WM’00 Conference, February 27 – March 2, 2000, Tucson, AZ

SYSTEMS ENGINEERING IMPLEMENTATION FOR HANFORD TANK WASTE FEED DELIVERY

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ABSTRACT

The U.S. Department of Energy (DOE) is seeking a cost-effective technical solution to Hanford Site tank waste cleanup. The strategy being implemented by DOE is to vitrify the tank waste in a privately owned (non-government) facility built on site. As such, planning for the design, construction and operation of government-owned systems to deliver the tank waste to the privately owned and operated vitrification plant presents a complex problem. This complex problem, coupled with the need to procure the waste feed delivery system in small pieces via separate line item projects, presents a significant system integration challenge.

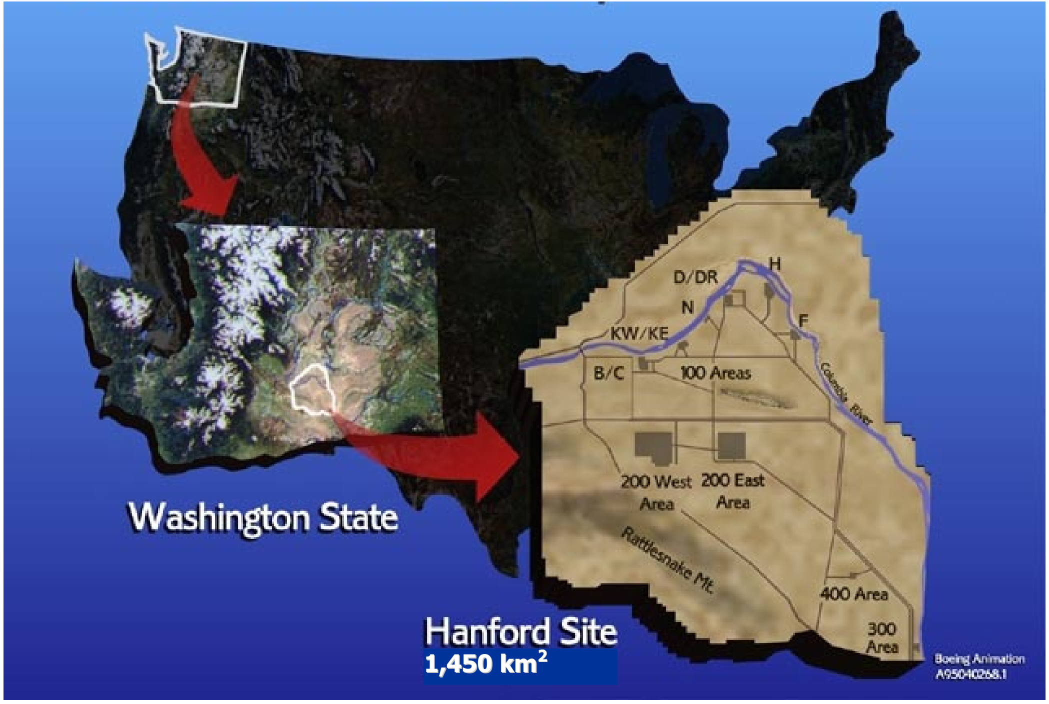
This paper discusses the systems engineering principles applied to the waste-feed delivery problem needed to address the issues of baseline control, system integration and development of design solutions that are independent of a validated requirements set. We present herein a methodology[a] for developing and applying a consistent, top-down derived set of technical requirements that enable the line item projects to design (conceptual and detailed), construct and turn over subsystems/components that make up an integrated waste-feed delivery system. This methodology addresses the fact that items designed, constructed and turned over by these line item projects must be integral to an existing system that was designed, constructed and is being operated to satisfy a completely different mission—safe storage of tank waste. This paper also discusses how specifications and other documentation that communicate the technical requirements and project scope definition were produced. The problem of implementing this new methodology in parallel with ongoing project activities is also discussed. Lessons learned to date in applying this methodology conclude the paper.

BACKGROUND/INTRODUCTION

The Hanford Site is a 1,450 km^2 reservation located on the Columbia River in the southeast portion of the state of Washington and is managed by the U.S. Department of Energy (see Fig. 1). The reservation started as a plutonium production complex that played a critical role in the nation's defense for more than 50 years. The Site has evolved into the world's largest environmental cleanup project with many challenges to be resolved in the face of political, regulatory, and cultural interests. These interests are represented in what is known as the Tri-Party Agreement (TPA) (1). The TPA is a formal agreement between the Washington State Department of Ecology, the U.S. Environmental Protection Agency and the U.S. Department of Energy (DOE). This agreement specifies how and when Hanford Site cleanup will proceed.

A major portion of the cleanup mission, as represented in the TPA, is the removal, immobilization and disposal of the waste stored in 177 underground storage tanks located in the 200 East and 200 West Areas of the Hanford Site (see Fig. 1). The waste stored in these tanks is the result of various chemical processes used to extract plutonium from irradiated reactor fuel rods. The capacities of the underground storage tanks vary widely—from 208 to 4,390 m^3. Tank design also varies from those made of reinforced concrete with one steel liner (single-shell tanks [SSTs]) to those made of reinforced concrete with two steel liners (double-shell tanks [DSTs]). There are 149 SSTs—built between 1943 and 1964 (2)—and 28 DSTs—built between 1968 and 1986 (2)—in service. Sixty-seven of the SSTs are designated as assumed leakers (3). The DSTs are sound and have not developed any leaks. Both the SSTs and DSTs were constructed in multiple tank groups known as tank farms with two to sixteen tanks per farm.

Fig. 1. Hanford Site Location.



The tanks, tank farms, shutdown fuel reprocessing facilities and other support facilities are interconnected through a network of underground waste transfer piping, valving, tank ventilation (both active and passive) and support structures that are in various stages of repair. The physical, chemical and radioactive properties of the wastes contained in the tanks vary with the range of plutonium production processes and waste storage methods used over the last 50 years as well. Waste properties vary in consistency from easily pumpable liquids to thick, peanut buttery sludges and saltcakes. The liquids contain soluble radioactive isotopes, such as cesium, whereas the sludges contain insoluble isotopes, such as strontium. This wide variety of wastes, waste storage vessels, and supporting structures will require innovative and creative technical management techniques to manage the removal, immobilization and disposal of these wastes in a cost-effective manner.

The baseline approach to the tank waste remediation problem has been divided into two phases per the DOE[b]. During Phase 1, a representative cross section of tank waste types will be removed from the DSTs and SSTs and transferred to a private contractor for pretreatment and vitrification. This phase will stabilize approximately 20 to 25 percent of the radioactivity in the 205,000 m^3 of waste currently stored in DSTs and SSTs (approximately 50 million curies) (4). The remainder of the waste will be removed during Phase 2 to a larger, production-scale facility for pretreatment and vitrification. After vitrification, immobilized high-level waste (HLW) will be stored on site until it can be transported to a national geologic waste repository for disposal. The immobilized low-activity waste (LAW) will be placed in disposal facilities on the Hanford Site. Because of the costs of handling and disposal of the HLW product, the DOE has provided incentives to both the vitrification facility contractor and the Hanford waste storage tank operations contractor to minimize the volume of immobilized HLW (IHLW) product. Decisions on how the tank wastes are sequenced (sometimes after blending) through the privatized vitrification plant have a significant impact on the minimization of vitrified HLW.

The problem of efficiently delivering waste feed to the treatment and vitrification plant is complex and requires major upgrades to the tanks, farms, and support equipment to properly characterize, remove, stage and blend waste types before it is transferred to the privately owned vitrification plant. This paper addresses the systems engineering methodology being implemented to manage the activity of the design and integration of the major system upgrades necessary to accomplish this mission.

In particular, the systems engineering methodology is being implemented to manage issues of baseline control, system integration, and the development of design solutions that are independent of a singular, validated requirements set for the Waste Feed Delivery (WFD) Program. These issues have been amplified by (a) dividing, among several Line Item Projects, the job of the design and construction of major DST and SST System upgrades; and (b) numerous changes in the WFD mission after project initiation. The systems engineering approach discussed herein remedies these problems via development of a consistent set of technical requirements, derived by flowing down and analyzing the top-level requirements and needs levied by the DOE to guide the development of the system upgrades needed to satisfy the WFD mission.

The problem of system integration and internal baseline control is more easily managed in that the WFD Program levies a singular set of requirements on all Line Item Projects. Level 1 (system) and Level 2 (subsystem) specifications and companion interface control documents (ICD), as described by DOE Order 430.1, *Life Cycle Asset Management* (5), are the resulting documents that help integrate and communicate the WFD Program requirements baseline to all WFD Line Item Projects. This paper will detail the systems engineering principles used by the WFD Program to derive this set of documentation and explain how the problem of doing this in parallel with ongoing project activities is being addressed. An informal "self evaluation/status" will be discussed in the Results section of this paper and lessons learned to date in applying this methodology will conclude the paper.

METHOD

The systems engineering process implemented by the WFD Program consists of four basic steps. These steps are repeated with increasing detail until complex, vague requirements and systems are broken down into well defined requirements and subsystems that can be designed and constructed by Line Item Projects. These steps are referred to throughout this paper as follows:

1. Functional Analysis – Defines what the system must do to accomplish the mission in terms of system functions. System functions are defined and their interaction with one another is established in the functional analysis.

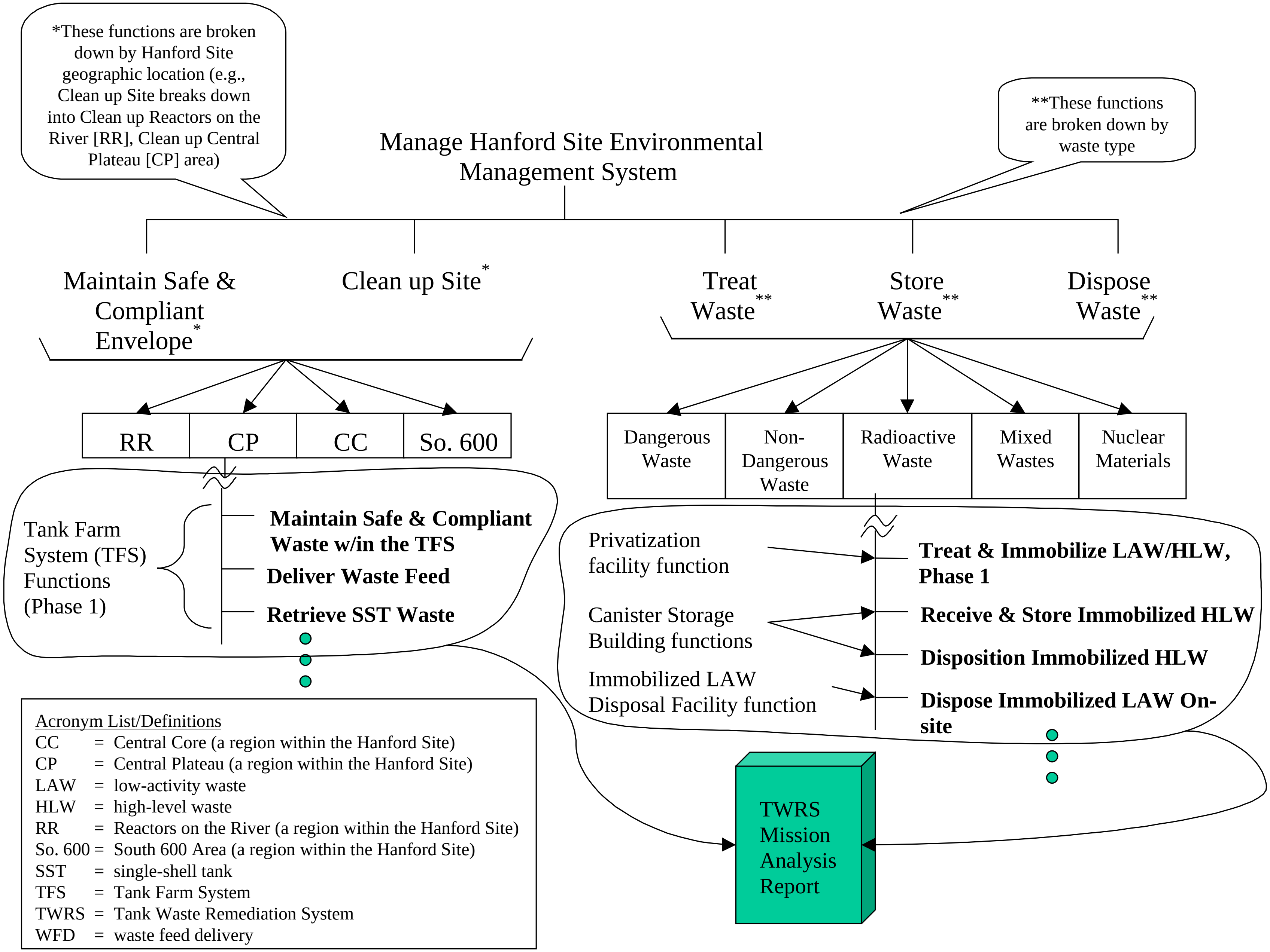
2. Requirements Analysis – Defines the requirements the system must satisfy. Requirements are analyzed and applied to functions (performance requirements), system architecture (design constraints) or interfaces (interface requirements). Performance requirements define how well a particular function must be performed. Design constraints are requirements that apply directly to system hardware design features (e.g., all waste transfer lines shall be double contained). Interface requirements can pertain either to performance or to design features as applied to system interfaces.

3. System Assessment – Evaluates the ability of the existing system to satisfy the functions and requirements of the system.

4. Alternative Analysis/Architecture[c] Selection– If the existing system cannot satisfy the functions and requirements, as identified in the System Assessment, the alternative analysis/architecture selection evaluates alternative design solutions and integrates the selected solution into the system definition.

Functional Analysis

The functional analysis being performed for the WFD problem is integral to the functional analysis already performed for the Hanford Site cleanup mission (see Fig. 2). The Sitewide functional analysis identified the various major portions of the Hanford Site cleanup mission. One of these major portions is the tank waste remediation mission, which includes the continued safe storage, removal, immobilization and disposal of mixed and radioactive waste stored in the underground storage tanks of the 200 East and 200 West Areas of the Hanford Site. Table I shows how this mission statement correlates to the site-level functional analysis results. To properly identify and document the scope of the River Protection Project (RPP) (formerly known as the TWRS Program), a mission analysis report was created to gather the "site-level" functions, requirements and systems that pertained to the tank waste remediation mission (6) (see Fig. 2).



Acronym List/Definitions

CC = Central Core (a region within the Hanford Site)
CP = Central Plateau (a region within the Hanford Site)
LAW = low-activity waste
HLW = high-level waste
RR = Reactors on the River (a region within the Hanford Site)
So. 600 = South 600 Area (a region within the Hanford Site)
SST = single-shell tank
TFS = Tank Farm System
TWRS = Tank Waste Remediation System
WFD = waste feed delivery

Fig. 2. Tank Waste Remediation Mission in Hanford Site Functional Decomposition.

Table I. River Protection Project Mission Statement Correlation to Site-level Functions.

Mission Statement	Site-level Function (Phase 1 Only)	System Performing Function
Continue safe storage of tank waste	- Maintain safe & compliant waste within the tank farm system	Tank Farm System
Remove tank waste	- Deliver waste feed - Retrieve SST waste	Tank Farm System
Immobilize tank waste	- Treat & immobilize LAW/HLW, Phase 1	Privatization Facility
Store & dispose of tank waste	- Receive & store immobilized HLW, Part 1 - Disposition immobilized HLW (ship to geologic repository)	Canister Storage Building
	- Dispose immobilized LAW onsite	Immobilized LAW Disposal Facility

The Site functional analysis is being further developed by the RPP to fully specify the requirements of the systems and subsystems needed to accomplish this mission. The Phase 1 WFD portion of this functional analysis is focused on what the Tank Farm Systems (TFS) of the 200 East and 200 West Areas must do to effectively remove and transfer stored wastes from the TFS[d] to a privatized waste treatment and immobilization facility. This TFS-level functional analysis is based on

1. The functions of the Tank Farm System shown in Fig. 2 and Table I above; and
2. The functionality represented in the system model that was created to optimize the operations and utilization of wastes stored in the TFS for WFD (7).

Fig. 3 shows the results of the TFS-level functional analysis in the form of a functional flow block diagram to show the sequential relationships between the functions.

The TFS-level functions shown in Fig. 3 are further broken down so that functions of the *subsystems* performing the WFD mission are identified. This process allows for the specification of performance parameters for subsystem designers. This more detailed functional analysis is based on the analysis of the waste processing necessary to accomplish WFD for representative underground waste storage tanks (8, 9, 10). This level of functional analysis accounts for the top-level architecture decisions made regarding the components of the TFS for WFD. Note also that since a majority of the subsystems involved in the WFD mission are within the DST System portion of the TFS, this more detailed functional analysis focuses on the DST System (see Fig. 4).

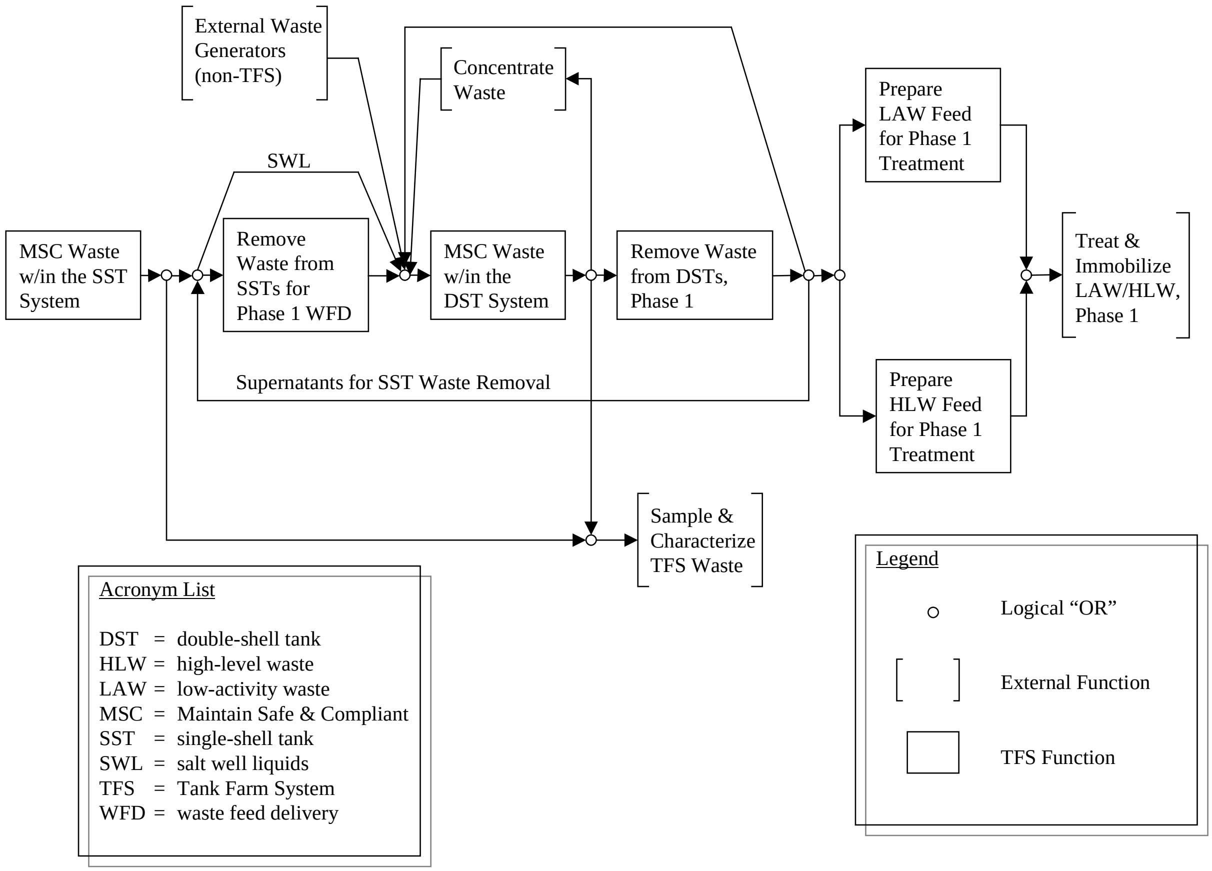


Fig. 3. Tank Farm System Functional Flow Block Diagram.

Requirements Analysis

The requirements analysis being performed for the TFS for the WFD problem is being approached on the three main fronts:

- Engineering analysis to quantify the performance requirements for the WFD functions
- Engineering analysis to quantify interfacing system inputs
- Engineering analysis to identify and analyze the design constraints applicable to the TFS and its subsystems.

The engineering analysis that quantifies the TFS’s functionality is based primarily on the quantitative output of the same system model used to describe the TFS functionality (7). The analyses to quantify the performance of the TFS subsystem functions are more unique, discrete studies that focus on answering specific questions brought out by the functional analysis for the individual subsystem. The assumptions and input conditions for these subsystem performance analyses are bound, but not deemed unchangeable, by the overall TFS performance requirements. Documenting the assumptions, constraints and calculation methods used to quantify the system and subsystem behavior is a crucial element of establishing the traceability for the requirements levied on the TFS and subsystems. This practice also aids in the ability to “trade” requirements, if warranted. If the subsystem analysis results in untenable system design parameters, the system level trades are then made with full awareness of their ramifications.

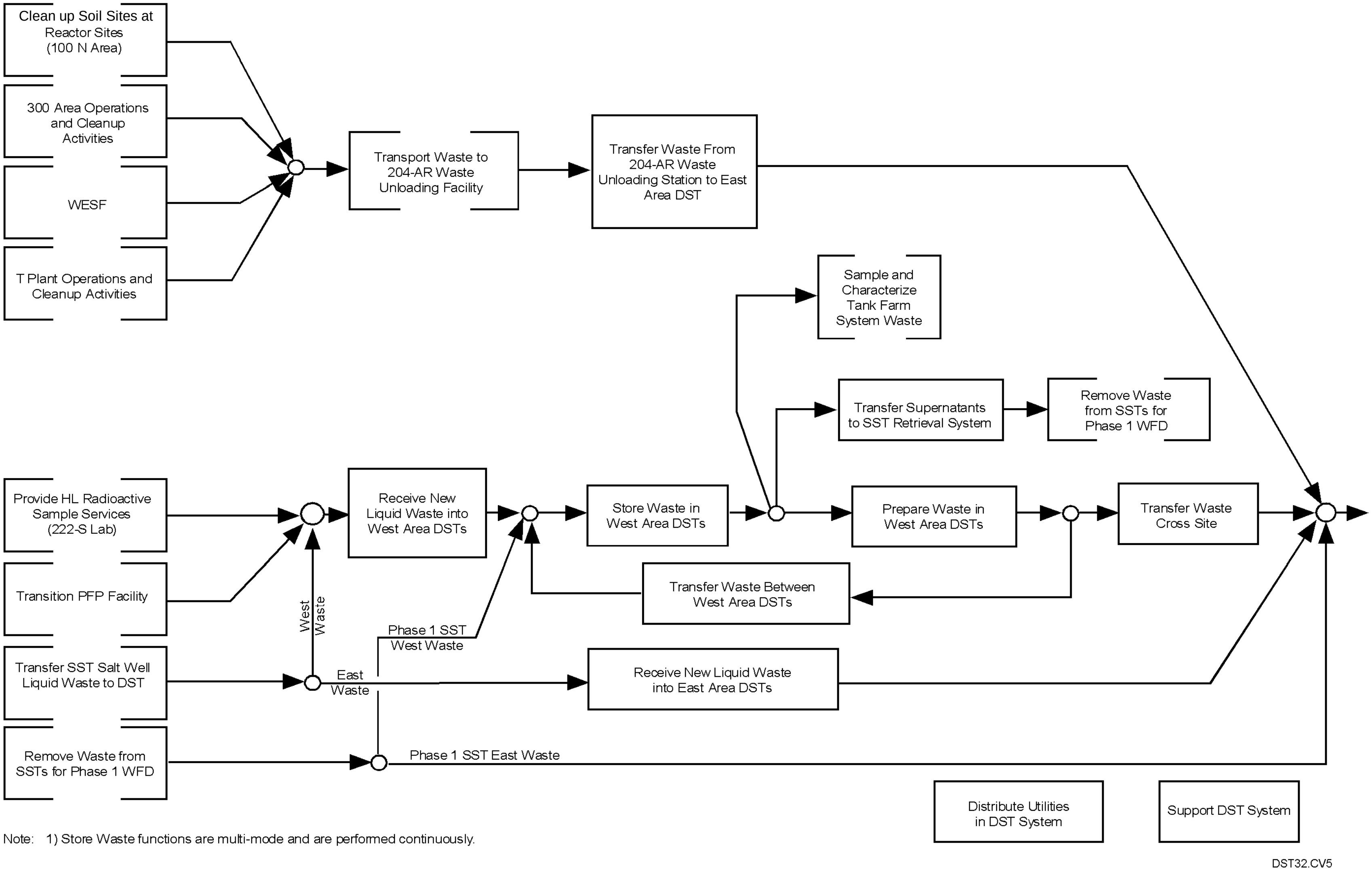
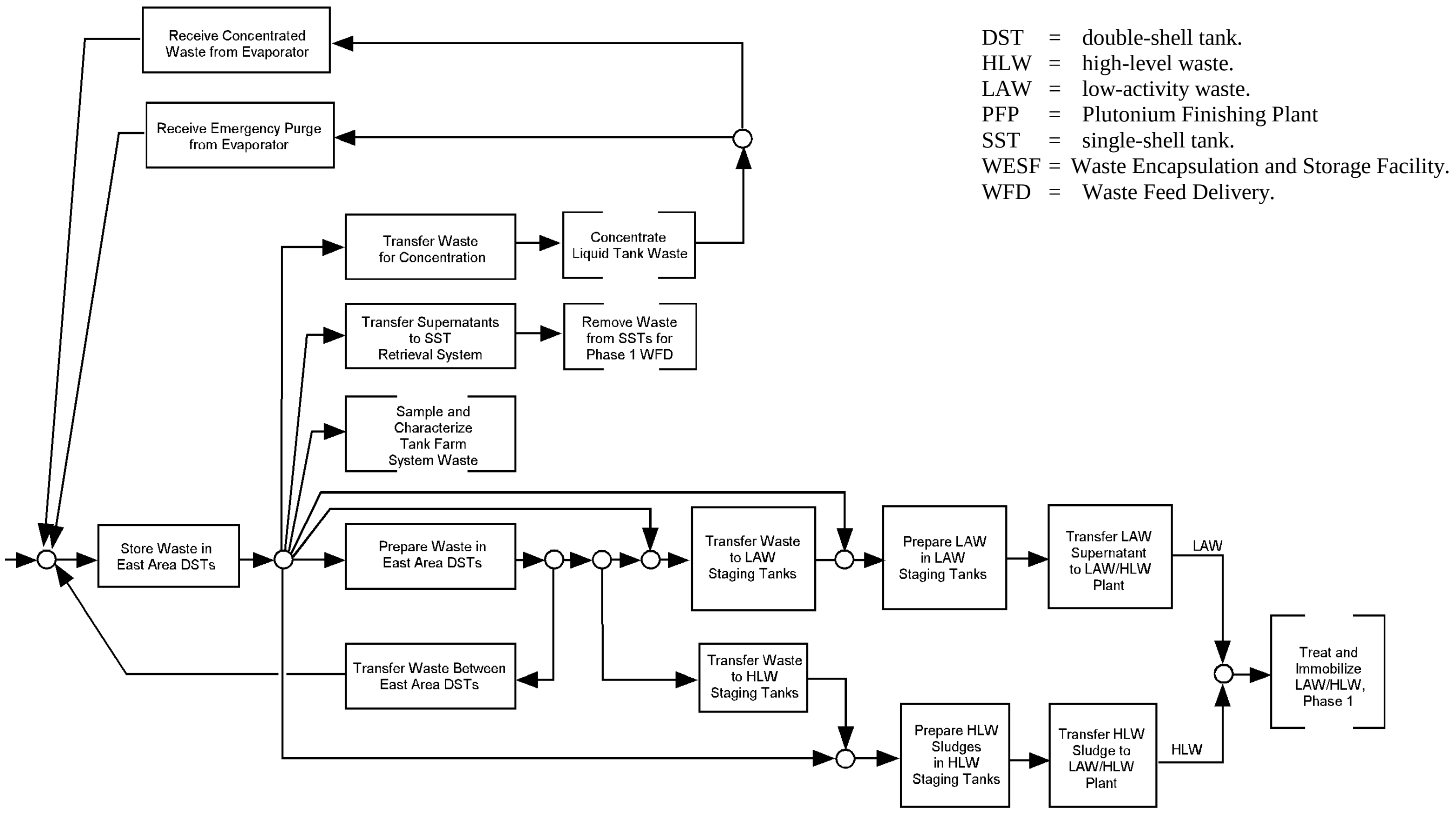


Fig. 4. Double-Shell Tank System Functional Flow Block Diagram.
(Sheet 1 of 2)



DST = double-shell tank.
HLW = high-level waste.
LAW = low-activity waste.
PFP = Plutonium Finishing Plant
SST = single-shell tank.
WESF = Waste Encapsulation and Storage Facility.
WFD = Waste Feed Delivery.

Note: 1) Store Waste Functions are multi-mode and are performed continuously.

DST32b-1.CV5

Fig. 4. Double-Shell Tank System Functional Flow Block Diagram.
(Sheet 2 of 2)

The principles of interface requirements analysis for the TFS are very similar to the performance requirements analysis described above. The interface requirements for the TFS, however, are dependent on the performance of the interfacing systems and are subject to negotiation with the owners of the interfacing systems rather than internal trades. This negotiation is documented and controlled in ICDs and agreed to by both parties responsible for the interfacing systems. The systems interfacing with the TFS during the WFD mission are identified in the Site-level functional analysis. The TFS interface requirements quantify the items flowing across the system boundary via system analysis and negotiations. These agreed-to quantities comprise the interface requirements for the TFS. Interfaces between TFS subsystems that are strictly internal to the TFS are handled in a similar way at this detailed level. With the exception of interfaces with existing subsystem components (e.g., existing DSTs with fixed capacities), trades on these internal interface requirements are entertained, with the WFD Program engineer acting as the decision maker. Interface requirements analysis also includes definition of the physical boundary and identification of the design constraints associated with interfaces at all levels of detail.

Design constraints for the entire TFS and its subsystems also are identified, analyzed and documented. The TFS design constraints result from an analysis of

- External agency requirements documents (e.g., DOE Orders, Washington Administrative Code[WAC], Code of Federal Regulation [CFR]) levied on the TFS via contractual agreement;
- The environmental conditions (both natural and induced) impinging upon the TFS and its subsystems; and
- Requirements associated with TFS subsystems/components that are unchangeable (e.g., DST and SST structural integrity requirements).

Applicable DOE Orders, WACs and CFRs and internal procedures are imposed on the TFS at the "document level" without an attempt to parse, analyze and interpret their individual requirements before levying them on the TFS. The activity of parsing, analyzing, interpreting and appropriately applying these design constraints is performed, as necessary, for the TFS subsystems. This progression is natural as a result of the increased definition and understanding of the composition of the TFS and therefore the applicability of individual requirements contained in these imposed requirements documents.

Table II shows various examples of performance requirements, interface requirements and design constraints as they apply to the DST System and its subsystems.

System Assessment

Given a complete functions and requirements set for a certain level of system definition (i.e., TFS or subsystem), the existing system or subsystem is analyzed to determine its ability to perform the necessary functions to the requirements. This analytical assessment uses the documented, operational baseline description of the system captured in active operating procedures, as-built drawings of the operational system, and design drawings from ongoing Line Item Projects. Subsystem assessments will include physical evaluations to determine the fidelity of the document-based assessment. Until these detailed physical evaluations are complete, further functional, requirements and architectural analysis is focused on deficiencies identified by the analytical assessment. It follows, then, that engineering development efforts in instances where the existing systems satisfy the derived functions and requirements can cease. The assessment activity acts as a focusing and scoping tool for the development of new subsystems needed to accomplish the WFD mission; however, it does not attempt to identify solutions to remedy the deficiencies.

Table II. Example Requirements.

Requirement Type	Requirement	Applicability
Performance requirement	The DST System shall be capable of delivering at least 3,820 m^3 of low-activity waste feed to the privatization facility in less than or equal to nine (9) days.	DST System (Level 1 Spec)
	The DST Transfer Pump Subsystem shall pump waste at a rate of at least 4.5 liters/sec with an end-of-line pressure of at least 540 kPa (7.6 cm line diameter).	DST Subsystem (Level 2 Spec)
Interface requirement	The DST System shall be capable of accepting at least 2,100 m^3 of waste from the SST System between 6/2006 and 10/2010.	DST System (Level 1 Spec)
	The DST Transfer Valving Subsystem shall be capable of withstanding a maximum pressure of 2.76 MPa during waste transfers.	DST Subsystem (Level 2 Spec)
Design constraints	The DST System shall incorporate secondary containment and leak detection features in accordance with WAC-173-303-640 (4).	DST System (Level 1 Spec)
	Cover blocks and existing process pits shall have a special protective coating to prevent waste absorption in the cover block from a spray leak.	DST Subsystem (Level 2 Spec)

Alternative Analysis/Architecture Selection

Solutions for TFS deficiencies are selected via a rigorous process of evaluating alternative system architectures. All alternative architectures evaluated during this process must satisfy the functions and requirements developed by the functional and requirements analyses. Additional criteria used to evaluate the alternatives include risk (both programmatic and technical), life-cycle cost, schedule, operability, overall effectiveness, ease of integration within the existing system, technical feasibility and/or other specialty engineering considerations (e.g., quality assurance, manufacturing, constructability). The degree to which each evaluation criterion is used/weighted depends on the complexity and overall cost associated with the architecture decision being made.

Primary Technical Baseline Documentation

The functions and requirements analysis, system assessments and alternative analysis/architecture selection are repeated at increasing levels of detail, as described above, until the TFS is broken down into smaller tractable DST subsystems with a complete set of functions and requirements. This process naturally allows for feedback to the upper-level system definition as more refined knowledge is gained at the lower levels. These processes result in requirements documentation at varying levels of detail that have a unique and important responsibility in succinctly communicating an integrated, traceable requirements set for a given level of system definition.

The document that succinctly communicates system level functions, requirements and architecture description is referred to herein as a Level 1 specification (see DOE Order 430.1A [5]). Companion ICDs are also written at a commensurate level of detail to capture and document the interface requirements analysis described above. Based on program management input and input from the Hanford Site systems engineering effort, Level 1 specifications and ICDs that cover the WFD mission for Phase 1 are written for the DST System and SST System. These systems comprise major portions of the TFS. The Level 1 specifications and companion ICDs serve as the WFD Program technical requirements integration tool for several reasons. These documents allow the Program to conduct analytical assessments of DST System to a baselined set of requirements, identify areas where major deficiencies exist, perform the required alternative analysis/architectural definition, and focus further development of subsystem-level functions and requirements analysis and architecture definition.

Subsystem-level functions, requirements, and subsystem architecture description are captured in Level 2 specifications and companion ICDs. Based on the WFD Program acquisition strategy of assigning the procurement of subsystem-level TFS architectures to the Line Item Projects, the purpose of the Level 2 specifications and ICDs is to communicate the "design-to" requirements consistently to all WFD Line Item Projects. These specifications also allow the WFD Program to focus detailed assessments on existing subsystems that may be of questionable suitability (e.g., specific waste transfer piping runs may need to be evaluated for pressure sensitivity, as specified in the applicable Level 2 specification).

Another important document created and used by the WFD Program is the project definition criteria (PDC). The PDC communicates the project scope based on (a) the system deficiencies identified in the system assessments; (b) programmatic considerations (cost and schedule); and (c) existing Line Item Projects' scope. The PDC specifies the quantities and locations of the subsystems to be provided by the project (e.g., two mixer pumps in Tank 241-AZ-101) and invoke the applicable Level 2 specifications and ICDs, or portions thereof, to which the subsystems are to be designed. The PDC therefore acts as a quasi contract between the WFD Program and the Line Item Projects to which both parties can manage their respective efforts.

The process of generating and documenting the requirements baseline for the TFS in a rigorous stepwise fashion as described above maintains baseline control and system integration and provides an integrated defensible requirements set for the design of subsystems. A status of where the WFD Program is in developing the above documentation and an informal, qualitative "self-evaluation" of how the above process helped alleviate these problems comprise the results section of this paper.

RESULTS

To date, the WFD Program has issued two Level 1 specifications—one for the DST System and one for the SST System—and ICDs for the DST System interfaces. The majority of the requirements development work for the TFS has been focused on the DST System[e]. Although an early draft of the DST System Level 1 specification was used in the DST System assessment activity, this specification has been used primarily as an integration and baseline control tool for the development of DST Subsystem (Level 2) specifications. The DST System Level 1 specification and companion ICDs have documented the translation of the TFS model's results, for the baseline WFD sequence, into the top-level performance and interface requirements for the DST System. Because the DST Subsystem functional and requirements analysis used the functional and requirements analysis developed for the Level 1 specification as the starting point, baseline control has been achieved for the DST Subsystem-level requirements development activity, as well as for activities that use the Level 2 specifications.

Level 2 specifications have been prepared for seven of the eleven DST Subsystems that contribute to performance of the WFD mission. These seven specifications represent the highest priority in terms of the Line Item Projects' need for a Program-directed requirements baseline. Three additional Level 2 specifications are currently under development (see Table III).

An integrated process for the development of ICDs at the subsystem level is presently under development. To date, implementation of subsystem-level interfaces has been handled within an individual Line Item Project organization.

The newest WFD Line Item Project, Project W-521, has been identified since the above described requirements development process was put in place. A PDC was written to identify the scope of Project W-521 and to invoke the requirements of the Level 2 specifications. The W-521 project scope includes the design and construction of various DST transfer system valving and piping modifications as well as DST transfer pumps, mixer pumps, ventilation systems and diluent and flush subsystems for selected DSTs and DST farms. Project W-521 is in the process of completing conceptual design activities based on the Level 2 specifications listed above.

Table III. Level 2 Specifications.

Level 2 Specification	Status
DST Transfer Valving Subsystem	Released
DST Transfer Piping Subsystem	Released
DST Transfer Pump Subsystem	Released
DST Mixer Pump Subsystem	Drafted
DST Ventilation Subsystem	Drafted
DST Diluent and Flush Subsystem	Drafted
DST Utilities Subsystem	Drafted
DST Monitor and Control Subsystem	In Development
DST Process Waste Sampling Subsystem	In Development
DST Maintenance and Recovery Subsystem	In Development

Similar scope exists for ongoing WFD Line Item Projects (e.g., W-211, W-314); however, these projects, because of their greater maturity, have been proceeding with design and construction in parallel with development of the Level 2 specifications. The requirements for these projects will be compared to the requirements in the released version of the Level 2 specifications. The comparison will determine the extent of the differences between requirements in the subsystem specifications and those in the project requirement baselines. The program will determine the significance of the differences and what changes, if any, should be made to the projects' requirements/design baselines. This activity, once complete, will bring all WFD Projects in-line with the singular, top-down derived WFD requirements baseline documented in Level 2 specifications. Table IV summarizes the applicability of the Level 2 specifications to the WFD Line Item Projects and how these specifications are being used or are planned to be used.

Table IV. Project Applicability and Usage of Level 2 Specifications. (2 sheets)

Level 2 Specification	Project W-211	Project W-314	Project W-521
DST Transfer Valving Subsystem	Use for baseline comparison	Use for baseline comparison	Used for conceptual design
DST Transfer Piping Subsystem	Use for baseline comparison	Use for baseline comparison	Used for conceptual design
DST Transfer Pump Subsystem	Use for baseline comparison	N/A	Used for conceptual design
DST Mixer Pump Subsystem	Use for baseline comparison	N/A	Used for conceptual design

Table IV. Project Applicability and Usage of Level 2 Specifications. (2 sheets)

Level 2 Specification	**Project W-211**	**Project W-314**	**Project W-521**
DST Ventilation Subsystem	N/A	May use for conceptual design	Used for conceptual design
DST Diluent and Flush Subsystem	Use for baseline comparison	N/A	Used for conceptual design
DST Utilities Subsystem	N/A	May use for conceptual design	Used for conceptual design
DST Monitor and Control Subsystem	Use for baseline comparison	Use for baseline comparison	Use for baseline comparison
DST Process Waste Sampling Subsystem	N/A under present project scope		
DST Maintenance and Recovery Subsystem	N/A under present project scope		
DST Confinement Subsystem	N/A	N/A	N/A

CONCLUSIONS/LESSONS LEARNED

The above results are neither quantitative (i.e., a cost benefit analysis of systems engineering implementation on WFD has not been given) at this point in time nor have the results of the process described above been fully realized. However, some important lessons have been learned during implementation of systems engineering on the WFD Program; these are documented in this section.

A successful requirements-driven design development activity depends on three basic ingredients:

1. Clear establishment of a technical baseline for system development and planning
2. Engineering management support for the system development process
3. Engineering resource training on the system development process.

The first ingredient for a successful requirements-driven design development effort is a relatively stable, well defined, agreed-to technical baseline from which requirements can be developed. Without a stable technical baseline, acceptable progress on requirements development cannot be made. The activity of "what-if'ing" the system model for the purposes of understanding sensitivities and optimizing the waste feed-delivery sequence depends on having a starting point—i.e., a clearly identified baseline. However, the requirements development activity cannot be blind to the results of the "what-ifs" being considered by the system modelers. The requirements development activity, meanwhile, must progress with the current approved baseline until the Program office directs a formal change.

The second essential ingredient for a successful requirements-driven design development activity is the support from all engineering management on the use of the requirements/design development processes. Because the above-described requirements/design development activity required a multi-disciplined team of engineers from several different engineering organizations, management "buy-in" throughout the engineering organization is essential. Further, engineering management must direct these engineering processes through management plans, procedures and, most important, by actually practicing these engineering processes. It is also important that the Line Item Project management team be considered part of this multi-disciplined team during the development of Level 2 specifications and subsystem ICDs. This is particularly true for projects that are already in the design development process. While the interests of the entire Program must not be compromised, project organizations' participation in requirements development is essential to a detailed understanding of the rationale for the requirements derivation. With this understanding, the Line Item Project team can properly implement the requirements handed down from the Program.

To properly implement the system development processes put in place by the management team, the engineering resources executing the work must be properly trained in the process. This training has been accomplished via an informal combination of management communication (e.g., briefings) on the contents of the management plans and procedures; formal training through extension courses at Washington State University; and mentoring. Each of these training methods played an essential role in the successful training of the engineering resources, leading to successful execution of the system development process. While engineering resource training is the most obvious ingredient for success, its importance cannot be diminished nor should it be left to be inferred.

The WFD Program has enjoyed success with the engineering processes described herein because the Program management team and its practitioners have recognized and seized various opportunities to bring about conditions wherein the above ingredients for success are present. Technical baselines have been established via published documentation (e.g., Ref. 7), management plans and procedures have been put in place for the entire RPP organization[f] (11, 12, 13) and engineering resource training continues via the methods described above.

As progress continues to the implementation level (i.e., Line Item Projects), successes can be seen in that the Line Item Projects are using the products produced by the above-described process. For example, Project W-521 is using the WFD Program-produced Level 2 specifications for its requirements baseline, as directed by the Project W-521 PDC. Also, Level 2 specifications are being used for the Project W-314 and W-211 baseline comparison activities. In this way, all WFD Projects are being designed and evaluated to the singular top-down-derived WFD requirements baseline documented and controlled in the Level 2 specifications. As these activities and others like it are completed, the benefits of a successful, integrated system development activity will be further realized.

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FOOTNOTES

[a] This methodology has been based on the Life Cycle Asset Management guidance given in DOE Order 430.1.

[b] Note: This approach is consistent with the TPA timeline for tank waste remediation.

[c] Architecture is a systems engineering term that refers to *the physical item* that is performing a given function (e.g., a tank is an architecture that is performing the function of storing waste).

[d] Major portions of the Tank Farm System include the DST System and the SST System.

[e] Because of the uncertainties surrounding the use of SSTs as sources of high-level waste (HLW) feed during Phase 1 WFD, the development of an integrated requirements set in this area has

been put on hold. The result is some large uncertainties regarding the interface between the SST and DST Systems.

[f] Note that the catalyst for establishing the systems engineering process at the Hanford Site was the Defense Nuclear Facilities Safety Board, Recommendation 92-4 (see Ref. 14).