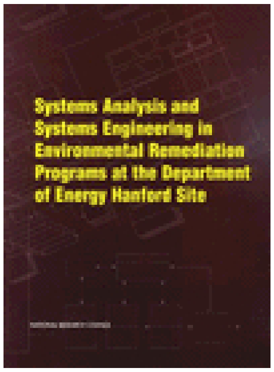

Systems Analysis and Systems Engineering in Environmental Remediation Programs at the Department of Energy Hanford Site

Committee on Remediation of Buried and Tank Wastes, National Research Council

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Committee on Remediation of Buried and Tank Wastes
Board on Radioactive Waste Management
Commission on Geosciences, Environment, and Resources
National Research Council

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Preface

The Committee on Remediation of Buried and Tank Wastes was established in 1993 with the general objective of addressing generic and specific issues relevant to the environmental remediation of radioactive waste contamination from a broad national perspective, including the use of systems engineering and risk-based assessment by the U.S. Department of Energy (DOE) Office of Environmental Management for planning and decision making. This objective was a continuation of one addressed by a predecessor of the committee, the Panel to Review Planned DOE Disposal of Radioactive Waste in Single-Shell Tanks at Hanford, which produced the report, *Comments on Draft Systems Engineering Study for Closure of Hanford Single-Shell Tanks*, in February 1992.

In August 1993 the committee received briefings on systems engineering activities at the Hanford Site in Washington. At the same time, Thomas Grumbly, then DOE Assistant Secretary for Environmental Restoration and Waste Management, requested that the committee evaluate the extent to which systems-analysis methods and perspectives are being used as inputs to the overall tank remediation program at Hanford. The committee issued a letter report on February 3, 1994 (Appendix B of this report), with its assessment of issues related to program execution and a commitment to continue its study to completion. This commitment was accepted by Mr. Grumbly in a letter acknowledging the report (Appendix C of this report).

As part of its study, in 1996, the committee organized a group of its members having expertise in systems analysis and engineering to gather information, review documents, and prepare a draft of findings and recommendations for the committee to develop into this report. This "systems group," composed of committee members Thomas A. Cotton, Donald R. Gibson, Jr., and Thomas M. Leschine, held a number of meetings at the Hanford Site in Richland, Washington, and examined numerous documents.

The committee acknowledges the contributions of many persons from the U.S. Department of Energy, including those from Headquarters and the Richland Office, as well as Hanford Site contractors, who assisted in providing information needed for the members to complete this study.

This report has been reviewed by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council (NRC) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the authors and the NRC in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The content of the review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

Vicki Bier, University of Wisconsin-Madison
B. John Garrick, PLG, Inc. (retired)
Mike Kavanaugh, Malcom Pirnie, Inc.
Edwin Kintner, GPU Nuclear Corp. (retired)
Nejmedin Meshkati, University of Southern California
Warner North, NorthWorks, Inc.
Frank Parker, Vanderbilt University
Chris Whipple, ICF Kaiser Engineers, Inc.

While the individuals listed above have provided many constructive comments and suggestions, responsibility for the final content of this report rests solely with the authoring committee and the NRC.

Contents

Summary

The primary purpose of systems engineering is to organize information and knowledge to assist those who manage, direct, and control the planning, development, production, and operation of the systems necessary to accomplish a given mission. However, this purpose can be compromised or defeated if information production and organization becomes an end unto itself. Systems engineering was developed to help resolve the engineering problems that are encountered when attempting to develop and implement large and complex engineering projects. It depends upon integrated program planning and development, disciplined and consistent allocation and control of design and development requirements and functions, and systems analysis.

The key thesis of this report is that proper application of systems analysis and systems engineering will improve the management of tank wastes at the Hanford Site significantly, thereby leading to reduced life cycle costs for remediation and more effective risk reduction. The committee recognizes that evidence for cost savings from application of systems engineering has not been demonstrated yet.

This report follows a 1994 letter report by the National Research Council's Committee on Remediation of Buried and Tank Wastes concerning development of systems analysis and systems engineering methods and perspectives for the Department of Energy's (DOE) Tank Waste Remediation System (TWRS) program at the Hanford Site. In that letter report, the committee, though encouraged by the trend it saw within DOE to make greater use of systems analysis and systems engineering, identified numerous areas in the DOE Environmental Management (EM) Program at the Hanford Site in which the tools of systems analysis and engineering could be used more effectively. This study stresses the implementation, control, coordination, and integration of the approaches to developing engineering projects throughout the site that remain to be demonstrated in Hanford's EM program. It examines the current status of the systems engineering program within TWRS, progress by the DOE Richland Office (DOE/RL) to establish a site-wide systems engineering program for the Hanford Site, and efforts to integrate the two programs.

TWRS is the DOE program to retrieve, treat, and dispose of the wastes in the 177 large underground storage tanks at the Hanford Site. Developed as a result of the 1992-93 renegotiation of the Hanford Tri-Party Agreement, TWRS is the largest single project in the DOE/EM program. Efforts to provide a basis in systems engineering for the approaches envisioned for TWRS commenced shortly after the inception of the program. For this report, the committee examined numerous documents pertaining to these efforts, as well as those related to the Westinghouse Hanford Company 1994 Hanford Site Systems Engineering Management Plan, which was initiated in response to criticisms of the lack of integration of systems engineering efforts at DOE/RL by the Defense Nuclear Facilities Safety Board. The committee also has examined more recent documents related to the ongoing interactions between the Board and Hanford Site representatives over the use of systems engineering.

A sound systems engineering approach, appropriately implemented, should result in effective integration of environmental remediation and waste management effects across the entire Hanford Site. Such site-wide integration is necessary to handle soil and ground water contamination underlying several operating areas, contaminants being retrieved from a particular area that will be disposed of elsewhere on the site, and the impacts that remediation of one area or facility may have on other areas of the Hanford Site.

The TWRS program should (a) develop a comprehensive systems engineering plan so that the performance requirements for the remediation of tank contents, tanks, and surrounding soils are fully integrated; (b) generate a complete system description that includes waste streams, containment and processing options, and the ultimate dispositioning of residual waste in a manner consistent with an optimized site-wide plan; and (c) clearly articulate alternatives for meeting the integrated performance requirements of the entire system, as well as the logic for the baseline alternative as it

relates to the complete system description. In other words, the TWRS program should focus on completing the technical baseline documentation (requirements, architectures, and supporting documents) in a manner that clearly and simply articulates a complete TWRS program (tank contents, tanks, and soils). Only that documentation necessary for successful implementation of the program should be developed. This is a "first of its kind" program so that there are significant uncertainties about cost, schedule, and technology performance. Consequently, systems alternatives need to be reevaluated periodically. Such a radical departure from standard practice can only be achieved with the firm commitment of top management.

Introduction

The Committee on Remediation of Buried and Tank Wastes (hereafter, the "committee") was organized in part to provide a focus on the use of systems engineering by the Department of Energy (DOE) Environmental Management (EM) Program for planning and decision making (see Appendix A for committee's statement of task). Over the last several years the committee has examined the application of systems analysis and systems engineering in programs at the Hanford Site, Richland, Washington; specifically (1) Hanford's Tank Waste Remediation System (TWRS), whose systems engineering effort is highly formalized, and (2) the Hanford Site Systems Engineering Management Plan (Westinghouse Hanford Company, 1994).

This report builds on earlier work of the committee, documented in a 1994 letter report to Thomas P. Grumbly, then Assistant Secretary of DOE for Environmental Management (National Research Council, 1994) (attached as Appendix B). The earlier report, prepared at Mr. Grumbly's request, evaluated the extent to which systems analysis and systems engineering methods and perspectives were being employed in the TWRS program at Hanford (the TWRS program was established in 1991 with a mission to improve management and integration of the tank waste remediation activities). The committee was encouraged by the trend it saw within DOE to make fuller use of systems analysis and systems engineering, though it also found that there were a number of areas in the DOE/EM Hanford Site program in which these tools could be used more effectively. In its 1994 report, the committee identified the following concerns:

- lack of clear, operational objectives tied to the TWRS mission statement;
- failure to define the "system" being analyzed in a way that is inclusive of the tank contents, the tanks themselves, and the wastes that have already leaked into the surrounding soil;
- failure to define and evaluate alternative courses of action comprehensively; and
- lack of iterative evaluation of program contingencies, risks, resources, and other external and internal factors.

In his response to the committee's letter report, Mr. Grumbly noted the continuing need to "establish a system integrated program site-wide at Hanford and across all of the Environmental Management program" (attached as Appendix C). This report provides a more in-depth review of the systems engineering component of the TWRS program, examines the on-going efforts at DOE Richland Office (DOE/RL) to establish the site-wide systems engineering program, and reviews DOE/RL's efforts to integrate the two programs. It also makes recommendations to help systems engineering become more effective at Hanford.

The Systems Engineering Process

Systems engineering, essentially an application of systems analysis to the design and procurement of hardware systems to accomplish specific ends, can be an effective tool of management when well defined and consistently implemented. The essential products of the systems engineering process and their programmatic use are described in this section.

The systems engineering process involves the top-down development of a system's functional and physical requirements from a basic set of mission objectives. The purpose is to organize information and knowledge to assist those who manage, direct, and control the planning, development, and operation of the systems necessary to accomplish the mission (Sage, 1992). The system's physical requirements lead to the specific hardware components that must be acquired or developed to perform the identified functions. The systems engineering process should be conducted in a way that includes consideration of alternative system configurations. The result should be a set of traceable requirements that may be used in design and procurement and in system verification and validation, a baseline description of the physical system, and a baseline description of the operational concept. This should also include a set of documented interfaces to ensure compatibility of different parts of the system as they are developed. The process being used in the Tank Waste Remediation System (TWRS) program at Hanford follows from what is described above; it is illustrated in Figure 1.

Several terms used in systems engineering are defined below for the convenience of the reader. *Traceability* imposes the conditions that the interdependencies among physical and functional requirements be made explicit and that each requirement be trackable longitudinally through the entire systems engineering process and through the system's full life cycle (Eisner, 1997). *System verification* is a two-step process to assure, first, that system design successfully captures the full set of system requirements, and second, that the system hardware and software fully implement the design. *System validation* is the process of assuring that, once the system is developed, its operational concept will meet the original system requirements (Sage, 1992).

Baseline descriptions, both of design of the physical system and of the functions the system is supposed to perform, once built, are essential to the process of modifying the system as new information or experience is obtained. *Configuration management and change control* are important quality assurance steps that ensure changes to the baseline occur in a planned manner and are thoroughly documented, so that implications for system performance are understood. The direction of desirable changes is specified through *configuration control* (Sage, 1992). The system's initial baseline description is also referred to as its *conceptual architecture*.

The systems engineering process provides value to the development, management, and implementation of a large program by ensuring:

- orderly definition of a system through top-down development of functions and requirements;
- clear distinction between design requirements developed by the program/project (potentially modifiable) and externally imposed constraints (not easily subject to modification);
- top-down consideration and evaluation of alternative solutions and designs, and
- completeness and traceability for design of system elements and interfaces, for configuration and change control, and for the system verification and validation plan(s).

This value of the systems engineering process may be realized in a number of ways, including:

- increased ability to estimate system life-cycle costs,
- reduced redesign due to consideration of the entire system throughout its development,
- increased ability to effect design changes and retrofits due to clear traceability of requirements, design features, and configuration control, and
- increased probability of achieving the best technical de-

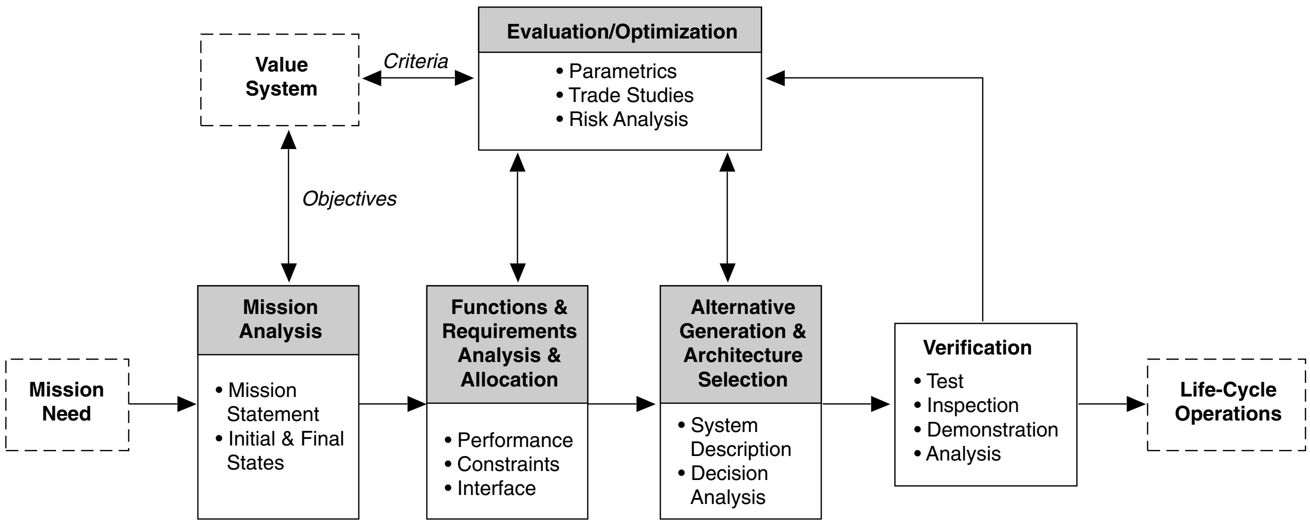

FIGURE 1 The Generic TWRS Systems Engineering Process. From Westinghouse Hanford Company, 1996a (Figure 3.1, p. 3-2), and U.S. Department of Energy, 1994a (Figure 2.3-1).

sign and operational concept through the iterative consideration of design alternatives, where "best" is defined through decision criteria such as cost, risk, and land use.

Although not necessarily performed for the purpose of reducing program costs, a sound systems engineering approach improves the ability of managers of large engineering programs to deliver a sound design and operational concept with reduced risk of cost growth.

A sound systems engineering approach, appropriately implemented, should result in effective integration of environmental remediation and waste management efforts across the entire Hanford Site. The hallmarks of a well-integrated program are consistency of approach throughout an organization, and a smooth flow of information both up and down the management chain. In such a program, work done by individual units is compatible with the objectives and goals of the larger organization, and individual projects are clearly related to the objectives of the organizational units in which they occur (vertical integration). Within organizational layers, individual units are aware of the efforts of others in related domains and work to assure that their own activity complements that being done by other units (horizontal integration). An additional consideration in the case of programs like DOE/EM, whose ability to go forward is highly dependent on public approval, is the need to assess continually the program objectives with respect to stakeholder values.

Discussion of Hanford Systems Engineering and Principal Findings

The Systems Requirements Review for the Hanford TWRS (TWRS SRR) (U.S. Department of Energy, 1995) was initiated in 1994 by then Secretary of Energy Hazel O'Leary in response to an earlier review of TWRS conducted by the Defense Nuclear Facilities Safety Board (DNFSB), and the Board's Recommendation 92-4 (Defense Nuclear Facilities Safety Board, 1992). The TWRS SRR, conducted by a high-level DOE headquarters team, found many deficiencies with the practice of systems engineering at the Hanford Site. The review has led to substantial changes in the TWRS management approach as described in the TWRS SRR Action Plan (U.S. Department of Energy, 1996b). These changes continue to be implemented as this report is being completed (U.S. Department of Energy, 1997a).

TWRS itself developed as a byproduct of the review and renegotiation of the 1989 Hanford Tri-Party Agreement (TPA) (Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, 1996—current version) that took place in 1992-93. What was then termed the "New Technical Strategy" involved combined and expedited retrieval, treatment, and disposal of both single-shell and double-shell tank wastes at Hanford. TWRS was established to deal with the wastes in the tanks, with the intention that it would use the methodology of systems engineering as the program's technical systems were developed and implemented.

The TWRS SRR team was unable to validate either the enabling assumptions or cost estimates of the TWRS conceptual architecture (i.e., the initial pre-design concept of the system to be developed). It found the reliance TWRS had placed on numerous first-of-a-kind architectures posed high programmatic risks (defined by DOE as risks with respect to cost, schedule, and technical performance that result from uncontrollable events, unforeseen circumstances, or unverified assumptions). The risks identified included the possibilities that remediation costs would be considerably higher than estimated, that schedules could not be met as planned, and that neither the high- nor low-level waste forms proposed would meet the relevant waste acceptance criteria.

The TWRS SRR team found that (U.S. Department of Energy, 1995, pp. iv-v):

- Systems engineering of TWRS has not yet reached the level of maturity needed to provide low risk "design-to" specifications.
- Systems engineering is not the driving force for current TWRS programs.
- The functional structure developed for TWRS is unnecessarily complicated and not well integrated with all site activities.
- Quantitative performance requirements have not been established for most of the functions.
- Processes for retrieval, pretreatment, and immobilization of waste often have been based on unverified assumptions rather than being selected from the results of defensible analyses of viable alternatives.
- Satisfactory performance of key processes has been assumed in the absence of substantive data.
- Key testing programs to obtain performance data do not follow proven engineering practice; they are focused on preferred processes with negligible attention being given to alternatives that might be needed if performance assumptions are not met.
- Cost constraints are not included as requirements, cost estimates for the TWRS system cannot be verified, and these cost estimates appear to be very optimistic for "first of its kind" systems.

Similar issues had been recognized by the committee prior to issuance of the TWRS SRR report. In effect, the benefits of the systems engineering process are slow in being realized for the TWRS program.

In response to these identified deficiencies, DOE and Westinghouse Hanford Company (WHC) undertook the development of the TWRS SRR Action Plan (U.S. Department of Energy, 1996b). The committee was briefed on this plan in March 1996. The plan acknowledges the lack of an effective decision-making process for TWRS, exemplified by an absence of traceability in the consideration or justification of key decisions on system architecture. A root-cause analysis conducted by a joint DOE-WHC review team identified numerous problems in planning, communication, and implementation (U.S. Department of Energy, 1996b). As a remedy, the TWRS SRR Action Plan recommends instituting a coordinated decision management process, with emphasis on the generation of alternative system configurations and their analysis via "trade studies" (comparisons of the relative advantages and disadvantages of alternatives). These trade studies would be conducted with specific reference to questions of programmatic risk.

With respect to the TWRS systems engineering program itself, numerous important components either have been completed or are now in the process of being developed under the TWRS SRR Action Plan. These include the TWRS Mission Analysis (Acree, 1998), the TWRS Systems Engineering Management Plan (Westinghouse Hanford Company, 1996a), and development of the privatization baseline (Lockheed Martin Hanford Company, 1997; Pacific Northwest National Laboratory, 1996, 1997), intended to ensure compatibility between the TWRS baseline and the efforts of the private contractors used by DOE to begin treatment of double-shell tank wastes. The systems to be designed, constructed, and operated under the privatization contract are considered to be within the TWRS project boundary (Acree, 1998).

FINDING: The TWRS systems engineering effort has not reached the level of maturity where a defensible conceptual architecture capable of achieving the TWRS mission has emerged. This point was acknowledged by DOE in its 1995 TWRS Systems Requirements Review (SRR). Implementation of the 1996 TWRS SRR Action Plan, which is now under way, should help remedy many of the deficiencies that DOE and this committee have identified in earlier reviews.

INTEGRATION OF TWRS WITH BROADER SITE CONCERNS

The committee's 1994 report (National Research Council, 1994) noted the programmatic separation within DOE among remediation efforts for tank wastes, the tanks themselves, and contaminated soils. Since that report, a memorandum of agreement between DOE/EM Offices of Waste Management and Environmental Restoration has placed programmatic responsibility for all of these remediation efforts under the DOE/EM Waste Management Office (DOE/EM-30) (Person, 1995). This is a positive step forward in the integration of these efforts. However, the original memorandum also indicated that there would be ". . . no funding allocated for the remediation of single-shell tanks contaminated soil and ancillary equipment after fiscal year 1994. [T]his transfer will have no further impact on cost or schedule for the Environmental Restoration Program." Although the responsibility has been formally transferred, this statement suggests that no activity for integrating the tanks and surrounding soils into TWRS is planned. Recently, the memorandum of agreement was revised to give TWRS responsibilities for developing and mapping a vadose zone program plan, indicating additional steps toward an integrated program to clean up contaminated soils adjacent to the tanks (Kinzer, 1997).

The TWRS Mission Analysis report (Acree, 1998) states that the TWRS program now includes contaminated soil sites. However, the report gives no details as to how the soil will be characterized or remediated. It does state that tanks will be closed with small quantities of residual waste that cannot practically be retrieved and that a surface barrier will be constructed over the tanks to limit infiltration of water. DOE has placed a high priority on the development of a sitewide strategy to address the impacts of Hanford tank contaminants in the surrounding unsaturated soils (vadose zone) and the groundwater beneath the Hanford site (U.S. Department of Energy, 1998).

A technology development effort, the Hanford Tanks Initiative, is underway to demonstrate the methods and requirements to retrieve difficult-to-remove waste from Hanford single-shell tanks. Included in this initiative is characterization of the soil contaminated by a tank leak and evaluation of the risk of the residual waste left in the tank and leaked into the soil. DOE now acknowledges that TWRS must be viewed as a subsystem of the larger Hanford Environmental Management mission and must be fully integrated within it (Acree, 1998). However, this acknowledgment currently stops short of specifically defining the key interfaces between the TWRS project and the external factors integral to TWRS (Figure 2).

The present lack of integration in the approach to remediation of the tank contents, tanks, and surrounding soils is exemplified by the TWRS Environmental Impact Statement (EIS) (U.S. Department of Energy and Washington State Department of Ecology, 1996), in which the preferred alternative is one in which all single-shell and double-shell tanks would be subject ultimately to the same waste removal goal, 99 percent. Consideration of remediation alternatives for nearby soils contaminated by tank leakage and past waste management is deferred to a future EIS, as is disposition of the tanks themselves and residual contents. Thus the contents of some tanks might be subject to extensive removal and treatment without regard to the ultimate disposition of the contaminants that have already leaked to the surrounding soils (National Research Council, 1996; Conaway et al., 1997).

DOE's approach to preparing the TWRS EIS reflects the commitments made in the Hanford TPA; however, enlarging the "system" under analysis to include contaminated soils may put DOE in the position of appearing to hedge on its

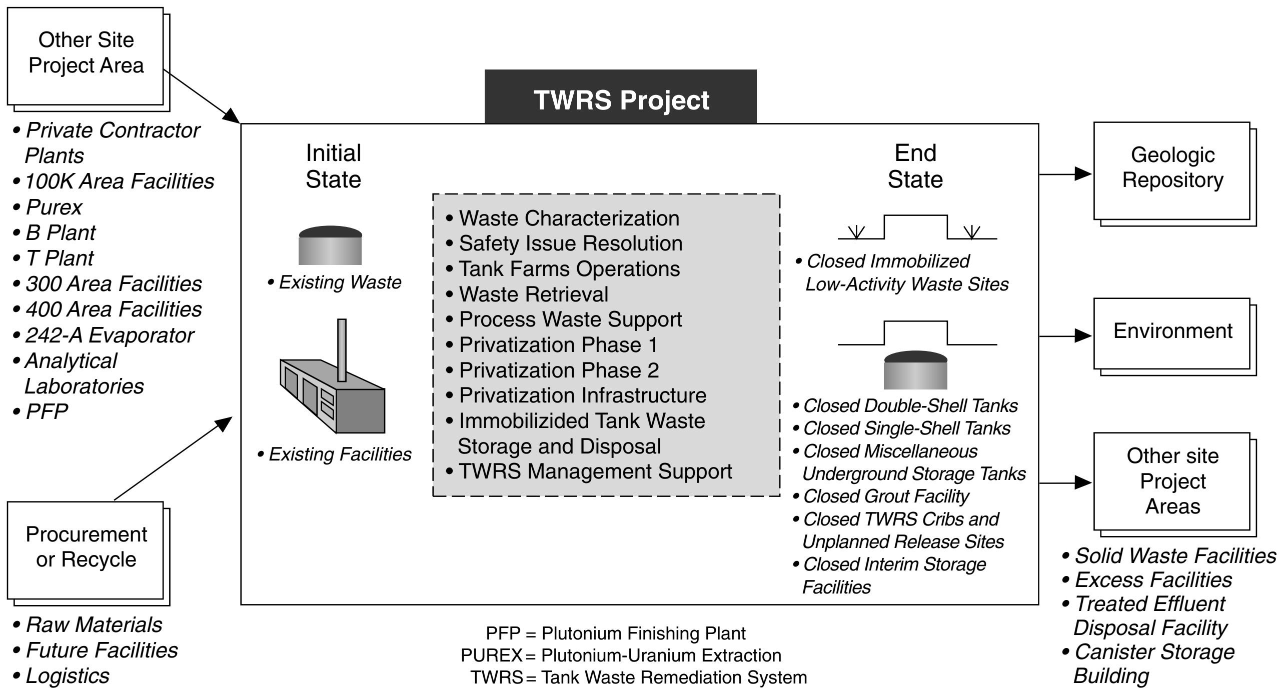

FIGURE 2 TWRS Project Boundary Diagram. From Acree, 1998 (Figure 2, p. 10).

TPA commitments. Nevertheless, organizing the systems engineering so that disposition of the contents of all tanks in the same way is taken as a "given" blurs a potentially useful distinction between externally imposed constraints (i.e., results of negotiation of the Hanford TPA and responses to other stated public values) and those derived from system requirements. Treating the problem posed by the tank contents in isolation from the problem posed by wastes already leaked from the tanks foregoes the opportunity to ask whether, for some tanks or tank farms, engineered systems proposed to slow the migration of leaked wastes might not also provide adequate mitigation of the risks associated with the wastes still in the tanks. The TWRS SRR team recognized this lack of integration in remediation planning for the tank contents, tanks, and soils.

A letter report by the committee's predecessor panels (National Research Council, 1991) commented on the Notice of Intent (Federal Register, October 22, 1990, vol. 55, no. 204, pp. 42633-42638) of DOE to prepare a programmatic environmental impact statement (PEIS) on the Department's proposed integrated environmental restoration and waste management program throughout the Defense Nuclear Weapons Complex. In the report the panels

> "applaud the intent of this PEIS. They have long been supportive of the need to develop such an integrated program to insure that decisions concerning waste site restoration and management practices are made systematically, with due consideration of the effect of each action on the overall situation. Critical elements for such decisions include knowledge of the character of both the waste materials and the sites, plans for future use of the sites, and informed public support. A nation-wide integrated program, in the Panels' opinion, would provide a great improvement over the present piecemeal application of limited funds at particular sites."

The PEIS that has recently been issued (U.S. Department of Energy, 1997b), however, has eliminated from its scope the analysis of environmental restoration alternatives.

FINDING: Despite the formal transfer within DOE of responsibility for the tanks themselves and the soils contaminated by tank leakage to TWRS, the "system" being analyzed by TWRS is largely confined to the wastes within the tanks. The result is a decoupling of strategies for reducing the risks posed by the tank wastes from consideration of the risks posed by residual contamination left in the tanks and surrounding soils once the tank contents have been removed.

PROGRESS TOWARD GREATER RELIANCE ON SYSTEMS ENGINEERING

The Hanford Site Systems Engineering Plan (Westinghouse Hanford Company, 1994) was initiated in response to DNFSB's Recommendation 92-4, which criticized the adequacy of integration of systems engineering efforts at DOE/RL. However, the scope of the plan is somewhat more limited than its name implies. Recognizing that some remediation activity, including physical systems acquisition, is already under way at Hanford, the plan reflects a "valued added" philosophy. Termed "situational systems engineering" by DOE, the goal is to manage the interfaces between projects and programs, particularly where common physical facilities or services are required. A Site Integration Group has been formed to serve as the primary technical integration forum for the site. A Hanford Site Systems Engineering Implementing Directive states that, "a detailed composite total site systems engineering network is not required" (U.S. Department of Energy, 1996c, Attachment A, p. 4).

The Hanford Site Systems Engineering Plan thus comprises a hybrid top-down, bottom-up approach (bottom-up in the sense that some system elements that would normally be developed through systems engineering already exist), in contrast to the classical "top-down" systems engineering model described earlier in this report. The goals of the plan include the production of a site-wide systems engineering database and a consistent set of integrated technical documents for site projects and programs. In addition to the formation of the Site Integration Group, Interface Control Working Groups have been formed to resolve inter-project or inter-site issues identified through systems engineering analyses and/or from interactions at the Site Integration Group. The DOE/RL representatives note that the current Hanford Site contractors also appear to be committed to high-level managerial oversight of systems engineering. A recent letter to the committee from the current contractor, Lockheed Martin Hanford Corporation, states that "we have made substantial progress employing systems engineering principles to develop a technically defensible and integrated baseline for TWRS" (Boston, 1998).

The Hanford Site Systems Engineering Implementing Directive provides a broad systems-level view of the Hanford site-wide remediation problem (Figure 3). It includes the concepts of both initial and desired end states of the site, trade studies (alternative solutions), and definition of the overall system architecture. The Implementing Directive states in part that, "Sitewide Systems Engineering will define and manage requirements, issues, assumptions, and interfaces for sitewide activities requiring physical facilities and the boundary inputs/outputs requirements for projects. All operable units are considered physical facilities." (U.S. Department of Energy, 1996c, Attachment A, p. 3). The total Hanford cleanup system envisioned by the Site Systems Engineering Plan is illustrated in Figure 4.

Detailed interface control documents (which define all interfaces between subsystems and between the system being developed and the external systems with which develop the system must inter-operate and assure compatibility [Eisner, 1997]) are being developed, together with the coordinating groups noted above. This should help assure that the work of multiple entities within DOE/RL having resources that functionally and physically connect is compatible and coordinated with the same basic mission and milestones. The committee recently learned from DOE/RL representatives that an integrated technical baseline for all site remediation activities (the Integrated Site Baseline) is being developed by the Site Integration Group under the Project Hanford Management Contract (PHMC).

The committee agrees with a recent communications of the Defense Nuclear Facilities Safety Board that acknowledges progress in implementing Board Recommendation 92-4 (Arcaro, 1997; Conway, 1997). The Board found, however, that "the systems engineering process at Hanford is not yet institutionalized to the point where it is clearly directed, proceduralized, implemented, and repeatable." Systems engineering is now being applied in a "demonstration" way by DOE/RL in the Double-Shell Tank Retrieval Project that is part of the Hanford Tanks Initiative.

FINDING: Progress has been made in infusing the systems engineering concept into remediation programs across the Hanford Site through institution of the Hanford Site Systems Engineering Plan. This plan has significant potential to improve site-wide integration if implemented effectively.

DOCUMENTATION

The primary purpose of systems engineering is to organize information and knowledge so that it assists those who manage, direct, and control the planning, development, production, and operation of the systems necessary to accomplish a given mission (Sage, 1992). But this purpose can be compromised or defeated if information production and organization becomes an end unto itself.

The primary products of the system engineering process should be a set of traceable design requirements that are used in design and procurement and in system verification and validation, a set of documented interfaces, a baseline description of the physical system, and a baseline description of the operational concept. These are the implementation-level products. Functional analysis (determination of the necessary functional requirements) and trade studies represent necessary preparatory work that result in background or backup documentation.

Although design and procurement decisions are now being made (e.g., waste vitrification plants), the requirements necessary for implementing such system functions have not been documented yet. A first step, the detailed development of logic diagrams, is under way. Systems engineering within the privatized facilities, such as evaluation and selection of processes to be used, is the responsibility of the privatization contractors. The baseline system description that illustrates how all program elements at the site will fit together is still under development. The TWRS SRR found that significant interface discrepancies existed, particularly with respect to TPA commitments. Plans to address 44 of the 179 identified findings from the TWRS SRR are documented in the TWRS

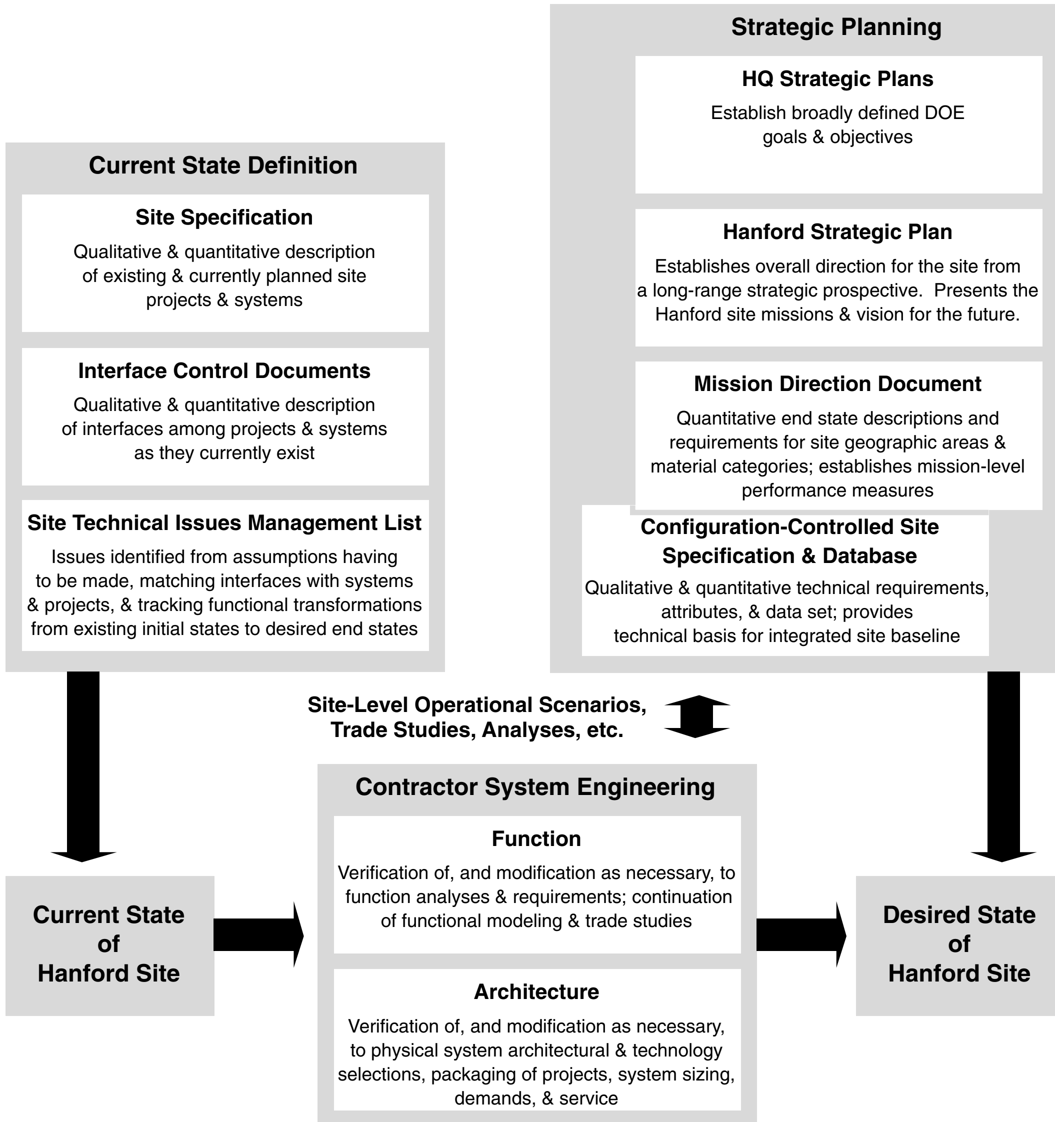

FIGURE 3 Project Hanford Systems Engineering Approach. From U.S. Department of Energy, 1996a (Figure 1).

SRR Implementation Plan (U.S. Department of Energy, 1997a). Until a clear description of the operational concept behind all significant remediation efforts planned for the site is produced, a credible site-wide assessment of the risk reduction that will be achieved through remediation is not possible.

An early version of what was then referred to as the Hanford Site Systems Engineering Management Plan (Westinghouse Hanford Company, 1994) contains the document hierarchy description shown in Figure 5. Several concerns exist regarding this approach to site-wide hierarchy description. The site-wide document hierarchy contains an undifferentiated mix of program directives and policies, work-breakdown structure, cost and schedule, and system technical descriptions. In addition, this hierarchy merely clones itself for site, program, and project levels, resulting in unnecessary repetition and over-complication. As such, the plan appears to emphasize the production of documents rather than to act as a vehicle that effectively organizes necessary products for successful site remediation. The extraneous complexity of the figure obscures its real message—that report production is supposed to support logical evolution of the program.

Another early version of the TWRS Systems Engineering Management Plan document hierarchy is shown in Figure 6. It is clearer than the Site Systems Engineering Management Plan figure (Figure 5) in that it delineates program policies, cost/schedule baselines, and technical documentation. How-

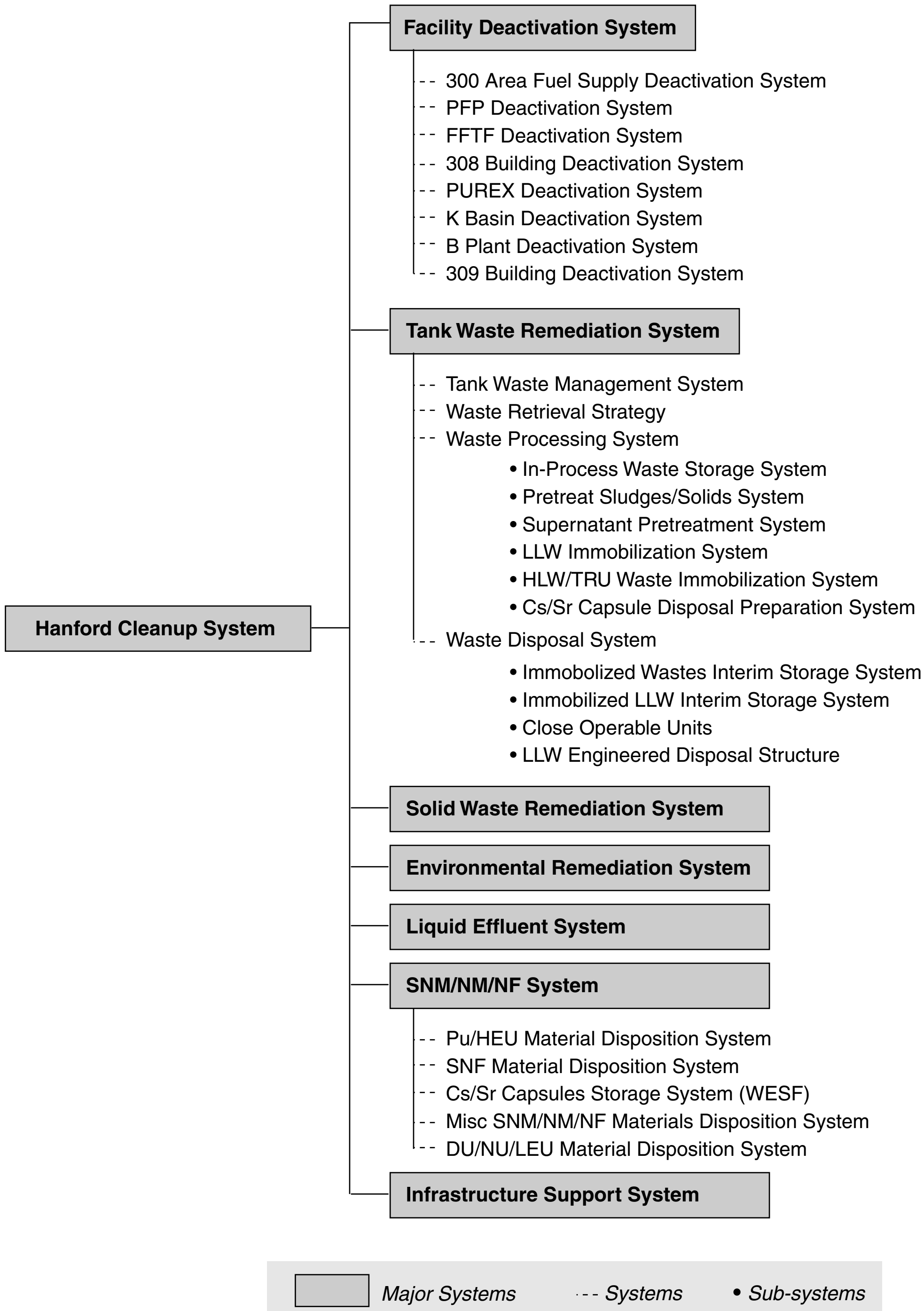

FIGURE 4 Hanford System Cleanup Hierarchy. From M. Grygiel, Westinghouse Hanford Company, March 1996 (viewgraphs entitled "Site Wide Systems Engineering Status Meeting").

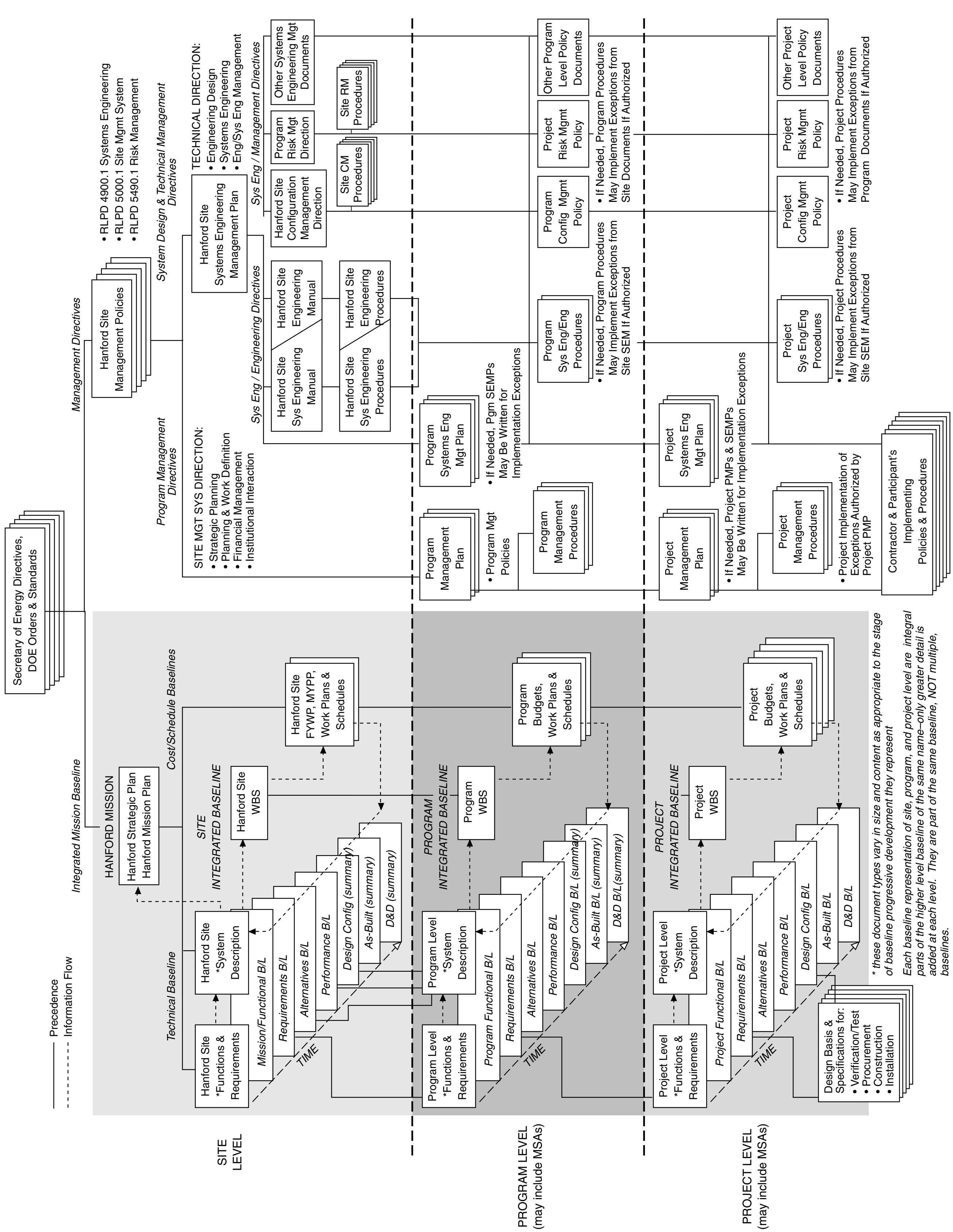

FIGURE 5 Hanford Site Information and Document Hierarchy. From Westinghouse Hanford Company, 1994 (Figure 1-1).

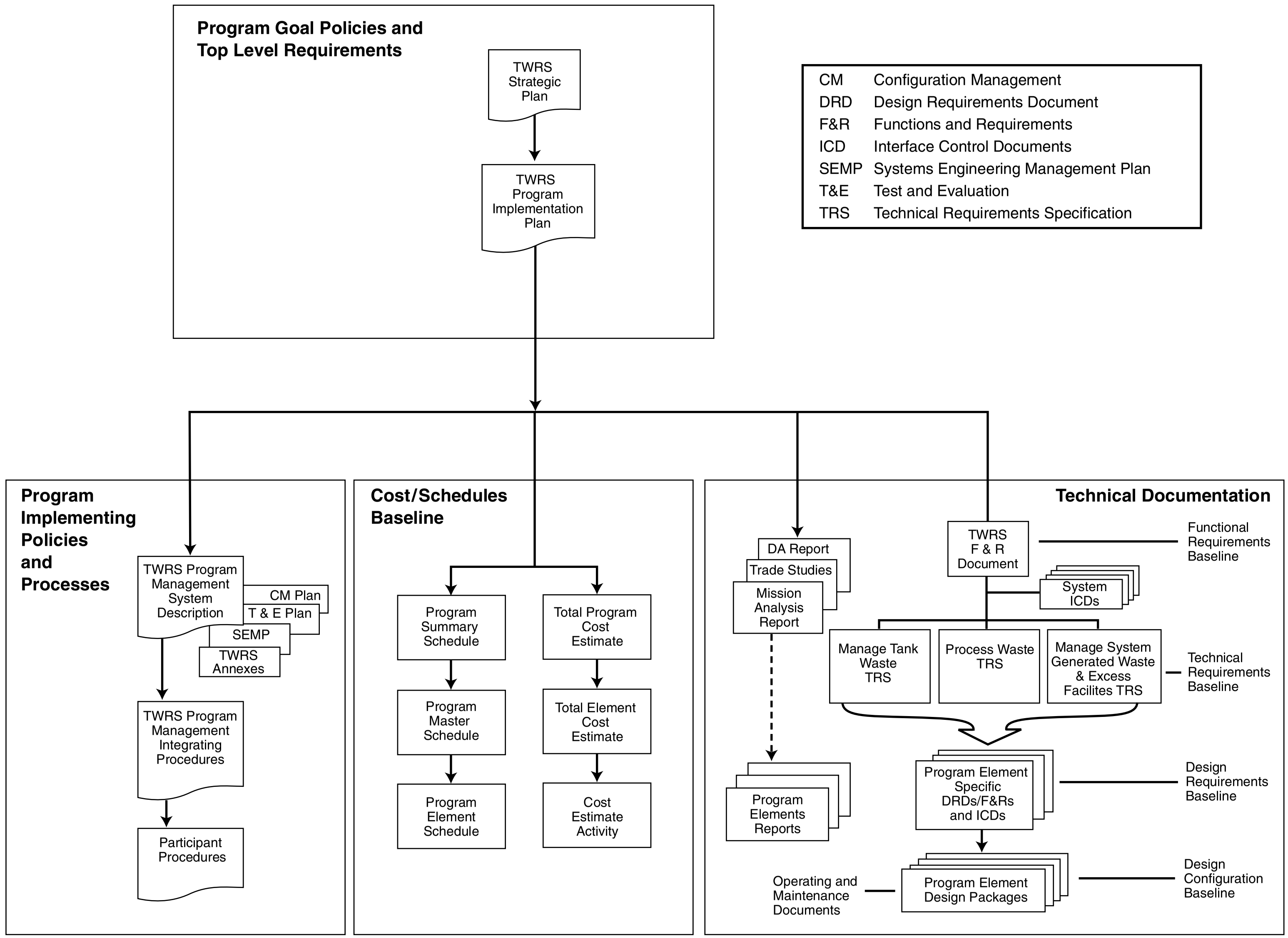

FIGURE 6 Systems Engineering Document Hierarchy. From U.S. Department of Energy, 1994b (Annex 2, Figure 3-2, page 1-4).

ever, it lacks a clear description of the system and the system operational concept. This problem appears to have been resolved in the updated TWRS Systems Engineering Management Plan (Westinghouse Hanford Company, 1996a). The updated hierarchy is shown in Figure 7. This hierarchy more clearly shows the system description documentation and the existence of background/support documentation.

FINDING: In the Hanford Site Systems Engineering Plan there generally has been an overemphasis on detailed analysis of systems functions, and, to date, an underemphasis on concrete system definition and evaluation of system alternatives. As a consequence, the primary purpose of systems engineering has been misconstrued as one of providing information as opposed to supporting the development and implementation of engineering solutions. This has led to an excessive emphasis on document production as the product of systems engineering, rather than implementation of activities at the site as the product.

REMEDIATION ALTERNATIVES

Retrofitting systems engineering to existing projects and programs requires that a mix of top-down and bottom-up systems analytic strategies be employed, unlike the classical, top-down approach to systems engineering. Where top-down analysis leads to derived requirements that can be further analyzed through trade studies, the bottom-up analysis that is being done by DOE in its "situational systems engineering" is flowing in part from requirements that are the products of legal and political constraints and are thus less amenable to trade-offs as the system architecture is defined.

In both of the systems engineering programs that were reviewed (TWRS and the Hanford site-wide), derived requirements of the physical system are not clearly distinguished from constraints presented in the Hanford TPA and applicable regulations. Examples include the low-level waste vitrification plant and the goal to achieve 99 percent removal of single-shell tank waste on a tank-by-tank basis, both specified in the TPA. Given the numerous technical uncertainties associated with these and other TPA commitments, trade studies still need to be conducted in ways that do not preclude the consideration of reasonable alternatives to the TPA-determined path. The schedules imposed by the TPA may also operate to constrain trade studies. Milestone M-33 in the Hanford TPA, for example, makes the negotiated dates for TWRS retrieval, treatment, and final closure into major TWRS milestones. As such, they are not tradable against issues raised by leaked wastes and the potential risk reductions that may be associated with alternatives for treating the tanks.

The Multi-Function Waste Tank Facility (MWTF) was the TWRS program's first major physical system acquisition. Conceived of by TWRS as six new double-shell tanks to be used for processing the wastes to be removed from the existing tanks at Hanford, the MWTF project drew the attention of the Defense Nuclear Facilities Safety Board (DNFSB). DNFSB Recommendation 92-4 expressed concern for the lack of a comprehensive systems engineering standard to guide the MWTF effort. A Technical Team created to advise the Hanford Advisory Board also raised questions concerning the need for the new tanks (Paulson et al., 1995). The project subsequently was scaled back to just two tanks, then cancelled. The fact that the TPA was subsequently re-negotiated to drop the MWTF requirement on the basis of new analysis leaves the committee hopeful that appropriate technical studies can lead to redefinition of the path that regulators and DOE program developers take through on-going TPA negotiation.

FINDING: The need to "retrofit" systems engineering to programs and projects already under way, in a context in which major commitments are negotiated through the Hanford Tri-Party Agreement, is making it difficult for DOE to use systems engineering methods to generate and evaluate alternatives to the preferred system. This complicates the task of ensuring that the chosen remediation strategy is the most appropriate from a sound risk and fiscal basis.

PROGRAMMATIC RISK

A previous NRC report (National Research Council, 1992) addressing systems engineering efforts at Hanford has noted the lack of adequate attention to uncertainties about technical assumptions and external influences that could affect adversely the ability to implement the preferred baseline program. This report presented a review of a draft systems engineering study for closure of the single-shell tanks and urged caution in placing confidence in technologies that have not been tested at the pilot-plant stage or that have not been applied previously at full scale under similar conditions to those for which they are proposed. The review recommended bringing promising options through the laboratory and pilot stages to ensure they would be ready for plant and field operation.

In its 1994 report to Thomas Grumbly, this committee noted the lack of iterative evaluation of program contingencies, risks, resources, and other external and internal factors that could affect program implementation. The report concluded that the planning basis for tank remediation seemed to have substantial and unnecessary technical risks that created programmatic uncertainties related to possible schedule delays and budget overruns. It called for systematic contingency planning, including, in some cases, work on alternative technologies at levels sufficient to permit their fuller development if needed.

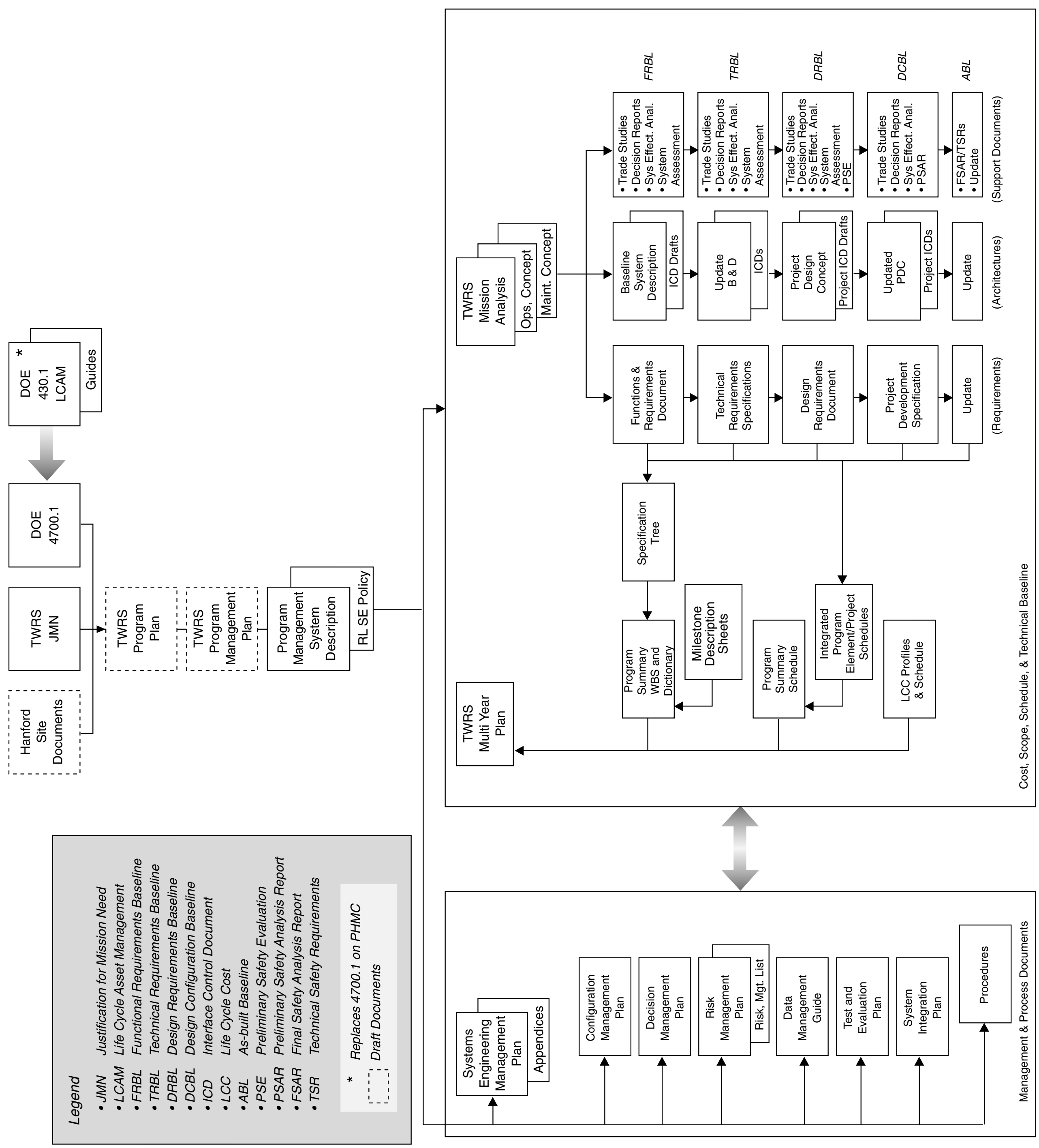

FIGURE 7 TWRS Integrated Baseline Document Hierarchy. From Westinghouse Hanford Company, 1996a (Figure 2.1, page 2-2).

The TWRS SRR team expressed similar concerns. It noted that plans for mitigating risks and validating key assumptions lacked sufficient detail, and it called for identifying important cost and schedule risks and development of mitigation plans. In response, the TWRS SRR Action Plan (U.S. Department of Energy, 1996b) called for preparation of a TWRS Programmatic Risk Management Plan (issued by Westinghouse Hanford Company, 1996b). The TWRS Systems Engineering Management Plan (Westinghouse Hanford Company, 1996a) includes an integrated and systematic risk management program approach involving three functions: risk assessment (identification of programmatic cost, schedule, and technical performance risks); risk analysis (quantification of the likelihood of an undesirable event and its impact should it occur); and risk handling (identification of appropriate actions, planning, implementation, and status tracking).

The Hanford Site Systems Engineering Implementing Directive (U.S. Department of Energy, 1996c, Attachment B) also includes a risk management plan. Because the sitewide systems engineering effort focuses on integration of the wide range of projects and services being conducted on the Hanford Site, its risk management approach should address issues having a major impact beyond any single project or service. Its focus on resolving conflicts or discontinuities between projects/services, omissions in project/service baselines, interface compatibility issues, and conflicts in requirements or planning assumptions should provide a mechanism for addressing and resolving such issues at the appropriate level. More recently, the so-called "Contractor Integration Report" prepared for Assistant Secretary Alm in support of the 2006 Accelerating Cleanup Plan used a prescriptive systems engineering approach in its complex-wide assessment of opportunities for cost savings in the EM program (Complex-Wide EM Integration Team, 1997, p.3).

FINDING: The TWRS systems engineering program is to be commended for the emphasis that it now places on explicit consideration and mitigation of programmatic risks—i.e., significant uncertainties about cost, schedule, or technology performance. Programmatic risk management procedures contained in the Hanford TWRS and Site Systems Engineering Management Plans, if implemented as proposed, and if implemented effectively, should remedy weaknesses that have been identified by earlier NRC reviews and by the TWRS Systems Requirements Review.

Recommendations

1) The TWRS program should (a) develop a comprehensive systems engineering plan so that the performance requirements for the remediation of tank contents, tanks, and surrounding soils are fully integrated; (b) generate a complete system description that includes waste streams, containment and processing options, and the ultimate disposal of residual wastes in a manner consistent with an optimized site-wide plan; and (c) clearly articulate alternatives for meeting the integrated performance requirements of the entire system and delineate the logic for the baseline alternative as it relates to the complete system description. In other words, the TWRS program should focus on completing the technical baseline documentation (requirements, architectures, and supporting documents) in a manner that clearly articulates a complete TWRS program (tank contents, tanks, and soils).

2) An analysis equivalent to the Tank Waste Remediation System Mission Analysis should be performed and documented for the Hanford site-wide program. The analysis should include the last two elements of the previous recommendation; specifically, generate a complete system description that includes waste streams, containment options, and ultimate dispositioning; and clearly articulate alternatives for meeting the integrated performance requirements of the entire site. A description of the overall site environmental management system and the key interfaces between individual remediation projects should be generated.

3) The Hanford site-wide systems engineering effort should simplify its documentation requirements with an objective of providing a clear description of an integrated site-wide remediation/waste management program. The description should include integrated performance requirements and their relationship to individual site projects. The emphasis in documentation requirements should be on producing only those that are necessary for successful implementation of the programs and projects they support.

4) An iterative evaluation of system alternatives is an important and explicit part of the system engineering process. DOE should continue to evaluate alternative system solutions even if a single baseline option is specified in existing agreements such as the TPA. This represents an acknowledgment of the need to continue searching for improved solutions and to develop contingencies for options with large technical and institutional uncertainties. One way this goal could be accomplished is by assembling a small group of top-level analysts at the program management level to identify and assess options continually at the appropriate level of detail and without being bound by regulatory constraints and programmatic preconceptions.

5) DOE must continue to work to involve program management more strongly in its technical systems engineering effort. An example of a situation in which continued management involvement is needed is the determination of whether the constraints imposed by compliance agreements should be accepted as "givens" for the purposes of systems analysis. Top-level managers responsible for systems engineering must communicate across programs and projects on a regular basis.

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APPENDIXES

A
Statement of Task

COMMITTEE ON REMEDIATION OF BURIED AND TANK WASTE

The Committee will provide scientific and technical review and evaluation of DOE's program of remediation of the environment contaminated by buried and tank-contained defense high-level, transuranic (TRU), and mixed radioactive wastes. The committee will have the following general objectives:

1) address critical generic and specific issues relevant to remediation of the environment contaminated by buried and tank-contained defense radioactive waste on a broad national (and global) perspective (e.g., identification of reasonable alternatives for remedial action including the baseline "no action" alternative, use of systems engineering and risk-based assessment for planning and decision making, and appropriate use of technology);

2) provide scientific and technical evaluation of the use of new technology and methodology for environmental remediation of buried and tank-contained defense radioactive wastes at DOE sites and facilities;

3) replace and assume the activities of two previous DOE-requested study groups, the Panel to Review Planned DOE Disposal of Radioactive Waste in Single-Shell Tanks at Hanford (HSST Panel) and the Panel to Review the DOE Assessment of Pre-1970 Buried TRU Waste at the Idaho National Engineering Laboratory (INEL Panel); and

4) provide, as requested by DOE and approved by NAS/NRC, critical review and evaluation of plans for and implementation of specific relevant environmental remediation actions at DOE sites and facilities other than Hanford and INEL.

The committee will be composed of experts from the fields of environmental sciences, radiochemistry, engineering, systems and risk analysis, regulatory policy, and health physics to address the broad and interrelated issues associated with the environmental remediation of the defense nuclear weapons complex.

The committee will meet on an average of four times each year. It will establish special subcommittees as necessary to collect and analyze detailed information pertinent to committee studies (e.g., risk assessment, systems engineering/integration, environmental characterization, applied technology, site-specific).

B
1994 Letter Report on Systems Engineering

NATIONAL RESEARCH COUNCIL
COMMISSION ON GEOSCIENCES, ENVIRONMENT, AND RESOURCES
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BOARD ON
RADIOACTIVE WASTE MANAGEMENT
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2001 Wisconsin Avenue, N.W. 20007

February 3, 1994

Mr. Thomas P. Grumbly
Assistant Secretary for Environmental
Restoration and Waste Management
U.S. Department of Energy
Washington, DC 20585

Dear Mr. Grumbly:

The National Research Council's Committee on Remediation of Buried and Tank Wastes (Attachment 1) has been in existence since early 1993, sponsored by the Department of Energy (DOE) Office of Environmental Remediation and Waste Management. In mid-August, you suggested to me that our Committee could assist you by evaluating the extent to which systems-analysis methods and perspectives are being used as inputs to the overall tank-remediation program at the Hanford Reservation in Washington. We have been able to respond to you relatively promptly because the issue that you raised fits very nicely into the larger charter of our Committee.

We will focus our response on the key elements that should characterize any systems-analysis/systems-engineering approach to a large technical program:

- articulation of a mission statement, including clear operational objectives;
- development of an inclusive definition of the system being analyzed;
- definition of a comprehensive set of alternative approaches to accomplishing the mission;
- evaluation of the alternatives, prior to selecting the approach to be taken;
- iterative evaluation of program contingencies, risks, resources, and other external and internal factors;
- definition of the program strategy, consistent with both the technical and programmatic evaluations;
- definition of detailed program elements, based on the strategy; and
- program execution, including feedback.

We have studied the Hanford tank-remediation program to ascertain the extent to which it includes the above elements. A key input to our study has been the newly re-negotiated "Tentative Agreement on Tri-Party Agreement Negotiations" (U.S. Department of Energy, U.S. Environmental Protection Agency, and Washington State Department of Ecology, 1993), hereafter called the "Tentative TPA", which we have assumed to embody the most up-to-date features of the overall tank-remediation program. (References cited in this letter are listed in Attachment 2.) Another important input has been a letter report (Attachment 3) written by a predecessor to this Committee, the Panel to Review Planned DOE Disposal of Radioactive Waste in Single-Shell Tanks at Hanford (National Research Council, 1992), commenting on a draft systems-engineering study for closure of Hanford single-shell tanks (Boomer et al, 1991 -- we understand that this draft was never finalized). We believe that many of the concerns expressed by that Panel have yet to be resolved, and indeed in many cases are identical to the concerns expressed herein.

Although we have a number of concerns, we also see some positive signs. Our evaluation follows.

Articulation of a mission statement, including clear operational objectives

The mission statement for the Hanford tank-remediation program appropriately establishes that the broad end point is "to store, treat, and immobilize highly radioactive Hanford waste in an environmentally sound, safe, and cost-effective manner" (U.S. Department of Energy Richland Field Office, 1993). However, to be effective, the mission statement must be translated into clear operational objectives, which seems not to have been done in this case. We observe that the specific program end points (such as specific objectives for public health, worker safety, environmental quality, and interim and ultimate land uses) are not fully defined. In part, they currently await input on future land uses, on how clean will be acceptable as clean enough, and on which desired end-point parameters are most important. Partly, the problem is a lack of comprehensive risk assessments to help guide the program; without them it is difficult to articulate the overall operational objectives clearly, and without well-defined end points, systems analysis becomes ineffectual.

The inability to define the specific mission end-point objectives severely handicaps the development of the program strategy and program elements. Given that the end points have changed more than once in the past few years (and are likely to change again, if history is any guide), every aspect of the tank-remediation program is correspondingly affected. The Committee believes that the DOE program strategy should anticipate further instability along these lines and should use systems-analysis/systems-engineering principles to build in resilience and redundancy (see below).

Development of an inclusive definition of the system being analyzed

The Committee believes that the operational definition of the overall tank-remediation system is seriously deficient. Specifically, the current Hanford tank-remediation system, as embodied in the actions and milestones in the Tentative TPA, concentrates mainly on wastes currently in the tanks. Only limited consideration is given to the leaked wastes and past-practice units, the physical tanks themselves (as distinct from their contents), and the ultimate fate of the products of the various remediation processes, including any repository to which the waste components are destined. The Committee believes that unless systematic consideration is given to the entire tank-remediation program from now to the completion of all remediation, the analysis of broad program options will inevitably be inadequate, leading to distorted or perhaps erroneous input to decision-makers. For example, the technical approach to remediating the problem of the wastes that have leaked from some of the tanks should be developed together with the technical approach to remediating the tank contents and the tanks themselves. These are linked issues, not separate ones, and the best overall solution may not be "best" for any one of the elements taken singly. One step in the right direction is the "Site-Wide Systems Analysis" described in the Tentative TPA as the basis for determining the requirements for a new "Multi-Function Storage Complex." We will be very interested in following the progress of this initiative. More such broad systems studies are needed.

Definition of a comprehensive set of alternative approaches to accomplishing the mission

Although the Committee believes that some important technical options have been foreclosed prematurely (see below), we know that DOE has long been aware of a large number of alternative approaches to accomplishing the tank-remediation objectives. In this sense, this third element of systems-analysis/systems-engineering may have been satisfactorily completed. However, the recent decision process seems not to have taken adequate account of the full breadth of available options (see below).

Evaluation of the alternatives, prior to selecting the approach to be taken

We recognize that the major programmatic choices are influenced by non-technical factors. For example, the recent glass-*vs*-grout decision about the waste form for the lower-activity fraction of the separated tank wastes took into account the non-technical aspects of land use, waste volume, and retrievability. Unfortunately, we believe that key program decisions have not benefited sufficiently from analyses of the technical aspects.

The Committee believes that technical evaluations have sometimes inadequately explored the possibility that a selected option might not perform as expected. For example, the programmatic uncertainties associated with the new vitrification schedule recently committed to in the Tentative TPA seem not to have been fully understood by --- or explained to --- the decision-makers. Issues such as possible technical infeasibility, higher costs, schedule delays, and occupational exposures greater than anticipated seem not to have been fully analyzed. In the absence of thorough analyses of these types of technical uncertainties, a decision process will inevitably be handicapped. The Committee urges that major efforts be devoted immediately to exploring all of the significant technical uncertainties associated with today's mainline option and with each of the reasonable alternatives.

The interactions between technical and non-technical aspects of alternatives have also not been adequately explored. One example is the key decision to designate all tank wastes as having been "actively managed" after 1980 (as defined under the Resource Conservation and Recovery Act, or RCRA), subjecting them to regulation as hazardous wastes. This decision seems to have been made with little analysis of its technical and programmatic implications or of alternative approaches available under the law. Its subsequent implementation seems not to have adequately considered the full range of risk management options available under RCRA and CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act).

The Committee also believes that the program is seriously handicapped by the lack of comprehensive and credible analyses of the environmental, public-health, and occupational-safety risks associated with all of the feasible options, including the "containment-in-place" option in which the wastes would be left in place, stabilized, protected against migration, and monitored as necessary. Without such analyses, the program cannot determine how much reduction of risk (by full comparison with the "containment-in-place" option) is associated with each of the other tank-remediation alternatives. To the extent that decisions about this program lack information from such analyses, and in light of the fact that the key rationale for the whole effort seems to be the perception among some that the risks of the "containment-in-place" option are unacceptable, the Committee believes that there is inadequate support for decision-makers as they balance the pros and cons of the various options. The Committee calls attention to similar comments put forth in the 1992 report by a predecessor Panel (Attachment 3).

Iterative evaluation of program contingencies, risks, resources, and other external and internal factors

Any well-executed project must continually evaluate program contingencies, especially those having high probabilities. While this has been done for some of the elements of the tank-remediation program, the Committee believes that in a number of important areas the evaluations are either weak or absent. Among these are the possibility of technical incompatibilities between the high-activity glass waste form and the not-yet-designated geological repository; the possibility of a substantial mismatch between available funding and the planned program, a possibility that could be minimized with a thorough cost-benefit evaluation of alternatives; the possibility that occupational risks may turn out to be far greater than now expected, forcing the expensive, time-consuming re-engineering of one or more of the planned remediation operations; and the previously mentioned possibility that the vitrification technology for the lower-activity fraction may not work out as expected.

On this last point, we believe, based on our review of vitrification technology, that there is significant uncertainty as to whether the low-level-waste vitrifier can be obtained commercially with only a small amount of shielding; whether it can operate with contact maintenance; and whether off-gas problems will not become severe as radiation levels rise. Extensive development and demonstration work will likely be needed before the suitability of this technology can be confirmed, and this element of the overall Hanford remediation program seems to lack enough contingency planning to account for potential problems such as those above.

The Committee is pleased that in several places the new Tentative TPA allows DOE greater flexibility to continue developing alternative processes as contingencies against the possibility that the planned mainline approaches may not work, and also to propose requisite modifications. We are concerned, however, that there seem to be no similar provisions for continued evaluation of alternatives to the planned mainline approaches embodied in the new Tentative TPA. We see no apparent evidence that serious attention is being given to technical work on some of the major alternatives --- on "hedging one's bets", so to speak.

Specifically, the Committee believes that the program has recently foreclosed some important technical options prematurely, by not choosing to carry along certain alternative options in parallel with the selected mainline option. In our opinion, there are several examples of premature foreclosure in the tank-remediation program; among them are the decision to abandon options that would leave much (if not almost all) of the tank wastes stabilized in place, and the recent decision to maintain the grout facility only in a standby condition and to defer further grout technology development in favor of developing a vitrification approach for the lower-activity fraction of the tank waste. In each case, the Committee recommends that DOE carefully evaluate the program uncertainties associated with foreclosing the technical alternatives prematurely, and that where appropriate DOE carry along alternatives at levels sufficient to permit their fuller development, if needed.

Definition of the program strategy, consistent with both the technical and programmatic evaluations and **Definition of detailed program elements, based on the strategy**

The Committee is pleased to observe that the Tentative TPA seems to tie together the various program elements and to promote the overall program strategy in a more consistent way than had been the case previously. A key example is the new paradigm for waste characterization; we strongly endorse the idea that characterization, which is both an expensive and a pacing element, be driven by the users of the information rather than by an arbitrary schedule as in the earlier version of the Tri-Party Agreement (Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, 1992). This is an excellent example of an integrated systems approach, although it can work in practice only if all of the identified users have input to the characterization program plan.

Unfortunately, the Committee does not find the same linkage in other major program elements. There is only a weak link, we believe, between the technical aspects which control what is feasible (or practical, or cost-effective, or even possible), and the programmatic aspects, which are driven by such non-technical considerations as the perceived need to get some actual remediation activities underway relatively soon, and the constraints imposed by the RCRA regulatory regime.

While it is always appropriate to consider non-technical constraints on the overall strategy of a technical program, the approach that emerges should still be within the range of technical reasonableness, which includes a hedge against technical surprises. Again, what has apparently emerged as the mainline solution --- what we were told is the current DOE "planning basis" --- seems to our Committee to carry substantial and unnecessary technical risks, as discussed above. These create programmatic uncertainties related to possible schedule delays, budget overruns, potential damage to morale, and loss of public support.

The Committee applauds the way in which the public participation process has been structured and implemented at Hanford. It can serve as a model for other DOE sites. We also applaud the efforts to establish effective communication channels, at several levels, among the three principal parties to the Hanford TPA (DOE, U.S. Environmental Protection Agency, and Washington State Department of Ecology). The likelihood of success for the current program strategy becomes significantly higher with open public information and participation.

Program execution, including feedback

Given the time available, the Committee did not make a thorough assessment of issues related to program execution. However, we have comments on one particular issue related to the indicated delegation of increased authority to the field offices for the execution of DOE remediation programs. While there are potential benefits to be realized by such delegation, we remain concerned about maintaining at a Department-wide level the overall definition of program missions, goals, budgets, and objectives, particularly as regards overall integration across the DOE complex. Implementing these top-level systems elements will require understanding of and adherence to national program goals by the field offices.

In conclusion, the Committee finds that several elements of the current approach use systems-analysis/systems-engineering methods and perspectives appropriately, and recent changes and trends indicate that these would be more fully used in the future. However, in several areas, including the most strategic aspects of the program, there are shortcomings described herein that we believe merit your attention.

The Committee hopes that its views on the systems approach with respect to the Hanford tank program are useful. We believe that although many program aspects are proceeding effectively, several key system elements need improvement. If you would like clarification or expansion on any aspect of our review, the Committee would welcome the opportunity to discuss it with you.

Sincerely yours,

Robert Budnitz

Robert J. Budnitz, Chairman
Committee on Remediation of Buried
and Tank Wastes

attachments (3)

COMMITTEE ON REMEDIATION OF BURIED AND TANK WASTES

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Attachment 1

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<u>Attachment 2</u>

COMMENTS ON DRAFT SYSTEMS ENGINEERING STUDY FOR CLOSURE OF HANFORD SINGLE-SHELL TANKS

Panel to Review Planned DOE Disposal of Radioactive Waste in Single-Shell Tanks at Hanford

Board on Radioactive Waste Management
National Research Council
National Academy of Sciences
Washington, DC

28 February 1992

Attachment 3

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the panel responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Frank Press is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding members, sharing with the National Academy of Sciences the responsibility for advising the federal government. That National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Robert M. White is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of the appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

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Support for this project was provided under funds for the Board on Radioactive Waste Management through the U.S. Department of Energy under Contract No. DE-AC01-86DP48039 and DE-AC01-89DP48070.

Copies of this report are available from:

Board on Radioactive Waste Management
National Research Council
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PANEL TO REVIEW PLANNED DOE DISPOSAL OF RADIOACTIVE WASTE IN SINGLE-SHELL TANKS AT HANFORD

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COMMENTS ON DRAFT SYSTEMS ENGINEERING STUDY FOR CLOSURE OF HANFORD SINGLE-SHELL TANKS

Panel to Review Planned DOE Disposal of Radioactive Waste in Single-Shell Tanks at Hanford

The National Research Council's Panel to Review Planned Department of Energy (DOE) Disposal of Radioactive Waste in Single-Shell Tanks at Hanford (hereafter called the "Panel") reviewed a six-volume, yet to be completed draft report by a DOE contractor, Westinghouse Hanford Company, Richland, WA, entitled *Systems Engineering Study for the Closure of Single-Shell Tanks* (Boomer et al., 1991). Volumes 1 and 2 constitute the text of the draft Study report, supported by extensive background engineering information in appendices found in the remaining volumes. The following comments provide a preliminary and partial response to a request from R.P. Whitfield, Office of Environmental Restoration, DOE, to provide a review of the initial results of the Systems Engineering Study.

The draft Study report provided to the Panel was referred to by its authors as the "60% draft", and it has many sections that have not yet been completed. This report, however, supplemented by presentations by the authors at several Panel meetings, was found to contain adequate details and conclusions for the Panel to provide general commentary at an early enough stage in the Study to influence its course before it becomes final. Upon completion of the Study, the Panel will be prepared to conduct a more extensive review, if requested by DOE.

Objectives of a Systems Engineering Study

The Panel members, having strongly recommended a systems engineering approach to tank closure at previous meetings, are pleased that the Study has embodied that approach. When first notified, in 1990, of the initiation of the Study, individual members of the Panel suggested the following three objectives. First, the Study should identify reasonable alternatives for managing the waste contained in the Hanford single-shell tanks, and it should present what is known and what must be learned with regard to waste characterization, in situ stabilization, retrieval, treatment, interim storage, site remediation, ultimate disposal, and needed technology to implement these alternatives. Second, the Study should establish the framework for this effort and provide the basis for refining the identified alternatives and other possible alternatives that may be introduced, evaluating the reliability of the required technology, and improving the estimates of cost and risk. Finally, information from the Study will provide a basis for preparing the Supplemental Environmental Impact Statement (SEIS) for closure of single-shell tanks at the Hanford site, and the concepts and capabilities that are developed may be equally useful for future planning of closure of the Hanford double-shell tanks.

The Draft Study Report

In the draft Study report, a number of "technology options" for various stages of waste handling and treatment are combined by a number of permutations into 16 "integrated alternatives" for closure. The integrated alternatives are then evaluated with a combination of qualitative and quantitative weighted rating factors. Finally, the draft Study report contains the recommendation that a group of the four integrated alternatives having the highest evaluations, plus two baseline cases [no action or deferred action, and the 1987 Hanford Defense Waste Environmental Impact Statement reference alternative for in situ waste stabilization and disposal (U.S. Department of Energy, 1987)], be included in the SEIS for further evaluation.

Findings and Recommendations

After reviewing the draft Study report and discussing its highlights as presented by the Westinghouse Hanford Company staff in briefings at the Panel meetings on 25-26 September and 31 October-1 November 1991, the Panel finds that the Study is responsive to most of the objectives set forth above. The report provides a logical and straightforward approach to evaluating technical processes for closure of the Hanford single-shell tanks. Some concerns on the adequacy of identified technology options and resulting integrated alternatives, and of the weight and rating factors used to calculate evaluations are included in the seven recommendations discussed below.

The Panel notes a number of specific issues of concern that it anticipates will be addressed as the present draft report is completed. The issues include; (a) adequate emphasis on weight factors related to public and occupational safety risks, especially for alternatives involving retrieval and off-site disposal, and on those factors related to environmental protection and restoration, (b) documentation on the feasibility and costs of technology options as they are developed and tested, (c) plans for presenting the results of the Study to the public for comment, (d) schedule for sampling and analyzing tank contents to characterize waste, and (e) use of absolute rather than comparative risk analysis for performance assessments.

The Panel makes the following general recommendations concerning the final report of the Systems Engineering Study:

(1) Explicitly address, at the beginning of the Study report, the cleanup objectives and risk levels to be met by closure of the single-shell tanks at Hanford, and the scientific and technical criteria upon which decisions to retrieve tank waste, or leave the waste

in place, will be based. In addition, state the critical assumptions underlying the rating factors, evaluations, and recommendations. Placement of this information early in the report will guide the reader through the evaluation process.

(2) Devote effort to identifying additional technology options and alternatives for the tank closure process through DOE advisory committees, conferences, public meetings, and invited innovative proposals from industry. For example, during the briefings to the Panel, individuals suggested the use of asphalt for treatment of on-site waste and of the calcining process for treatment of retrieved waste for off-site disposal, two technology options that were not addressed in the draft Study report. Additional feasible combinations of technology options should be more fully explored. Specifically include additional alternatives that combine selective retrieval and in situ treatment technology options. The Panel suggests development of a matrix of technology options that can be easily manipulated to examine the consequences of different combinations. Such a matrix may lead to identification of new, reasonable alternatives and provide a valuable tool for decision making.

(3) Identify and evaluate alternatives for individual tanks or groups of tanks having similar waste compositions. Optimum effectiveness in closure may result from use of several alternatives, no one of which is suitable for every tank. With the above mentioned matrix of technology options, decision makers can test various strategies for each tank or group of tanks.

(4) Do not reduce the number of technology options or alternatives at this early stage in the Study. It is unsuitable to foreclose any technology or alternative before the various benefits, risks, and costs have been thoroughly delineated and carefully reviewed. The Panel has not yet received sufficient evidence to convince it that the four integrated alternatives recommended in the draft Study report are preferable to others that might be considered for tank closure. The completed Study report should contain a summary in which all the integrated alternatives (or groups of alternatives) are assessed for key decision-making factors such as total deaths, total masses of waste to be managed, and total costs.

(5) Sharpen the focus for, and reevaluate the weights assigned to, evaluation categories on critical items by presenting detailed assessments concerning human health and mortality, worker risks, and environmental impacts. The weights and rating factors used as performance measures of the evaluation categories for each integrated alternative are far from definitive, and they are certainly not appropriate for use in deleting integrated alternatives at this time. The cumulation of quantitative rating factors, some based on measurable evaluation criteria and some based on qualitative judgements, is particularly disconcerting.

(6) Be cautious about placing confidence in waste handling and treatment technologies that have not been tested at the pilot-plant stage or that have not been

applied previously at full scale under similar conditions. Three of the four recommended alternatives depend on in situ vitrification (ISV) for treatment of non-retrieved waste and tank farm closure; another group of three of the four recommended alternatives rely on use of transuranic solvent extraction (TRUEX) technology for partitioning of retrieved waste. The Panel believes that neither ISV nor TRUEX have achieved a level of technical development such that their performance can be evaluated with much confidence [a recent independent engineering review raises concerns about the current state of development of the TRUEX process in light of its important role in partitioning the waste stream before vitrification of the high-level components (U.S. Department of Energy, 1991)]. The Panel urges that sufficient effort be devoted to bringing promising technology options through laboratory and pilot-plant development to assure that they would be ready for plant and field application. Early closure activities in single-shell tanks containing low levels of radioactive waste may provide demonstration of such technology options for closure of the more difficult and risky tanks.

(7) Conclude the Study report by listing the information gaps and uncertainties that must be remedied, and state the actions recommended for this purpose. Address the items on this list when developing information for the subsequent Study reports.

Conclusions

The Panel commends DOE for initiation of the Systems Engineering Study that will become an important management tool for future planning and development. The Panel is concerned that the program for closure of the single-shell tanks at Hanford seems to be driven by schedule constraints rather than by the broad, investigative approach that is appropriate for a program expected to cost tens of billions of dollars and to be conducted over a period of about 30 years. The draft Study report presents analysis from a small group at one organization; the Study needs input and review from a much larger and disparate segment of the scientific and technical community, as well as from the lay public. The Panel understands that the Study is scheduled for completion in February 1992, to be followed by technical evaluation of the four most promising integrated alternatives, plus the two baseline alternatives, during the following 14 months. The Panel recommends that this 14-month period be spent not in focusing on a narrowed list of integrated alternatives, but in using the completed Study report as a framework for identifying other technology options and integrated alternatives, to examine more closely the information base of the efficacy of the technology options, and to improve the methods for evaluating the impacts of the various proposed systems on public health and the environment. It is important to recognize that factors in addition to those based on waste management science and technology may become important considerations for decision making by upper-level DOE managers. Developing an easily understood matrix of technology options and evaluation criteria, as recommended above, should aid in this process.

The Panel wishes to emphasize that the above concerns are not intended to reflect negatively on the quality of this substantial work, but rather to affirm that this Study is in an early stage. The Panel agrees with a goal of achieving single-shell tank closure at the Hanford facility as soon as possible, but it believes that a thorough initial Study effort will justify itself not only by attaining effective closure with the needed public support, but also by avoiding subsequent delays. The Panel looks forward to continuing oversight of the Study as it evolves into a plan of action deserving broad acceptance.

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C
Response from DOE to 1994 Letter Report

Department of Energy
Washington, DC 20585

MAY 2 4 1994

Dr. Robert J. Budnitz, Chairman
Committee on Remediation of Buried
and Tank Wastes
National Research Council
Commission on Geosciences, Environment,
and Resources
2101 Constitution Avenue, N.W.
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Dear ~~Dr.~~ Bob Budnitz:

Thank you for your February 3, 1994, letter transmitting the Committee's evaluation of the extent to which systems analysis is being applied to the Tank Waste Remediation System (TWRS) Program at the Department's Hanford site.

As you know from our discussions of last August, my interest in the application of a systems approach is broader than the TWRS program -- I believe the rigor of a systems approach must be applied across the Environmental Management program.

I am pleased that the Department staff at both Headquarters and the Richland Operations Office, as well as the Westinghouse Hanford Company staff have met with you on February 24 and April 7, 1994, to explore more fully the concerns you raised. It should be apparent from those meetings that the TWRS program has made notable progress in implementing a systems approach since you completed your review. For example, key system engineering documents such as the draft TWRS Functions and Requirements and the draft TWRS Engineering Management Plan have been revised. These documents were provided to you at the April 7, 1994, meeting. In addition, to facilitate discussion about tank waste treatment alternatives, a computer simulation model has been acquired and developed and was demonstrated to you on April 7, 1994. However, my staff and I recognize that there is considerably more work to be accomplished, and we are committed to establish a system integrated program site-wide at Hanford and across all of the Environmental Management program.

I greatly appreciate the effort of the Committee and look forward to continued interactions between the Committee and my staff. It is important that we make progress in addressing the concerns raised in your letter. I fully anticipate requesting a similar system review from you in the future, when we have made more progress in developing and implementing a systems approach throughout the program.

Sincerely,

Thomas P. Grumbly
Assistant Secretary for
Environmental Management

cc:
J. Lytle, EM-30
P. Whitfield, EM-40
J. Wagoner, RL

5/23
Bob -
Give me the "true scoop" about whether we are really making progress on this problem.
Tom.

D
Biographical Sketches of Committee Members

THOMAS M. LESCHINE, *Chair*, is Associate Professor in the School of Marine Affairs at the University of Washington. He is a former Fellow in Marine Policy and a Policy Associate at the Woods Hole Oceanographic Institution. He is the Chair of the National Research Council Committee on Remediation of Buried and Tank Wastes and also has served on the National Research Council Committee on Risk Assessment and Management of Marine Systems. His major research interest is in the area of environmental decision making as it relates to marine environmental protection and the use of scientific and technical information in environmental decision making. He is also interested in the use of mathematical modeling and systems analysis in environmental management. Dr. Leschine received his Ph.D. in mathematics from the University of Pittsburgh.

DENISE BIERLEY is Vice President and co-founder of Redhorse, LLC in Edgewood, New Mexico. Redhorse specializes in a wide variety of environmental issues with emphasis on Native American concerns. Her specialties are broad environmental issues and program management. Prior to founding Redhorse, she dealt with various environmental, regulatory, and water resource issues for federal, state, tribal, and private entities. Ms. Bierley holds B.S. degrees in biology and geology from Wright State University.

ROBERT J. BUDNITZ is President of Future Resources Associates, Inc. in Berkeley, California. Previously, he served as Deputy Director and Director of the U.S. Nuclear Regulatory Commission's Office of Nuclear Regulatory Research, and he also held several management positions at the Lawrence Berkeley Laboratory of the University of California. His professional interests are in environmental impacts, hazards, and safety analysis, particularly of the nuclear fuel cycle. He has been prominent in the field of nuclear reactor safety assessment and waste-repository performance assessment, including probabilistic risk assessment. Dr. Budnitz has served on numerous investigative and advisory panels of scientific societies, government agencies, and committees of the National Research Council. His most recent NRC committee service was with the BRWM and its Committee on Buried and Tank Wastes and Committee on Technical Bases for Yucca Mountain Standards. He received a B.A. degree from Yale University and a Ph.D. degree in physics from Harvard University.

THOMAS A. BURKE is associate professor of health policy and management at The Johns Hopkins University School of Hygiene and Epidemiology in Baltimore, Maryland. His work includes the evaluation of population exposure to the environmental pollutants, assessment of environmental risks, and the application of the epidemiology and health risk assessment to public policy. Prior to his appointment at Johns Hopkins, he was deputy commissioner of health for the State of New Jersey. He is a member of the Council of the Society of Risk Analysis and has served on Office of Technology Assessment advisory panels on Risk Assessment of Chemical Carcinogens and Managing Nuclear Materials from Warheads. He received a B.S. from Saint Peter's College, an M.P.H. from the University of Texas, and a Ph.D. in epidemiology from the University of Pennsylvania.

ROBERT J. CATLIN is a licensed medical physicist and certified health physicist. He retired in 1995 as executive director, clinical and laboratory safety, at the University of Texas Health Sciences Center, Houston, where he also served as executive director of the Positron Diagnostic and Research Center and taught radiological science at the School of Public Health. Previously, he served as scientific adviser for the Electric Power Research Institute and had careers in federal service and industry. Mr. Catlin is a member of Sigma Xi, the American Academy of Health Physics, and other professional societies. He has participated as a consultant to the former Soviet Union and to the U.S. Department of Energy on radiological matters for incidents at Chernobyl and Chelyabinsk. He has served on numerous industry and government advisory committees, including those of the National Council on Radiation Protection and Measurements and the National Research Council's Board on Radioactive Waste Management. Mr. Catlin received his A.B. degree in biology from Princeton University and an M.S. equivalent in health physics at Oak Ridge National Laboratory.

JAMES H. CLARKE is Chairman of the Board of ECKENFELDER INC., Nashville, Tennessee, an environmental engineering and applied scientific services firm specializing in industrial waste management. He has over 25 years of experience in environmental chemistry and chemical risk assessment. His primary areas of interest include the fate and transport of chemicals in the environment, the design of environmental data acquisition programs for evaluation of the risks associated with chemical releases, and innovative and emerging technologies for hazardous waste site remediation. He is an Adjunct Associate Professor with the Department of Civil and Environmental Engineering of Vanderbilt University and serves on the faculty of several continuing education programs, including those of the American Institute of Chemical Engineers, the Center for Professional Advancement, and several universities. Dr. Clarke received a B.A. in chemistry from Rockford College, Rockford, Illinois, and a Ph.D. in theoretical physical chemistry from The Johns Hopkins University, Baltimore, Maryland.

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ALLEN G. CROFF is associate director of the Chemical Technology Division at Oak Ridge National Laboratory (ORNL). His areas of focus include initiation and technical management of research and development involving waste management, national security, nuclear fuel cycles, transportation, energy efficiency, and renewable energy. Since joining ORNL in 1974, he has been involved in numerous technical studies that have focused on waste management and nuclear fuel cycles, including: (1) updating and implementing the ORIGEN-2 computer code; (2) developing a risk-based, generally applicable radioactive waste classification system; (3) multidisciplinary development and assessment of actinide partitioning and transmutation; and (4) leading and participating on multidisciplinary national and international technical committees. He has a B.S. in chemical engineering from Michigan State University, a Nuclear Engineer degree from the Massachusetts Institute of Technology, and an M.B.A. from the University of Tennessee.

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Abbreviations

DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DOE/EM	DOE Office of Environmental Management
DOE/ER	DOE Office of Environmental Restoration
DOE/RL	DOE Richland Operations Office
EIS	environmental impact statement
EPA	U.S. Environmental Protection Agency
LMHC	Lockheed Martin Hanford Company
MWTF	Multi-Function Waste Tank Facility
NRC	National Research Council
PHMC	Project Hanford Management Contract
PNNL	Pacific Northwest National Laboratory
TPA	Hanford Tri-Party Agreement
TWRS	Tank Waste Remediation System
TWRS SRR	Tank Waste Remediation System, Systems Requirements Review
WHC	Westinghouse Hanford Company