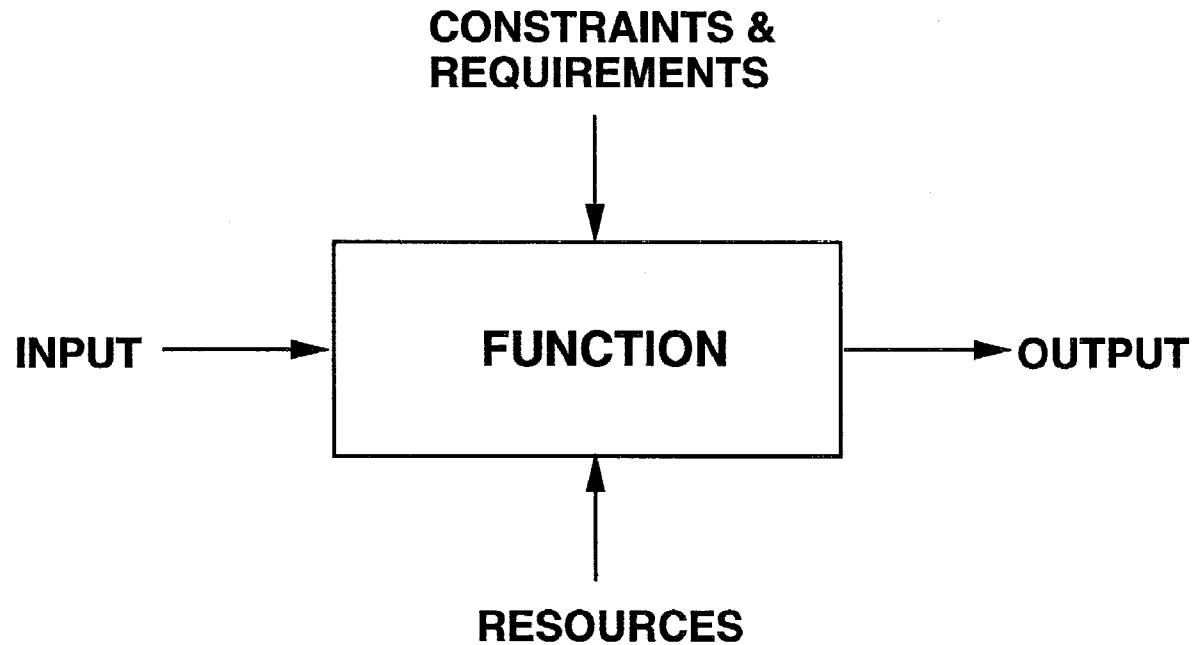
Drivers

Policy
Mission
Constraints
Requirements
Criteria
Budget & Schedule

LLW Strategic Plan

SE Process

See Figure 2

Technical

Functional Req.

Requirements Document

Program

Functional Req.

Technical Requirements*

Prepare LLW
Store LLW
Dispose of LLW

*Examples

Plans*

Program Management Plan
QAPD
Tech. Integration Plan
Stakeholder Plan

Sites

TOP LEVEL DIRECTIVES

Manage LLW

Prepare LLW | Store LLW | Dispose of LLW

Program Products

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Figure 3

INPUT/OUTPUT DIAGRAM

**CONSTRAINTS &
REQUIREMENTS**

INPUT ——→ **FUNCTION** ——→**OUTPUT**

RESOURCES
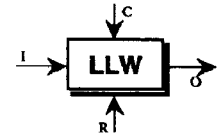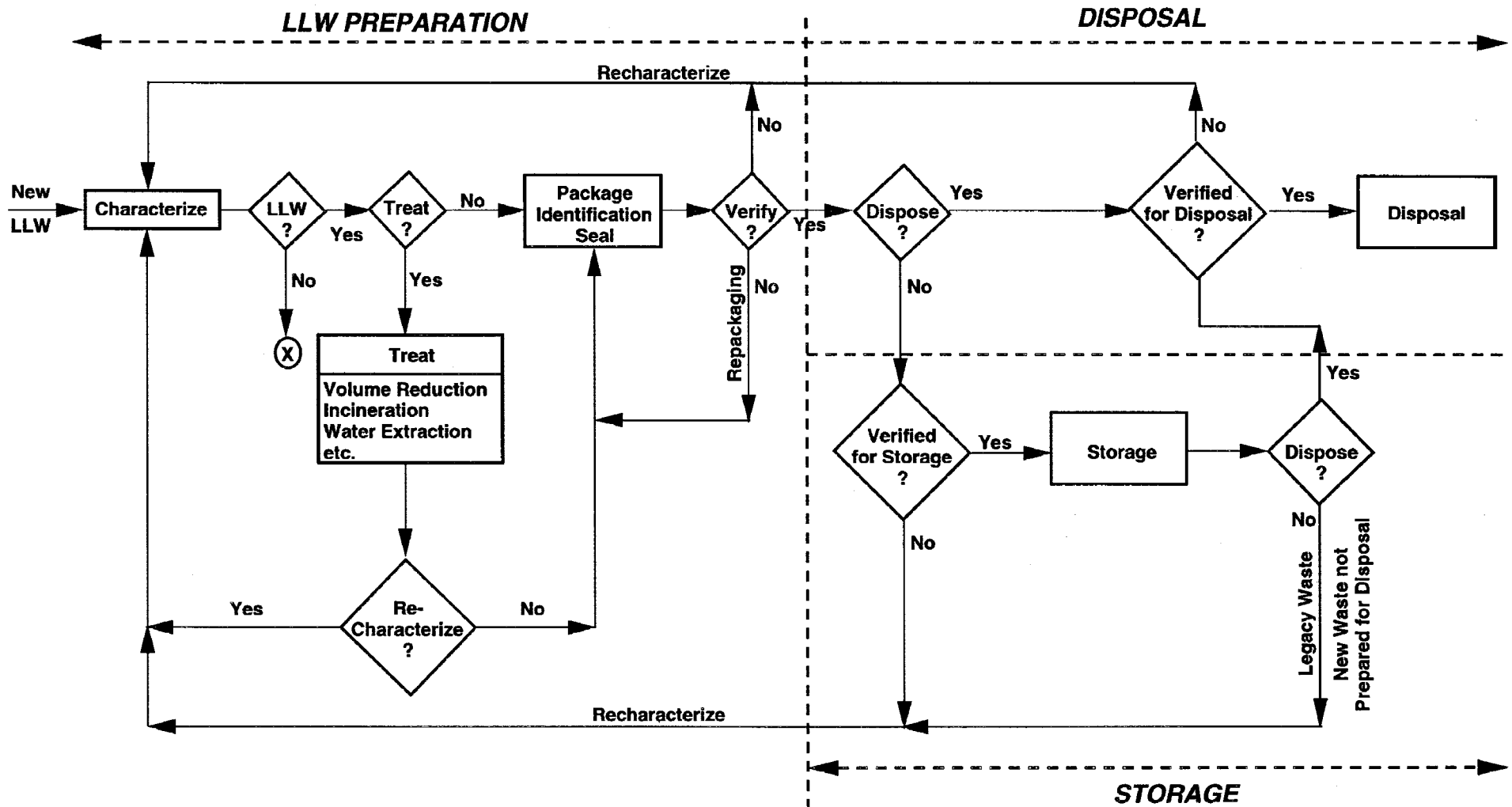
The Function operates on the Input with the
provided Resources to produce a desired Output
that meets the Constraints and Requirements.

Figure 4

I → LLW → o
C
R

LOW LEVEL WASTE FUNCTIONAL LOGIC NETWORK

LLW PREPARATION | *DISPOSAL*

Recharacterize

New LLW → Characterize

LLW ? — Yes → Treat ? — No → Package Identification Seal → Verify ? — Yes → Dispose ? — Yes → Verified for Disposal ? — Yes → Disposal

No (from Verify) → Recharacterize

No (LLW?) → (X)

Yes (Treat?) ↓

Treat
Volume Reduction
Incineration
Water Extraction
etc.

Repackaging — No

No (Dispose?) ↓

Verified for Storage ? — Yes → Storage → Dispose ?

No (Verified for Disposal?) → Recharacterize

Re-Characterize ? — Yes / No

No (Verified for Storage?)

No (Dispose?)

Legacy Waste
New Waste not Prepared for Disposal

Yes

Recharacterize

STORAGE

Figure 5

LLW PROGRAM

Examples Of An N2 Diagram – Input-Output Key

Figure 6
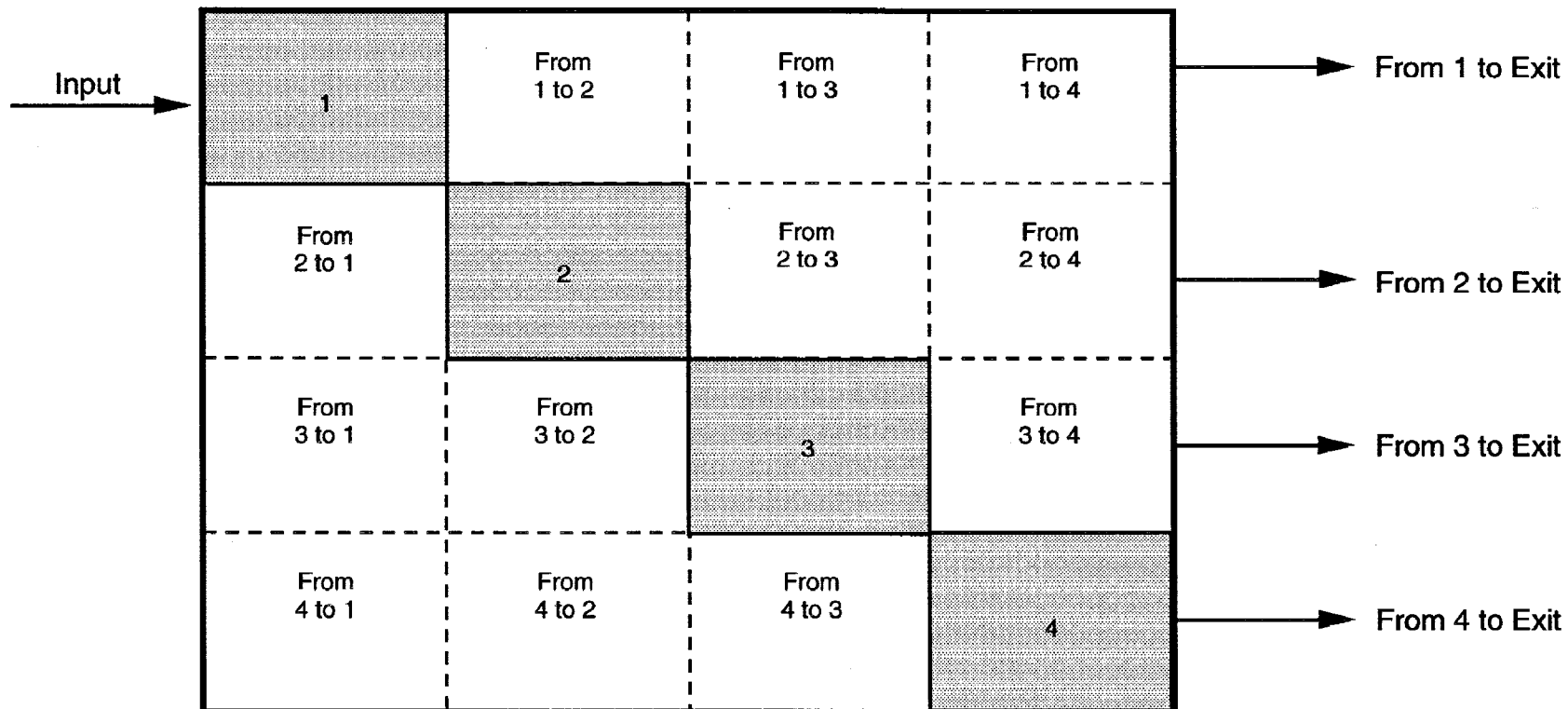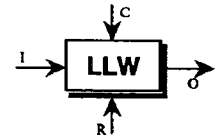
LLW Program

PRELIMINARY TECHNICAL FUNCTIONS

```
                          ┌─────────────────┐
                          │     Manage      │
                          │      LLW        │
                          │      LO         │
                          └────────┬────────┘
          ┌────────────────────────┼────────────────────────┐
┌─────────────────┐      ┌─────────────────┐      ┌─────────────────┐
│  Prepare LLW for│      │    Store LLW    │      │  Dispose of LLW │
│Storage or Disposal│    │     L1, F2      │      │     L1, F3      │
│      L1, F1     │      │                 │      │                 │
└────────┬────────┘      └────────┬────────┘      └────────┬────────┘
```

Prepare LLW for Storage or Disposal L1, F1	Store LLW L1, F2	Dispose of LLW L1, F3
Characterize LLW L2, F1.1	Verify LLW for Storage L2, F2.1	Verify LLW for Disposal
Treat LLW L2, F1.2	Operate LLW Storage L2, F2.2	Operate LLW Disposal Facility L2, F3.2
Package LLW L2, F1.3	Retire Facilities L2, F2.3	Close LLW Disposal Facility L2, F3.3
Verify LLW L2, F1.4		

Figure 7

Requirements/Constraints

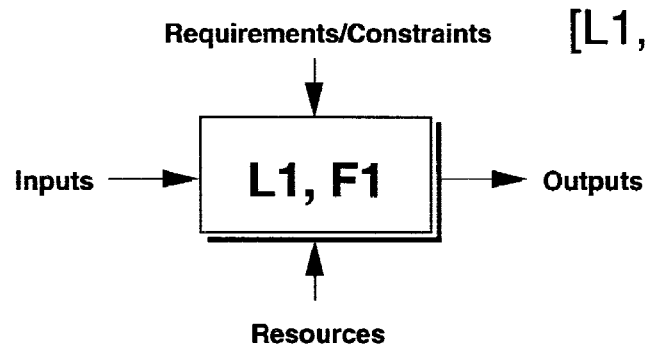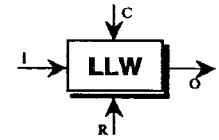Inputs → **L0** → Outputs

Resources

[L0] *MANAGE LOW LEVEL WASTE*

Definition: Safely, reliably, and efficiently manage and dispose of Low Level Waste

Inputs	Outputs	Requirements & Constraints	Resources
Stored waste	Closed facilities	Comply with laws, orders, codes, and standards	Existing Facility
New waste from generator	Post-closure management	Involve Stakeholders	Existing Technology
Waste that fails verification		TBD	Existing Management and Staff
			Funding

Figure 8

LLW PROGRAM

Requirements/Constraints
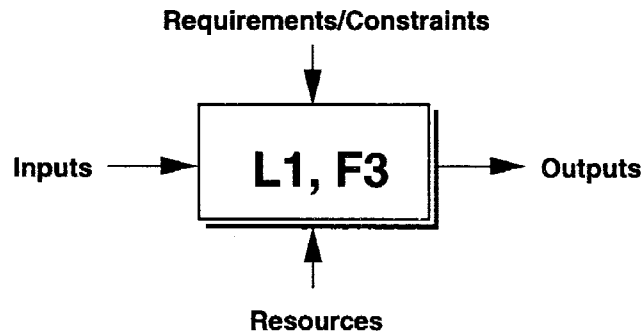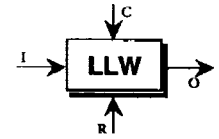
Inputs → **L1, F1** → **Outputs**

Resources

[L1, F1] *PREPARE LLW FOR STORAGE OR DISPOSAL*

Definition: Prepare LLW to meet the specific requirements and constraints for transfer, storage, and/or disposal. Determine the waste composition and properties and verify that the waste is LLW. Treat LLW to modify the waste characteristics and containerize for transfer, storage, or disposal.

Inputs	Outputs	Requirements & Constraints	Resources
Stored waste	Characterized, treated, packaged LLW for storage	Transport requirements	Characterization capabilities
New waste from generator		Storage requirements	Treatment capabilities
Waste that fails verification			
	Characterized, treated, packaged LLW for disposal	Disposal requirements	Packaging capabilities
		Required technology	Existing technology
		TBD	TBD

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Figure 9

LLW PROGRAM

[L1, F2] *STORE LOW LEVEL WASTE*

Requirements/Constraints

Inputs → **L1, F2** → Outputs

Resources

Definition: Operate and maintain LLW storage facilities within safety requirements. Provide storage for LLW waste awaiting treatment or disposal capacity. Insure that all stored LLW is suitably packaged and maintained for safe storage. Remove and transfer LLW for disposal or preparation for disposal. Decommission retired facilities.

Inputs	Outputs	Requirements & Constraints	Resources
Characterized, treated, packaged LLW for storage and/or disposal	LLW for disposal	TBD	TBD
	LLW not acceptable for disposal		
	Decommissioned Facilities		

Figure 10

LLW PROGRAM

Requirements/Constraints

**Inputs** → **L1, F3** → **Outputs**

Resources

[L1, F3] *DISPOSE OF LLW*

Definition: *Provide capacity for timely LLW disposal. Emplace LLW in a disposal facility in a safe and environmentally sound manner within prescribed limits, without the intent of retrieval. Operate and maintain LLW disposal facilities within safety and environmental requirements. Close the facility when useful capacity is reached. Provide post-closure management including long-term facility monitoring.*
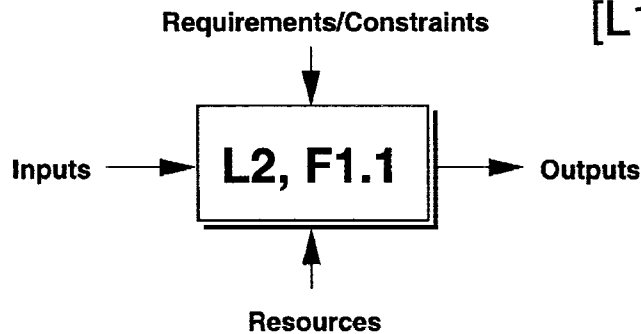
Inputs	Outputs	Requirements & Constraints	Resources
Stored LLW waste New LLW prepared for disposal	Closed facility Post-closure management	TBD	TBD

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Figure 11

Requirements/Constraints

Inputs → **L2, F1.1** → **Outputs**

Resources
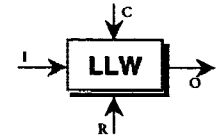
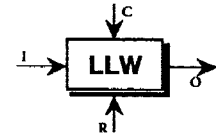## [L1, F1] *PREPARE LLW FOR STORAGE OR DISPOSAL*

[L2, F1.1] *CHARACTERIZE LLW*

Definition: Determine the waste characteristics and properities to meet transfer, treatment, storage, or disposal requirements and constraints. Verify that the waste is LLW. Provide transport and characterization capabilities. Provide documentation of characterization.

Inputs	Outputs	Requirements & Constraints	Resources
Stored waste	Characterized LLW for	Transport requirements	Characterization Capabilities
New waste from generator	treatment	Storage requirements	Existing Technology
Waste that fails verification	Characterized LLW for	Disposal requirements	TBD
	packaging, storage and/or	Characterization	
	disposal	requirements and	
		constraints	
		Required technology	
		TBD	

[L1, F1] *PREPARE LLW FOR STORAGE OR DISPOSAL*

Requirements/Constraints

Inputs → | **L2, F1.2** | → **Outputs**

Resources

[L2, F1.2] *TREAT LLW*

Definition: Change the physical or chemical character of LLW, including volume reduction, to satisfy the requirements and constraints for transport, storage, and/or disposal.

Inputs	Outputs	Requirements & Constraints	Resources
Characterized LLW for storage Characterized LLW for disposal	Treated waste for packaging, storage, and/or disposal	Transport requirements Storage requirements Disposal requirements Treatment requirements and constraints Required technology TBD	Treatment capabilities TBD

Figure 13

Requirements/Constraints

Inputs → **L2, F1.3** → Outputs

Resources

[L1, F1] *PREPARE LLW FOR STORAGE OR DISPOSAL*

[L2, F1.3] *PACKAGE LLW*

Definition: Provide a container that meets transport, storage, and/or disposal requirements and constraints. Emplace LLW in containers, seal and label. Provide documentation of packaging contents.

Inputs	Outputs	Requirements & Constraints	Resources
Characterized LLW for storage and/or disposal Characterized and treated LLW for storate and/or disposal	Characterized, packaged LLW for storage and/or disposal Characterized, treated, packaged LLW for storage and/or dispoal	Transport requirements Storage requirements Disposal requirements Packaging requirements and constraints Required technology TBD	Packaging capabilities Existing technology TBD

Figure 14

LLW PROGRAM

LLW

Requirements/Constraints

Inputs → **L2, F1.4** → Outputs

Resources

[L1, F1] *PREPARE LLW FOR STORAGE OR DISPOSAL*

[L2, F1.4] *VERIFY*
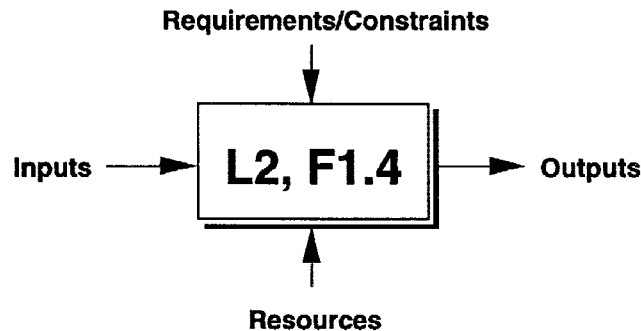
Definition: Provide physcial, radiological, chemical, visual inspections or documented assurance that the waste is LLW, and LLW meets the constraints and requirements needed to assure that it can be safely stored and/or disposed.

Inputs	Outputs	Requirements & Constraints	Resources
Characterized, packaged LLW for storage and/or disposal	Verified, characterized, packaged LLW for storage and/or disposal	Transport requirements Storage requirements Disposal requirements Packaging requirements and constraints Required technology TBD	Packaging capabilities Existing technology TBD
Characterized, treated, packaged LLW for storage and/or disposal	Verified, characterized, treated, packaged LLW for storage and/or disposal		
	LLW that fails verification		

Figure 15

LLW PROGRAM

[L1, F2] *STORE LOW LEVEL WASTE*

[L2, F2.1] *VERIFY FOR STORAGE*
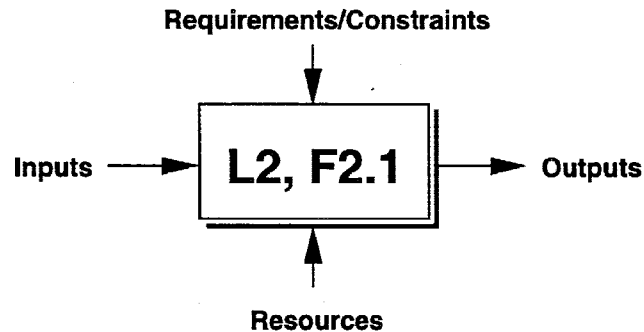
Requirements/Constraints

Inputs → **L2, F2.1** → Outputs

Resources

Definition: Provide physical, radiological, chemical, visual inspections or documented assurance that the LLW meets the storage facility constraints and requirements for safe storage and retrieval.

Inputs	Outputs	Requirements & Constraints	Resources
Characterized, treated, packaged LLW for storage and/or disposal	Verified incoming LLW for storage Verified incoming LLW for disposall	Storage requirements Disposal requirements Required technology TBD	TBD

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Figure 16

LLW PROGRAM

Requirements/Constraints

Inputs → **L2, F2.2** → **Outputs**

Resources
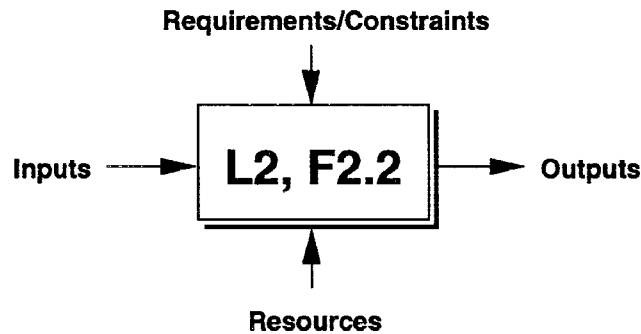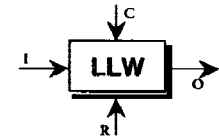
[L1, F2] *STORE LOW LEVEL WASTE*

[L2, F2.2] *OPERATE LLW STORAGE*

Definition: *Provide storage capacity to accommodate legacy and new LLW awaiting disposal. Operate and maintain LLW storage facilities within safety requirements. Provide waste handling capability for placement and retrieval of waste in storage. Inspect waste and remediate leaking or suspect containers. Remove and transfer LLW for disposal or preparation for disposal.*

Inputs	Outputs	Requirements & Constraints	Resources
Verified LLW characterized, treated, packaged for storage	LLW disposal LLW to be prepared for disposal Legacy Waste for treatment prepared for disposal	Storage requirements Required technology TBD	TBD

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Figure 17

Requirements/Constraints

Inputs → | L2, F2.3 | → Outputs

Resources
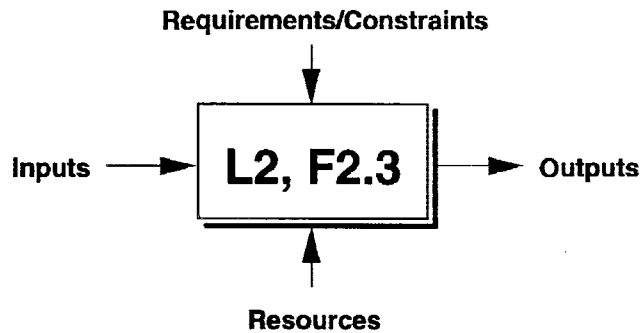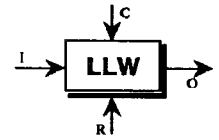
[L1, F2] *STORE LOW LEVEL WASTE*

[L2, F2.3] *RETIRE FACILITY*

Definition: Prepare facility no longer needed by the program for release to another user or for decomissioning. Leave the facility in a negotiated acceptable condition.

Inputs	Outputs	Requirements & Constraints	Resources
Empty LLW storage facility Records and data for turn over	Retired facility ready for release to another user or for decomissioning. Facility is in a negotiated acceptable condition.	Negotiated acceptable condition TBD	TBD

LLW PROGRAM

Requirements/Constraints

Inputs → **L1, F3.1** → Outputs

Resources
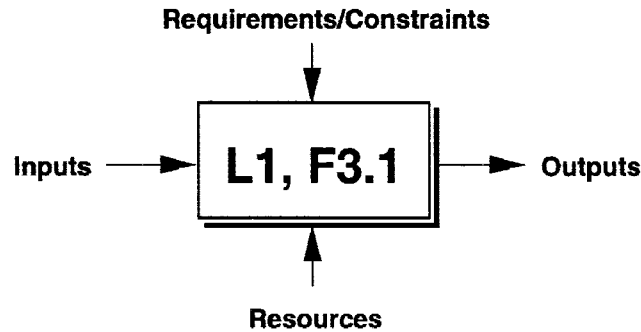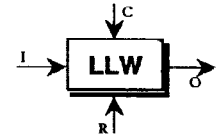
[L1, F3] *DISPOSE OF LLW*

[L2, F3.1] *VERIFY*

Definition: Provide physical, radiological, chemical, visual inspections or documented assurance that the LLW meets the disposal facility constraints and requirements for safe disposal.
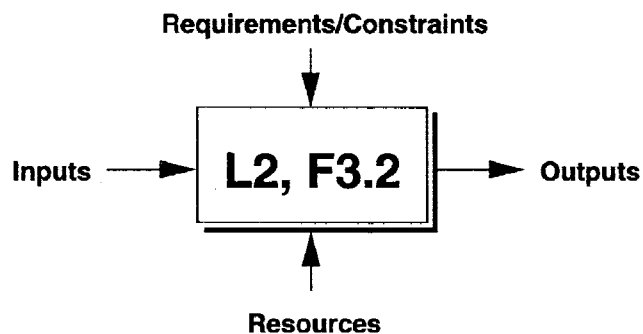
Inputs	Outputs	Requirements & Constraints	Resources
Characterized and packaged LLW for disposal Characterized, treated, and packaged LLW for diposal	Verified LLW for disposal LLW that has failed verification for disposal	Disposal Requirements TBD	TBD

Figure 19

LLW PROGRAM

Requirements/Constraints

Inputs → **L2, F3.2** → **Outputs**

Resources
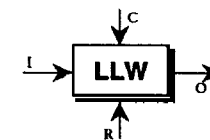
[L1, F3] *DISPOSE OF LLW*

[L2, F3.2] *OPERATE LLW DISPOSAL FACILITY*

Definition: Provide timely disposal capacity. Emplace LLW in the disposal facility in a safe and environmentally sound manner within prescribed limits, without the intent of retrieval. Operate and maintain LLW disposal facilities within safety and environmental requirements. Prepare facility for closure when useful capacity is reached.

Inputs	Outputs	Requirements & Constraints	Resources
Verifed waste for disposal	Full facility Records & data	Disposal Requirements TBD	TBD

Figure 20

Requirements/Constraints

Inputs → **L2, F3.3** → **Outputs**

Resources
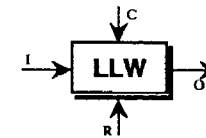
[L1, F3] *DISPOSE OF LLW*

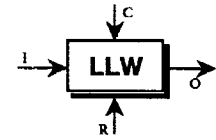## [L2, F3.3] *CLOSE LLW DISPOSAL FACILITY*
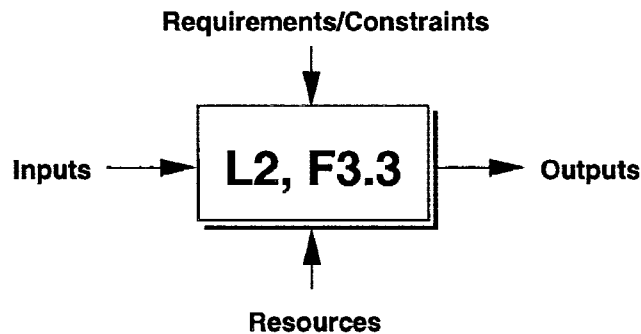
Definition: Design and implement final closure of facility. Provide post-closure management including long-term facility monitoring.
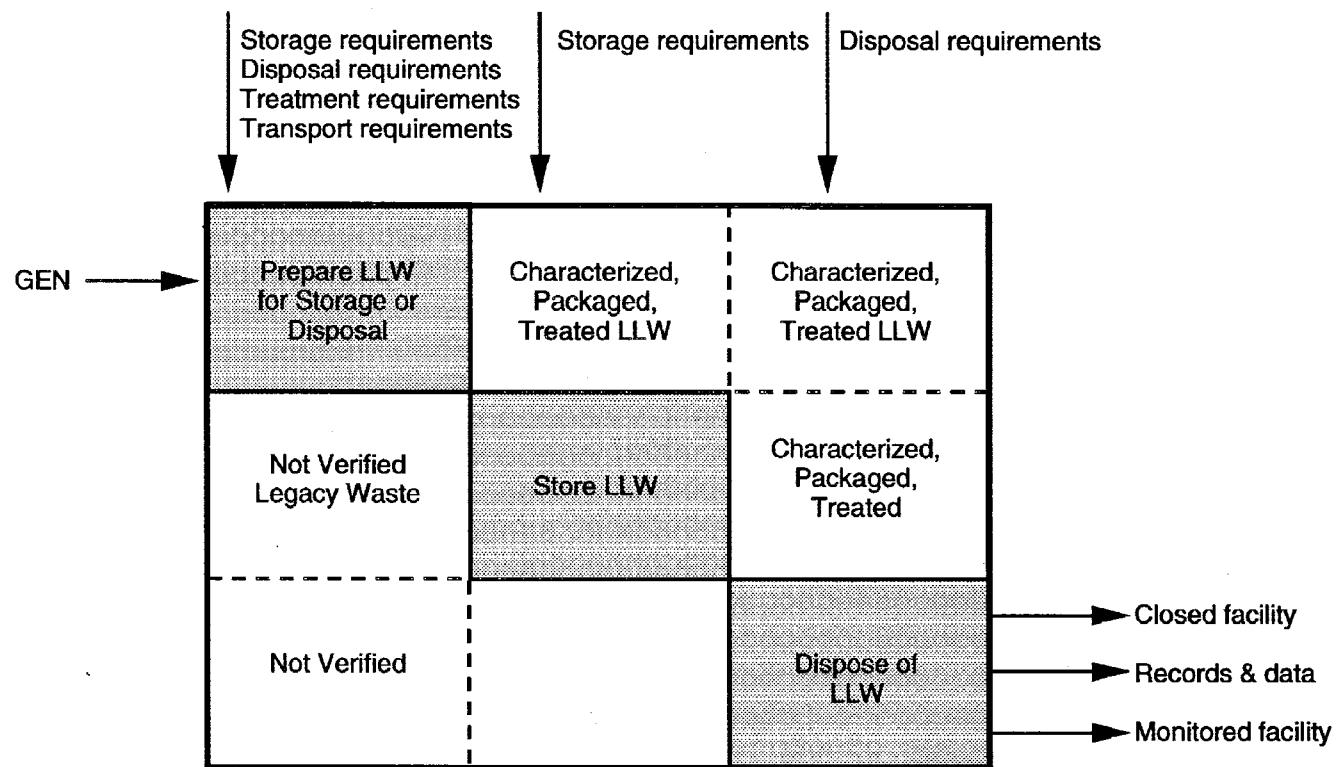
Inputs	Outputs	Requirements & Constraints	Resources
Full facility	Closed facility	Disposal requirements	TBD
Records & data	Post-closure management	Closure requirements	
	Records & data	Post-closure monitoring	
	Technology	requirements	
		TBD	

Figure 21

C
I → [LLW] → O
R

Manage LLW

Storage requirements Storage requirements Disposal requirements
Disposal requirements
Treatment requirements
Transport requirements

GEN →

Prepare LLW for Storage or Disposal	Characterized, Packaged, Treated LLW	Characterized, Packaged, Treated LLW
Not Verified Legacy Waste	Store LLW	Characterized, Packaged, Treated
Not Verified		Dispose of LLW

→ Closed facility
→ Records & data
→ Monitored facility

PREPARE LLW FOR STORAGE OR DISPOSAL

Transport requirements
Storage requirements
Disposal requirements
Technology requirements

Treatment requirements

Packaging requirements

Verification requirements

Data
Technology

Rejected LLW
New LLW
Legacy LLW

Characterized LLW	Characterized Treatment Requirements	Characterized No Treatment		→ Non LLW
Recharacterize	Treat LLW	Treated LLW		→ Non LLW
		Package LLW	Packaged LLW	
Recharacterize		Repackage	Verify LLW	→ Verified LLW for Disposal → Verified LLW for Storage → Verified LLW for Repackaging or Retreatment

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Figure 23

STORE LLW

Assumptions

Operate SNF Storage Includes:
– Provide Facility
– Ov erpack Leaking Drums

Figure 24
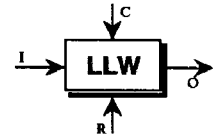
DISPOSAL OF LLW
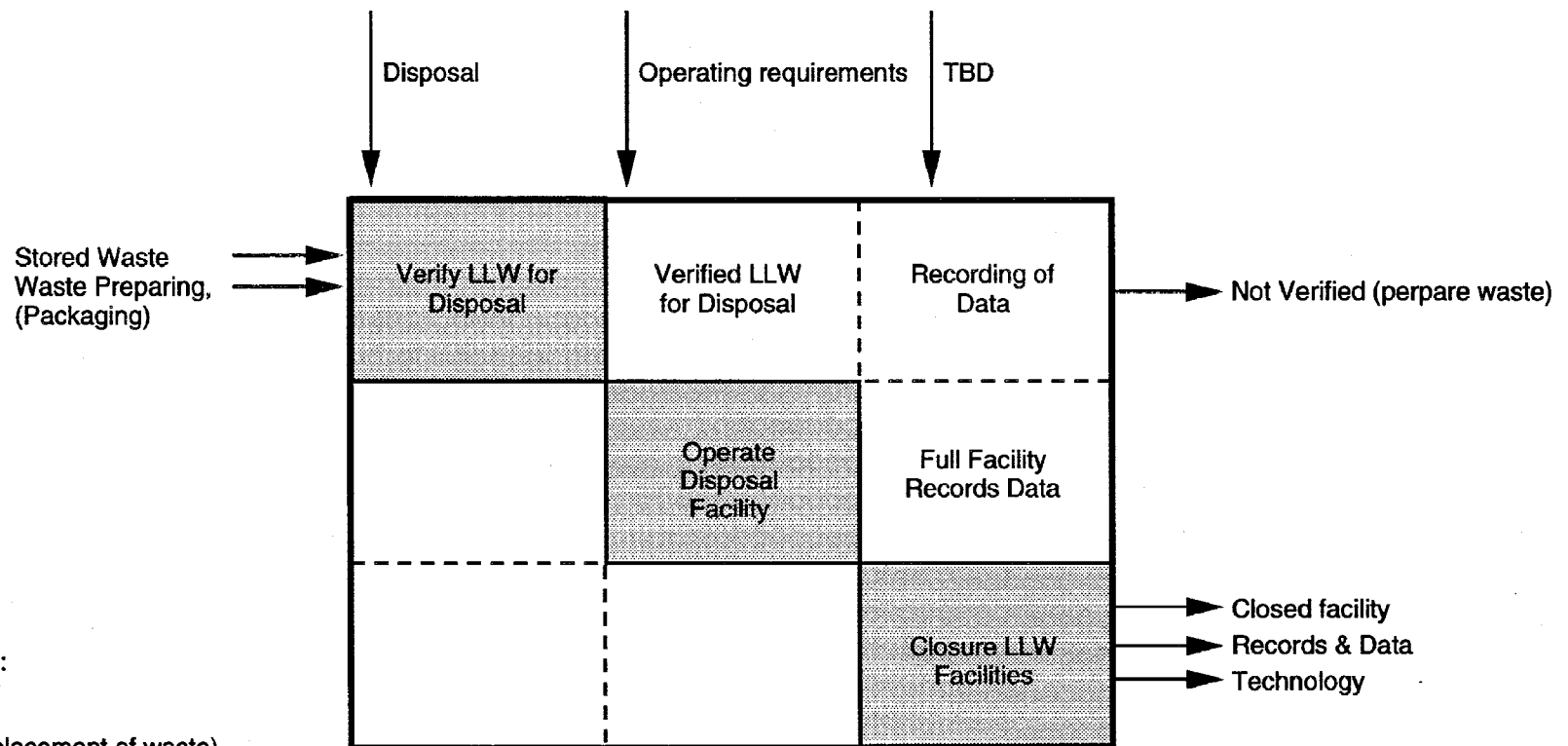
Assumptions

Operate Includes:
– Provide Facility
– Maint.
– Operation (emplacement of waste)

Closure includes:
– Close Facility (cap)
– Post-closure Action (monitor)

Figure 25