RECEIVED
MAY 03 1993
OSTI

PNL-8560 Vol. 1
UC-902

An Underground Storage Tank Integrated Demonstration Report

Volume 1: Waste Characterization Data and Technology Development Needs Assessment

M. J. Quadrel
V. L. Hunter
J. K. Young
D. C. Lini
C. Golberg

April 1993

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

Battelle

PNL-8560 Vol. 1

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401. FTS 626-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

PNL-8560
UC-[redacted]
902

AN UNDERGROUND STORAGE TANK INTEGRATED DEMONSTRATION REPORT

Volume 1: Waste Characterization Data and Technology Development Needs Assessment

M. J. Quadrel
V. L. Hunter
J. K. Young
D. C. Lini[a]
C. Goldberg[a]

April 1993

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

(a) Westinghouse Hanford Company, Richland, Washington

ABSTRACT

The Waste Characterization Data and Technology Development Needs Assessment provides direct support to the Underground Storage Tank Integrated Demonstration (UST-ID). Key users of the study's products may also include individuals and programs within the U.S. Department of Energy (DOE) Office of Technology Development (EM-50), the Office of Waste Operations (EM-30), and the Office of Environmental Restoration (EM-40).

The goal of this work is to provide the UST-ID with a procedure for allocating funds across competing characterization technologies in a timely and defensible manner. It resulted in three primary products:

1. It organizes and summarizes information on underground storage tank characterization data needs.
2. It describes current technology development activity related to each need and flags areas where technology development may be beneficial.
3. It presents a decision process, with supporting software, for evaluating, prioritizing, and integrating possible technology development funding packages.

This report presents the first two of these results; another report[a] describes the decision process and software. These reports offer a general model for technology development selection, prioritization, and funding. They are intended to support funding decisions over repeated fiscal cycles. Consequently, recommendations are developed within a framework that can be abbreviated or expanded to accommodate shifts in the fast-changing technical, economic, and regulatory environments affecting characterization technology development. The data presented in this document can be readily updated as the needs of the Waste Operations and Environmental Restoration programs mature and as new and promising technology development options emerge.

Taken together, the needs data, technology activity summary, and decision process provide a means for ensuring that appropriate criteria are

(a) Quadrel, M. J., J. Ulvila, and J. Chinnis. 1993. R&D Prioritization and Resource Management for Technology Selection. Vol. 2, Limited Distribution.

driving technology investments, that completed demonstrations will meet high-priority and relatively stable underground storage tank characterization needs, that selected technologies have the highest probability of improving systems' performance, and that innovative technologies and alternative funding schedules are anticipated to most effectively apply technology development budgets. In addition to enhancing good stewardship of public funds, the products of this work provide a mechanism for explaining and, if needed, defending the UST-ID funding process for characterization technologies.

EXECUTIVE SUMMARY

Technology development funding decisions must be based on reliable, comprehensive information about technology needs and promising technology development responses. This Waste Characterization Data and Technology Development Needs Assessment provides a framework for summarizing needs and technology development information. The work was funded and developed for use by the Underground Storage Tank Integrated Demonstration (UST-ID) and was produced jointly by Pacific Northwest Laboratory (the Technology Policy Analysis and Waste Technology Centers) and Westinghouse Hanford Company (the Systems Engineering Group). It was reviewed by technical experts from the Hanford Site and Ames Laboratory at Iowa State University representing both the U.S. Department of Energy (DOE) Office of Technology Development (EM-50) and the Office of Waste Operations (EM-30).

The ultimate objectives of this effort were to structure the characterization technology development funding problem, using a general framework, and to summarize currently available needs data to support immediate funding decisions. Those data can be updated to support future funding cycles. The report does not prioritize or recommend specific technology developments. Rather, given high levels of uncertainty surrounding underground storage tank (UST) characterization needs and the fast-changing remediation environment, it identifies

- "reliable" (e.g., relatively well substantiated) characterization data needs
- the most promising technologies for addressing these needs.

Evaluation criteria and procedures for prioritizing and integrating those responses into coherent funding packages are described in a separate report.[a]

(a) Quadrel, M. J., J. Ulvila, and J. Chinnis. 1993. R&D Prioritization and Resource Management for Technology Selection. Vol. 2, Limited Distribution.

Chapter 2.0 of this report identifies approximately 30 distinct UST waste characterization needs to support specific remediation system functions (Table 2.1). Only six of these clearly require no technology development (Table 2.2); specific technologies requiring at least some development could be identified for another 11 needs, and the remaining needs represent apparent gaps in technology development. Data needs were identified directly by EM-30 programs to support other programmatic functions (Table 2.3); all of the data needs specified by those programs are not expected to be met by the current UST characterization program. All identified data needs requiring technology development of some type are organized into 12 characterization data need categories in Table 2.4.

Chapter 3.0 lists specific technology development options for each data need category (Table 3.1). In total, approximately 50 distinct development efforts are identified. These are distributed unevenly across the data need categories. Approximately 10 data needs have no identifiable technology response at present. To assess the adequacy of current funding for these technologies, this report first summarizes remediation system requirements for each data need category, including a general timeframe for meeting system needs at Hanford (Section 3.3). Section 3.3 concludes with a status of characterization technology development funding, complex-wide (revealing development gaps), and remaining development uncertainties (Table 3.2).

This report recognizes that each characterization data need or specific technology development option represents a different sized problem, benefit, and investment of resources. The needs are therefore not directly comparable. Nevertheless, the authors thought it of value to summarize the number of identified technology development options currently "covered" by some funding effort. Of the 50 characterization technology development options identified, 17 (about 30%) were being addressed by one or more of the FY92 UST-ID Technical Task Plans (TTPs); each of the funded TTPs addressed at least one of the identified needs. Six specific technology development options (spanning three data need categories) were identified that do not appear to be funded by any DOE Office of Environment Restoration and Waste Management (EM) source. These include 1) in situ methods to measure abrasiveness of tank wastes, 2) in situ methods for measuring rheology of sludges and hard waste (sludge tensiometer and fracture resistant probe), 3) samplers for measuring tank structural integrity, 4) thin film resonators for the in situ monitoring of flammable gasses, and 5) in situ methods for measuring chemical reactivity/shock sensitivity.

Table 3.3 summarizes current funding gaps and highly uncertain technology development efforts. In addition to the gaps identified above, currently funded efforts requiring significant additional funding to meet system requirements include 1) in situ measurement of physical properties (e.g., heated line source, neutron scattering), 2) process monitoring and control (e.g., long-range alpha, low-energy GEA/GEA, neutron activation for fissiles), 3) representative sampling methods (e.g., advanced core sampling techniques, vapor and head space samplers), 4) laboratory automation, 5) in situ chemical measurement technologies (e.g., specific ion electrodes and chemical microsensors) 6) in situ radiological measurement technologies (e.g., fiber optic scintillation, neutron activation for fissiles), and 7) characterization for decontamination and decommissioning tasks (e.g., long-range alpha).

Combining information from the systems engineering analysis (Table 2.2) and current technology development funding status, several needs appear particularly critical, either because they are basic to multiple UST remediation and management process and are needed for the program to progress in the near term, or because they address unanswered safety questions. These include 1) additional representative waste samplers, 2) advanced core sampling methods, 3) in situ organic speciation of tank wastes and vapors, and 4) in situ methods to measure physical properties such as thermal conductivity, moisture, and settling rates.

A key observation and critical issue for this report is that the essential drivers for characterization technology development have not been clearly articulated by the UST waste management and remediation programs. Decisions requiring UST characterization data are not rigorously defined or scheduled, data qualifiers (i.e., when and to what degree of specificity the data are needed) are generally not specified, and relevant information is typically in a form that is neither formally documented nor easily located. This situation necessarily limits the number of characterization technology development options that can be confidently funded because unsubstantiated needs are likely to change as programs mature and become better defined.

RECOMMENDATIONS

To address this uncertainty, the UST-ID might take one of the following approaches:

1. *Address the most reliable needs in the system.* Focus on satisfying multi-site, multi-system, multi-process characterization needs. This is a low-risk approach: if many programs require the same measure now, regardless of the system alternative or process that is implemented, one or more programs likely will need it when the instrument is ready for deployment. This would lead to support for instruments and deliver systems that will provide in situ measurement of

    - physical waste properties, such as thermal conductivity, viscosity, porosity, hardness, and abrasiveness, using technologies such as remote relative viscometer, sludge tensiometer and fracture resistant probe, or acoustic methods

    - chemical constituents, including organics, minor anions and cations that interfere with processing, and in-tank vapors, using technologies such as remote spectroscopy (e.g., laser raman) or other remote laser techniques; or chemical reactivity, using technologies not yet identified

    - radionuclides, such as total transuranic waste and gross alpha, beta, and gamma radionuclide content for evaluating treatment alternatives, using technologies such as neutron activation and in situ foils for fissiles, fiber optic scintillation, or Gamma Energy Analysis (GEA)

    - moisture content and percentage of solids and liquids, using technologies such as in situ neutronics or fluidized bed samplers.

2. *Develop only instruments that provide multiple measures.* This is another low-risk approach that helps to ensure the developed instrument will be used. The trade-off is that these technologies may produce less accurate results). Candidates include laser raman spectroscopy and other remote laser techniques.

3. *Emphasize technology development that will support applications of a variety of characterization technologies (e.g., instrument delivery systems).* This option leverages the entire characterization effort.

To ensure this leverage is viable, the UST-ID should support system needs that are invariant across waste management alternatives and sites. This would lead to support of the following types of technologies:

- sampling methods (e.g., slant drills, tank heel samplers, vapor space samplers, gas-tight samplers, fluidized bed samplers)

- deployment systems for in situ characterization (e.g., a light-weight utility arm, a remotely controlled or robotic mole).

4. *Develop characterization instruments that will support UST-ID technology demonstrations.* One option would provide vadose zone monitoring to support a tank closure demonstration. In situ physical measurements identified none that would support retrieval demonstrations.

5. *Emphasize technologies that address UST safety issues.* This approach would lead to development of technologies that address gas generation and retention (composition of major constituents in aqueous and solid waste functions, physical properties of waste, composition of gaseous effluents, temperature profile in tanks, or organic carbon content), high heat in single-shell tanks (same measures without temperature profile and with chemical reactivity), cyanide and ferrocyanide (add distribution and concentration of ferrocyanide complexes), organics (add total inorganic carbon content), or tank vapor sampling (flammable gas concentration, toxic concentrations of inorganic gasses, toxic or hazardous concentrations of organic materials, quantitative measurement of semivolatile organic compounds). Such technologies include

   - remote (infrared) spectroscopy (e.g., laser raman); remote laser technologies, fiber optic sensors, or ion chromatography for in situ chemical constituents (e.g., organic and cyanide speciation, major and minor constituents of waste); or methods for measuring and separating solids and liquids in UST waste in support of pretreatment technology demonstrations

   - in situ measurement of physical waste properties, such as thermal conductivity, viscosity, porosity, hardness, and abrasiveness, using technologies such as remote relative viscometer, sludge tensiometer and fracture resistant probe, shear vanes, or acoustic methods (as part of the retrieval demonstration)

   - vapor space samplers.

6. *Fund technologies that represent current "funding gaps" in characterization technology development.* These would include technologies that are either unfunded or inadequately funded for meeting the data needs they are intended to address, either because the problem is long term and technically difficult or because currently

funded activities may not completely address system requirements for deployment. Technologies that fall in this category include

- in situ measurement of physical properties (fiber optic scintillation and neutron activation), tank structural analysis devices, process monitoring and control (long-range alpha, low-energy GEA/GEA, neutron activation for fissiles), representative sampling methods (advanced core sampling techniques, vapor and head space samplers) laboratory automation, in situ measurement of chemical constituents (chemical microsensors, chemical reactivity, specific ion electrodes, and thin film resonator), tank decommissioning and decontamination (long-range alpha), hot cell segment scanning.

In lieu of a more extensive funding review (addressed in the companion report), the information above can be used by the UST-ID to narrow the set of possible options for additional characterization funding. For example, in response to incremental budget increases, the demonstration may want to focus on natural extensions to its current characterization program (to better meet system requirements). Or, to enhance the probability of early "successes" in meeting key EM-30 needs, the demonstration may focus on safety needs that can be accommodated within its current characterization program. To further define the particular technology development needs meeting these objectives, the demonstration would use information from

- Tables 2.2 and 2.3 to identify data needs relating to different remediation functions, including safety concerns, at Hanford and other sites
- Table 3.1 to identify technology development options addressing those needs
- Table 3.2 for a summary of their funding status and specific uncertainties
- Table 3.3 for the set of development options representing current funding gaps and inadequacies. Following the logic described above, the following example options emerge:

Technology Development Option	Related Uncertainty or Need
Remote spectroscopy, including laser Raman (provides measures of chemical constituents, meeting multiple remediation program needs)	Integrate with fiber optics or other means of light transmission Validate on UST waste matrices Solve interference problems from background radiation
Vapor, headspace samplers (flammable gas, toxic concentrations, etc., affecting tank safety)	Solve deployment problems
Process monitoring and control devices, e.g., low-energy GEA/GEA (a safety concern, measures total radiation levels)	Requires proof of principle in tank Solve interference problems from background radiation Incorporate into scanning hot cell testbed Integrate into scanning platform
In situ physical waste sampler to address moisture content and percent solids and liquids (a safety concern) using neutron scattering	Validate on UST waste matrices, reduce size

GENERAL OBSERVATIONS

While the UST-ID is currently addressing many of the identified characterization needs, its efforts will not significantly improve UST characterization and, ultimately, remediation if the following important criteria are not addressed by EM-50 or EM-30:

- *Physical deployment of a technology*: Can the technology be made to meet tank access, temperature, and radiation requirements? Can the technology be successfully monitored under the stresses of normal operations? Will a compatible delivery system be available? Will a compatible decontamination system be available? Can worker safety be ensured? Are supporting management tools available? Will other as yet undeveloped technologies be required to implement the instrument? Will the tool be properly tested on waste simulants, or are waste standards available to ensure proper design? Promising technologies will advance only if they can be deployed within (and successfully integrated into) a complete, practical, and safe characterization system. System requirements for specific categories of technology responses are provided in Chapter 3.0 and may be useful as an initial screening device. Principal investigators (PIs), however, will need to be aware of many more specific system and functional requirements, some set of which might undermine their efforts if not attended to from the start. To address this issue, this study recommends that funding be available to team PIs with technology users from the relevant sites from the outset.

- *Validity of the data produced*: Are mechanisms available to ensure that the data produced are interpretable, reliable, and accurate? Can in situ instruments be successfully calibrated? Can the signals be clearly delivered and represented? A technology may be successfully deployed and still not provide valuable information if no means are available to validate it. The validation task is critical to the success of a characterization system and could itself require substantial time and resources. Tools requiring new validation methods may never improve system performance unless the UST-ID is sure that these validation methods will be developed.

ACRONYMS

BWID	Buried Waste Integrated Demonstration
CVAA	Cold Vapor Atomic Absorbance
D&D	Decommissioning and Decontamination
DOE	U.S. Department of Energy
DSC	Differential Scanning Calorimetry
DST	double-shell tank
EHW	Extremely Hazardous Waste
EM	Office of Environmental Restoration and Waste Management
EM-30	Office of Waste Operations
EM-40	Office of Environmental Restoration
EM-50	Office of Technology Development
FTIR	Fourier Transform Infrared Spectroscopy
GEA	Gamma Energy Analysis
HMP	Hanford Mission Plan
HWVP	Hanford Waste Vitrification Plant
ICP	Inductively Coupled Plasma
IR	Infrared Spectrometry
LA	Laser Ablation
LIMS	Laboratory Information Management System
MS	Mass Spectrometry
NDE	Non-Destructive Evaluation
PI	principal investigator
PNL	Pacific Northwest Laboratory
RFP	Request for Proposal
SST	single-shell tank
TGA	Thermo Gravimetric Analysis
TIC	Total Inorganic Carbon
TOC	Total Organic Carbon
TRU	Transuranics
TSG	Technical Support Group
TTP	Technical Task Plan
TWG	Technical Working Group

TWRS	Tank Waste Remediation System
USQ	unreviewed safety question
UST	underground storage tank
UST-ID	Underground Storage Tank Integrated Demonstration
VOA	Volatile Organic Analysis
WHC	Westinghouse Hanford Company
XRF	X-Ray Fluorescence

ELEMENTS

Al	Aluminum
Ca	Calcium
Cs	Cesium
H	Hydrogen
Hg	Mercury
I	Iodine
Na	Sodium
Ni	Nickel
Pd	Palladium
Pu	Plutonium
Rh	Rhodium
Ru	Ruthenium
Si	Silicon
Sr	Strontium
Tc	Technetium
U	Uranium
Zr	Zirconium

ACKNOWLEDGMENTS

The authors would like to thank the following individuals who were especially helpful in providing technical guidance:

Harry Babad, Westinghouse Hanford Company
David B. Bechtold, Westinghouse Hanford Company
Robert J. Cash, Westinghouse Hanford Company
James Chinis, Decision Science Associates
Jonathan M. Cruse, Westinghouse Hanford Company
David A. Dodd, Westinghouse Hanford Company
Julian G. Hill, Westinghouse Hanford Company
Larry G. Morgan, Pacific Northwest Laboratory
Melissa S. Peffers, Pacific Northwest Laboratory
Dale N. Price, Westinghouse Hanford Company
Monty R. Smith, Pacific Northwest Laboratory
Joel M. Tingey, Pacific Northwest Laboratory
Gary L. Troyer, Westinghouse Hanford Company
Jacob Ulvila, Decision Science Associates

We also would like to thank John S. Hartman and Roger M. Bean (Pacific Northwest Laboratory), William I. Winters (Westinghouse Hanford Company) and William Haas (Iowa State University, Ames), for their invaluable review and guidance, and Richard A. Fowler (Pacific Northwest Laboratory) for graphic support.

CONTENTS

FIGURES

TABLES

1.0 INTRODUCTION

This report and its companion document[a] present a model for assessing current characterization technology needs and activities and for making subsequent technology development funding decisions. The goals of this task are to provide a general framework for 1) assessing characterization data needs; 2) describing technology responses and assessing currently funded technology development that addresses those needs; and 3) evaluating, prioritizing, and integrating characterization technology development options into coherent funding packages. The work was conducted jointly by Pacific Northwest Laboratory (PNL) and Westinghouse Hanford Company (WHC). The Underground Storage Tank Integrated Demonstration (UST-ID) funded the task; however, the information also will be valuable to the U.S. Department of Energy (DOE) Office of Technology Development (EM-50), the Office of Waste Operations (EM-30), and the Office of Environmental Restoration (EM-40).

The needs assessment (Chapter 2.0) identifies the drivers for characterization technology development and is critical for ensuring that investments are directed to areas that will benefit most from technology development dollars. The technology development assessment (Chapter 3.0) identifies general categories of technology development to meet the needs identified in Chapter 2.0, describes system requirements for different categories of technology development, and summarizes the status of specific technologies being developed in each of these categories.

A separate report outlines a process, with criteria and supporting software, to facilitate defensible funding decisions and to promote technology development that is innovative, effective, and economical.[a] In addition to enhancing good stewardship of public funds, the products of these two reports provide a mechanism for explaining and, if needed, defending the UST-ID funding decision process for characterization technologies.

(a) Quadrel, M. J., J. Ulvila, and J. Chinnis. 1993. R&D Prioritization and Resource Management for Technology Selection. Vol. 2, Limited Distribution.

1.1 ASSUMPTIONS

A number of assumptions helped shape this study's approach to characterization assessment. These are presented below.

1.1.1 Needs Assessment

- Hanford Site underground storage tank (UST) characterization comprises some of the most difficult technical problems and a significant portion of the DOE complex UST characterization technology needs. As a result, although this study focuses on Hanford's USTs, it supports UST characterization across the DOE complex.

- Characterization needs originate from unresolved safety questions (USQs), regulatory requirements (including Tri-Party Agreement milestones at Hanford), and remediation design and process requirements. Historically, the Hanford characterization program has focused on the first two of these. This study organizes and summarizes current knowledge on characterization needs and technology development to include remediation design and process requirements.

- EM-50 supports EM-30 and EM-40. As a result, technology needs information in this study is elicited from an EM-30 or EM-40 perspective; individuals and programs involved in EM-50 are not relied upon for needs information.

- There are three basic options for disposition of UST waste: treat and close, retrieve and dispose, or no (defer) action. Of these, some variant of the retrieve and dispose strategy is likely for Hanford waste. Consequently, although data to support other options are considered for comparison, this study focuses on characterization needs to support that action.

1.1.2 Technology Development Assessment

- There are three sources of characterization information: historical records, sampling and laboratory analysis, and in situ measurement. This work focused on the latter two.

- For greatest impact on remediation, technology development must be considered from a systems perspective.

- The UST-ID will focus on technologies that can be developed and deployed within 2 to 5 years.

- The UST-ID may be a sole funder of a technology and its deployment system or may elect to team with other integrated demonstrations or integrated programs, EM-30 or EM-40 funded activities, or industry efforts. Thus, technology development activity relevant to UST characterization needs in any of these arenas is relevant to funding decisions.

- Hanford has the most complex mixture of wastes, resulting from three reprocessing flowsheets and a wide variety of operation management flowsheets.

1.1.3 Decision Process

- To ensure effective and defensible decisions, the UST-ID technology development funding process requires independent expert opinion concerning the technical, regulatory, and institutional merits of proposed technology development options.

- Technology development funding options in characterization must be integrated with and compared to options from other technical areas (e.g., retrieval, pretreatment) to optimize the technology development budget.

- Budget levels may vary significantly over the course of a given year, as well as across years. Consequently, the UST-ID needs a rational method for readily narrowing or expanding its development program.

1.2 BACKGROUND

This study was initially designed as a "characterization systems study." Funds for the original systems study were allocated at the start of the 1992 fiscal year. At that time, the UST-ID recognized a significant deficiency in the funding decision process: while characterization activity was central to UST remediation, no documented list of characterization needs for process design and operation existed. A characterization systems study could describe the remediation strategies for USTs and deduce characterization needs from the system design and process requirements. The UST-ID could then identify characterization technology options and weigh these against system requirements. Ideally, such a study would reflect complex-wide UST remediation activities, complex-wide characterization needs, and complex-wide characterization capabilities and technology development activities that would support those needs.

In April 1992, the UST-ID awarded contracts to both PNL and WHC to begin the study. WHC was responsible for a systems engineering perspective; PNL provided direct user needs assessments and structured information on technology responses so the final product functioned as a practical decision support tool. Because of the short time period, a decision was made to focus on Hanford UST characterization needs, but to survey the entire complex for current characterization capabilities and technology development activities that would address those needs.

By the time the study was initiated, the Hanford Tank Waste Remediation System (TWRS) rebaselining task had begun. The TWRS objective was to select, by March 1993, the best strategy for addressing Hanford UST waste. To support the rebaselining effort, the existing Single Shell Tank Systems Study was redefined and expanded to become the TWRS Systems Engineering Study. System alternatives were re-structured and re-evaluated. As a result, a baseline remediation system was not defined. This raised doubts about the utility of a full-blown characterization systems study. Consequently, the study emphasis shifted from a formal systems engineering approach to a more general, multi-method approach to characterization technology development identification, evaluation, and funding. The final approach was re-titled the Waste Characterization Data and Technology Development Needs Assessment.

To accomplish its goals, this report accesses a wide range of information sources. Initial data on characterization needs, technology responses, and evaluation criteria were summarized from the existing literature. To develop current information, however, research staff relied on material available through EM-30, EM-40, and EM-50 staff (obtained through interviews); draft reports; workshops conducted as part of the TWRS effort and the Hanford Mission Plan (HMP); and technical reviews of the study's products. Because there were few documented sources of current information, it was critical for this study's success to establish links with relevant EM-30, EM-40, and EM-50 activities. Staff had close contact with TWRS characterization technical advisory committees and helped to structure and facilitate workshop activities for technology users within the TWRS, the HMP, and the UST-ID Characterization Technical Support Group (TSG). Initial data collection activities were coordinated with the Westinghouse Hanford/TWRS Characterization Program. Staff also reviewed the results of potentially relevant EM-50 activities beyond the UST-ID, such as the Technology Selection Filter (Mayberry et al. 1991) and the Volatile Organic Compound Characterization technical task plans. Results of these reviews were compared to results from the HMP Science and Technology Needs workshops. Finally, technical reviewers for the report were solicited from both TWRS and UST-ID technical advisory panels (the TWRS Characterization Technical Working Group, or TWG, and the UST-ID Characterization TSG).

1.3 APPROACH

1.3.1 Task Description

The first study task (Chapter 2.0) reports characterization data needs from two perspectives: 1) an abridged systems engineering assessment of characterization needs, based on an evaluation of the functions and processes to support the primary alternatives for UST remediation at Hanford and 2) a direct user assessment of perceived characterization needs not expected to be met by the existing characterization program, based on interviews with characterization data users at Hanford and other sites. The first perspective links each data need to a specific process and function required for mitigating or remediating UST waste. The second addresses a very specific question: what data do UST programs need to meet a specified design, process, or regulatory requirement? The goal was to converge on a set of characterization needs that are substantiated (can be traced to specific functional and regulatory requirements or to key design decisions).

The second study task (Chapter 3.0) mapped complex-wide laboratory capabilities and technology development activities onto the needs list to assess possible gaps in available characterization technology. To do this, specific characterization needs were organized into 12 technology development categories, each of which is associated with a different set of system requirements. Specific technology development options were then mapped onto each of these more general categories, and their funding and development status was assessed. Technology development options were drawn from within the DOE complex, private industry, and universities. The goal of this task was to 1) assess the availability of technology for characterizing UST waste (identifying possible technology gaps in the system), 2) describe the system requirements associated with general categories of technology development, and 3) use this information to generate possible funding options and criteria for evaluating the possible success of these options.

The third major task was to develop a decision process, with supporting software, for structuring, evaluating, and packaging the technology development options.[a] The process has two parts. The first assumes as initial input the data needs and proposed technology development options uncovered in the preceding tasks. These form the basis for a UST-ID request for proposal (RFP).[b] Once specific proposals (TTPs) are received, experts in relevant technical, regulatory or institutional areas evaluate these against a set of recommended criteria including benefits and costs, and individual evaluations are combined to provide a general assessment of the relative merit. Characterization experts can then use this information to develop funding packages, consisting of the set of proposals (old or new, supported by the UST-ID or jointly with other programs) that best satisfy the UST-ID program objectives at different funding levels (e.g., minimal, recommended, and optimal).

These packages form the input to the second part of the process. Whereas the first tool is used by experts within specific technical areas (e.g., the TSGs), the second tool operates at the coordinating level and is used by either the UST-ID Coordinator or the UST-ID Core Planning Group. At this level, the recommended characterization funding packages are combined with those from other funding areas (e.g., retrieval or pretreatment) and are evaluated against a second set of criteria reflecting different UST-ID program objectives (e.g., maximum number of early successful demonstrations, maximum

(a) This task is described in Quadrel, M. J., J. Ulvila, and J. Chinnis. 1993. R&D Prioritization and Resource Management for Technology Selection. Vol. 2, Limited Distribution.

(b) If there are too many needs, these should also be ranked, not only against technical and regulatory requirements, but also against demonstration goals (e.g., can they be developed within currently planned technology demonstrations, which are likeliest to be successfully addressed within the existing demonstration program). Needs that are ranked highest become the more specific focus of an RFP.

number of industry spinoffs). This second tool prompts decision makers to make funding decisions as integrated packages in support of identified demonstration goals rather than as single investments.

Taken together, the needs data, technology activity summary, and decision process provide a means for increasing the chances that completed demonstrations will meet high-priority and relatively stable underground storage tank characterization needs, that selected technologies have the highest probability of success, that the organization(s) selected to carry out development are best qualified and most committed, and that innovative technologies and alternative funding schedules are anticipated to most effectively apply technology development budgets.

1.3.2 Study Criteria

The final format for each of the study products was guided by a set of criteria. These are described below.

1. Information and recommendations must be reliable. This criterion reflects the current uncertainty of design and process requirements for managing and remediating tank waste, particularly at Hanford. To increase reliability, the study assesses needs from multiple perspectives and recommends technology development strategies that address needs that were identified by several different sources and are associated with multiple remediation alternatives and program functions.

2. The product must be substantiated. Needs must be linked to specific drivers and traced to specific characterization data users; likewise, the logic and algorithms comprising the decision tool must be theoretically and methodologically correct. The theoretical basis for the process and all data manipulations codified in the software are behavioral decision theories. Specifically, the tool is grounded in a multiattribute utility theory (von Winterfeldt and Edwards 1976).

3. The product should direct technology development, if needed. The study does not focus on needs that are already satisfactorily addressed by existing characterization methods. Interviewers asked users to focus on their high-priority characterization needs that had not been met, and the engineering assessment focused on Hanford remediation functions and design requirements that had not previously been supported by the Hanford characterization program.

4. The product must be practical. Specifically, UST-ID TSG or Core Planning Group members must be able to review, evaluate, and apply

the information or tool in the context of a 1- to 2-day meeting. (This criterion reflects the requirements of a decision process that relies heavily on nationally recognized technical experts who need to be aware of the applied needs of UST remediation but who do not have the time or resources to digest large volumes of information.)

5. Information must be easily updated and edited. The information should allow individuals to tailor criteria, weights, and output to their particular needs, and should be theoretically and methodologically correct.

1.4 APPLICATIONS

The products of this study are distinct from other characterization studies in several respects. First, needs information focuses on characterization needs that require technology development. This distinguishes it from characterization program plans (which focus on what needs the characterization program plan will address in the next activity period) and from comprehensive characterization data reports (which focus on data required to support known regulatory and programmatic needs).

Second, this study provides current data within a general model for organizing characterization information and technology evaluations. The data presented within are currently neither detailed nor final. Instead, they illustrate the current state of the UST waste characterization "universe." Because this universe is currently being defined, the data should be updated as the definition proceeds. Although specific needs may change, the framework is general.

Third, the study includes a decision process for prioritizing technologies and making funding decisions. The process was designed to be used within the current UST-ID infrastructure. However, it presents a general approach to decision making that can be applied throughout the funding process wherever evaluations, budgets, or information management and review are important. The tool can be used to make initial funding decisions, as well as updating and reviewing those decisions in light of new information, budget changes, or system changes. The spreadsheet format of the software makes it practical for use within workshops and by anyone familiar with Lotus 1-2-3 or Excel. Also, the process can be used in conjunction with other technology prioritization procedures currently in use (e.g., the Technology Selection Filter, Mayberry et al. 1991). New information about characterization needs or options can be used to modify funding options or criteria and their definitions or weights and to update their evaluation. As such, the tool offers a compromise between a very formal and data-intensive evaluation tool, such as the BWID Technology Selection Filter and more informal consensus-based procedures for making funding decisions.

2.0 CHARACTERIZATION NEEDS ASSESSMENT

This chapter describes the results of two tasks, each aimed at assessing characterization needs. The first task is a systems engineering assessment of data needs that focuses strictly on the Hanford TWRS and takes a functions and requirements approach to needs assessment. Three general alternatives for addressing UST waste are described. Each is then divided into a number of functions and processes that lead to identification of characterization data requirements. The framework is generalized to accommodate a range of specific strategies that might be implemented within any of the three general alternatives. The second task undertakes a direct user assessment of characterization needs. Individuals within specific remediation programs at Hanford and other sites were interviewed to determine what characterization needs they expect that are not addressed by existing characterization programs. These are presented in terms of the need, its driver(s), and the program(s) and site(s) identifying it.

The two tasks comprise a multimethod approach to needs assessment; the engineering assessment checks potential biases of interviewees who may have estimated their characterization needs liberally, while the interviews elicit characterization needs from those who will use the data and are most familiar with their programs' needs. The direct assessment has the added benefit of focusing on data needs requiring technology development that are recognized by EM-30 programs. This dual perspective should converge on a set of clearly identified and well-documented data needs that provide the essential justification for specific technology developments.

2.1 SYSTEMS ENGINEERING ASSESSMENT

2.1.1 Objective

The systems engineering assessment of characterization needs provides a functional basis for specifying characterization data needed for remediating UST waste. The objective is to provide EM with an inventory of specific UST characterization needs to support UST waste management, remediation, or restoration. To do this, the assessment begins with UST waste remediation or management alternatives, describes these by function and operation or process alternatives, and then derives specific characterization needs required to support the design and demonstration of these unit operations or processes. Knowing why data are needed accomplishes several objectives: it keeps data needs to a minimum, by identifying only those that are functionally relevant; it provides context for developing performance requirements (accuracy, precision, and measurement ranges, cost, speed, etc.) for technology developers to ensure that the technology can be deployed within the waste management system it addresses; and it provides a basis for updating data needs as the remediation system changes over time.

2.1.2 Approach

To accomplish this, a functional flow diagram representing the most basic alternatives for remediating USTs was prepared. This was then elaborated to identify more specific processes that require characterization data.

The primary functions for remediating tank waste are shown in Figure 2.1. The diagram represents classes of remediation alternatives for Hanford tank waste, but generalize to USTs beyond Hanford. At the highest level, there are only two alternatives for tank waste remediation. They are the take action and dispose of the tank waste (shaded portions) or the defer action (no action) alternatives. The defer action alternative is simply a continuation, for an indefinite time, of the current Waste Tank Safety and Operation Program. The take action alternative has two subalternatives indicated by the crosshatching: 1) in situ waste treatment and tank closure (i.e., "treat and close") or 2) waste tank retrieval, treatment, and disposal (i.e., "retrieve and dispose"). The latter alternative can be restricted to retrieval of some or all of the tank waste and eventual closure of the waste site, or it can include the retrieval of the waste, the waste tank, including contaminated soil as required, and subsequent closure of the waste site.

Alternatives within the TWRS mission are depicted in Figure 2.2. This logic flow diagram identifies the major functional blocks and decisions to achieve disposal of the tank waste and tank closure. The major alternatives

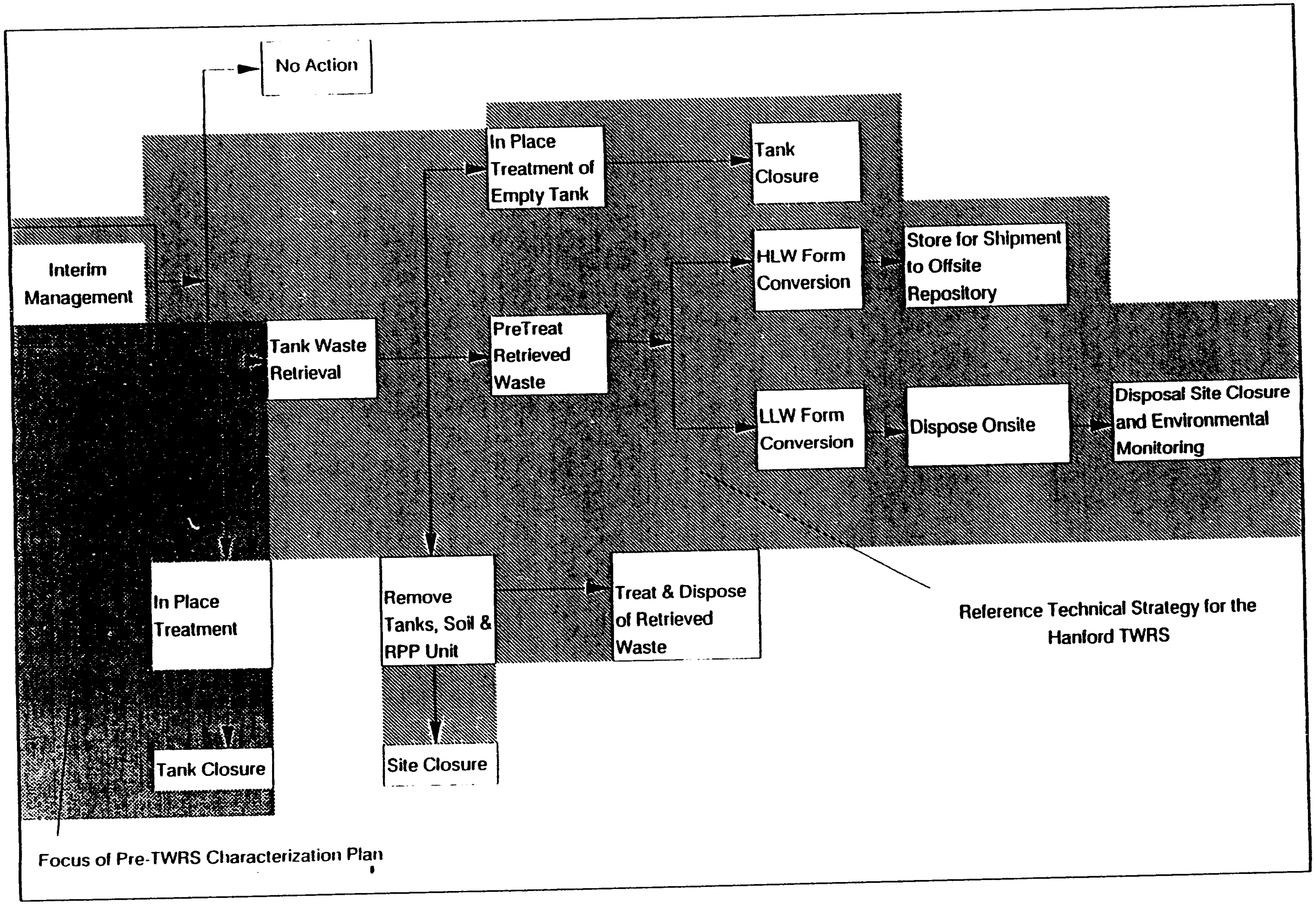


FIGURE 2.1. Primary TWRS Remediation Alternatives and Functions

depicted in Figure 2.1 can be found in Figure 2.2 by following the logic along different paths. The No Action alternative is identified by the left-most line through both sheets. The Retrieve and Dispose alternative is described by the major functional blocks following a "Yes Retrieve" path from the bottom, left-hand column. The Treat and Close alternative is indicated by following the "No Retrieve" path from that same point. For each functional block, several processing options may be available to accomplish the desired function. For example, in the case of tank waste retrieval, retrieval can be accomplished using hydraulic/sluice pump, pneumatic arm, or mechanical arm technology. A TWRS reference case has been tentatively identified, which includes tank waste retrieval, pretreatment, and conversion to grout and glass for the low-level and high-level waste fractions, respectively.[a]

The functions and alternatives identified in Figure 2.2 provide a starting point for identifying characterization data requirements (Table 2.1). Table 2.1 is organized according to the three major alternatives depicted in Figure 2.1: Defer Action, Retrieve and Dispose, and Treat and Close. These major alternatives are further described by their major functions (column 1). For example, the defer action alternative has three functions: 1) mitigation of safety issues, 2) continued waste storage, and 3) interim stabilization. The retrieve and dispose alternative has five functions: 1) waste retrieval, 2) waste separation, 3) high-level waste form conversion, 4) low-level waste form conversion, and 5) in-place treatment of empty tank. The treat and close alternative has two functions: 1) in-place treatment and disposal of waste and 2) waste site closure.

For each major function, activities were identified that require tank waste characterization support (column 2). Next, process alternatives are proposed that can accomplish the identified activity (column 3). The general characterization elements needed to support development of the technology or design of the unit operation for each of the alternatives are then listed (column 4). The major characterization elements were further defined to a

(a) The selection of a formal reference is currently under way with the TWRS. Requirements for final closure, in particular, are not yet specified by EM-40.

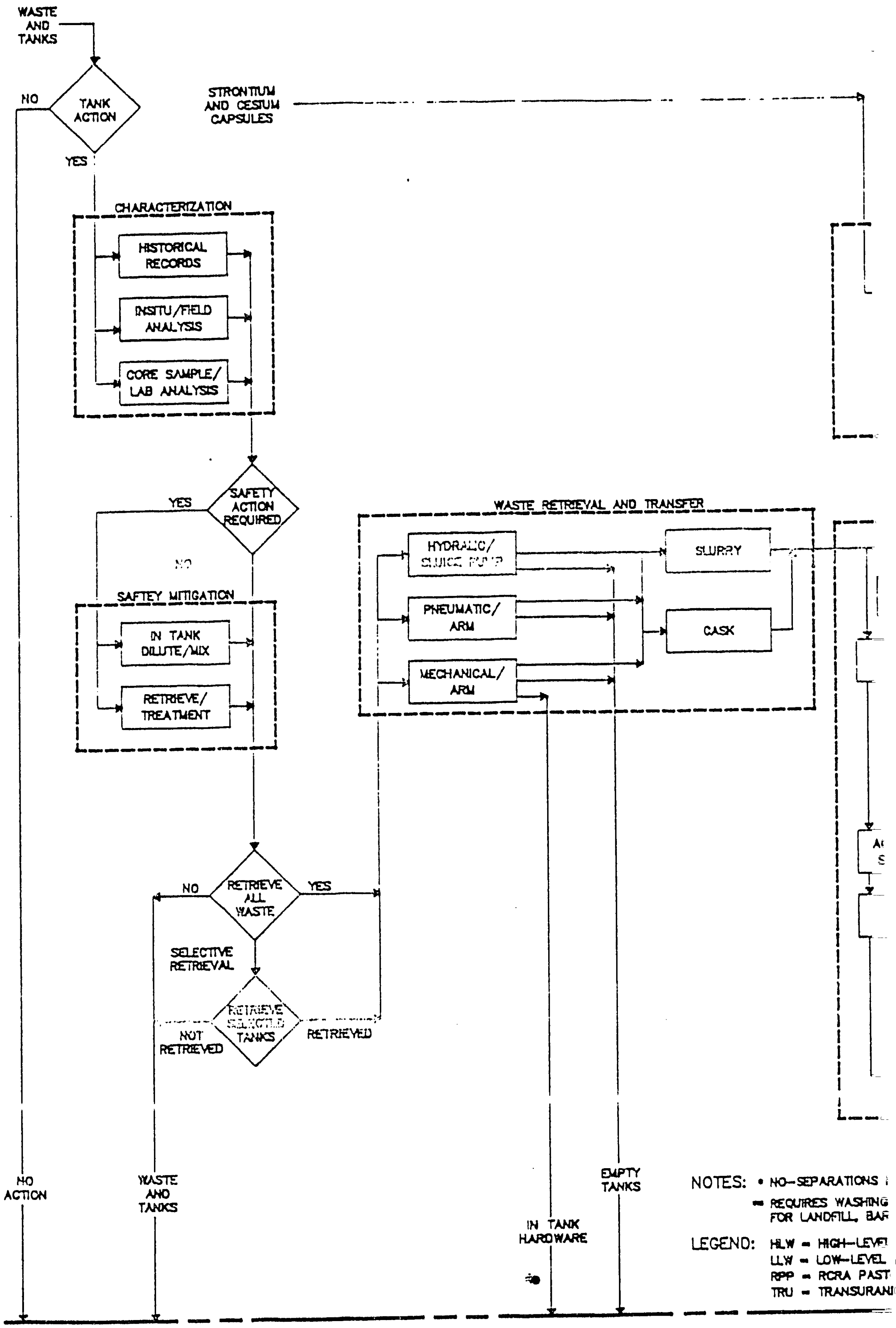
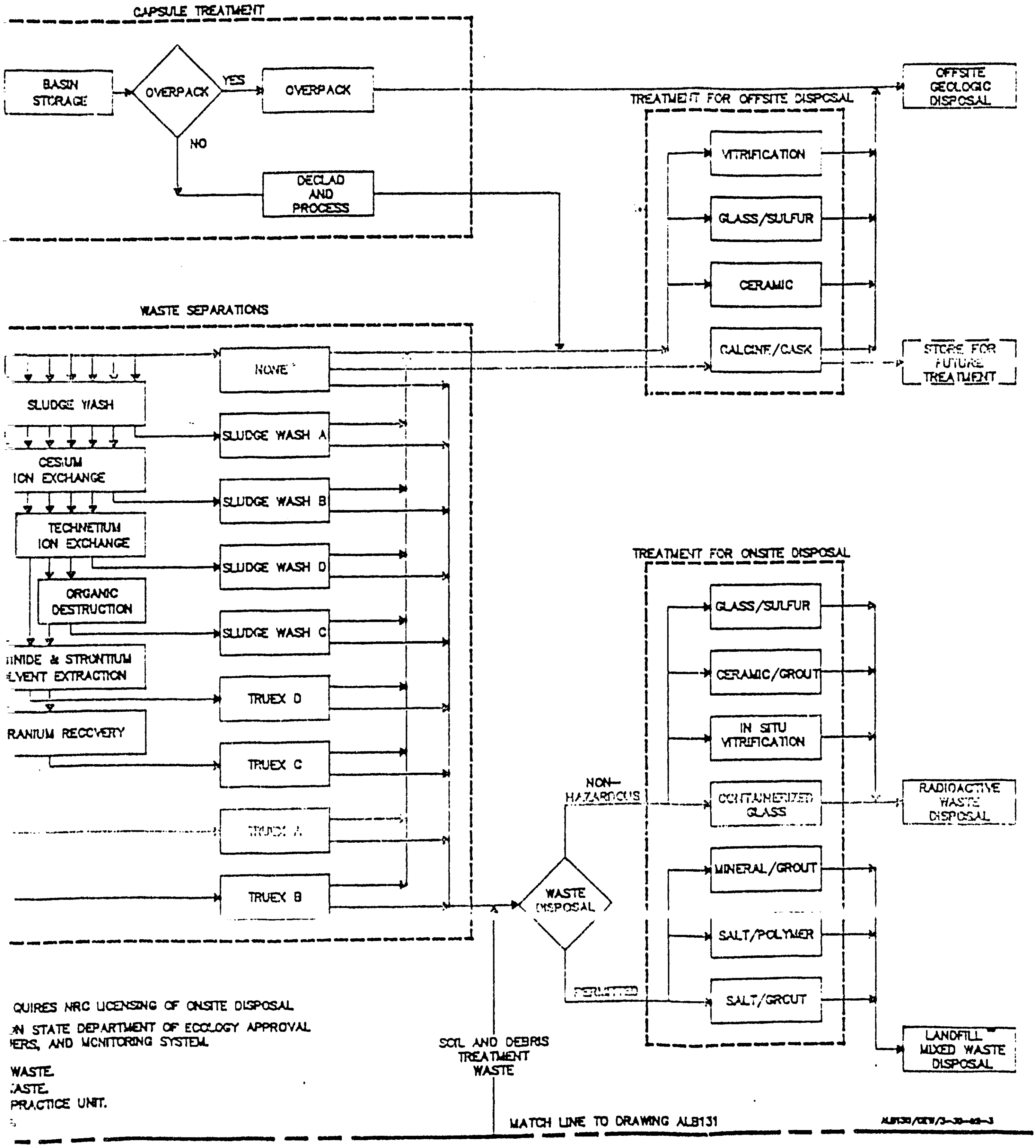
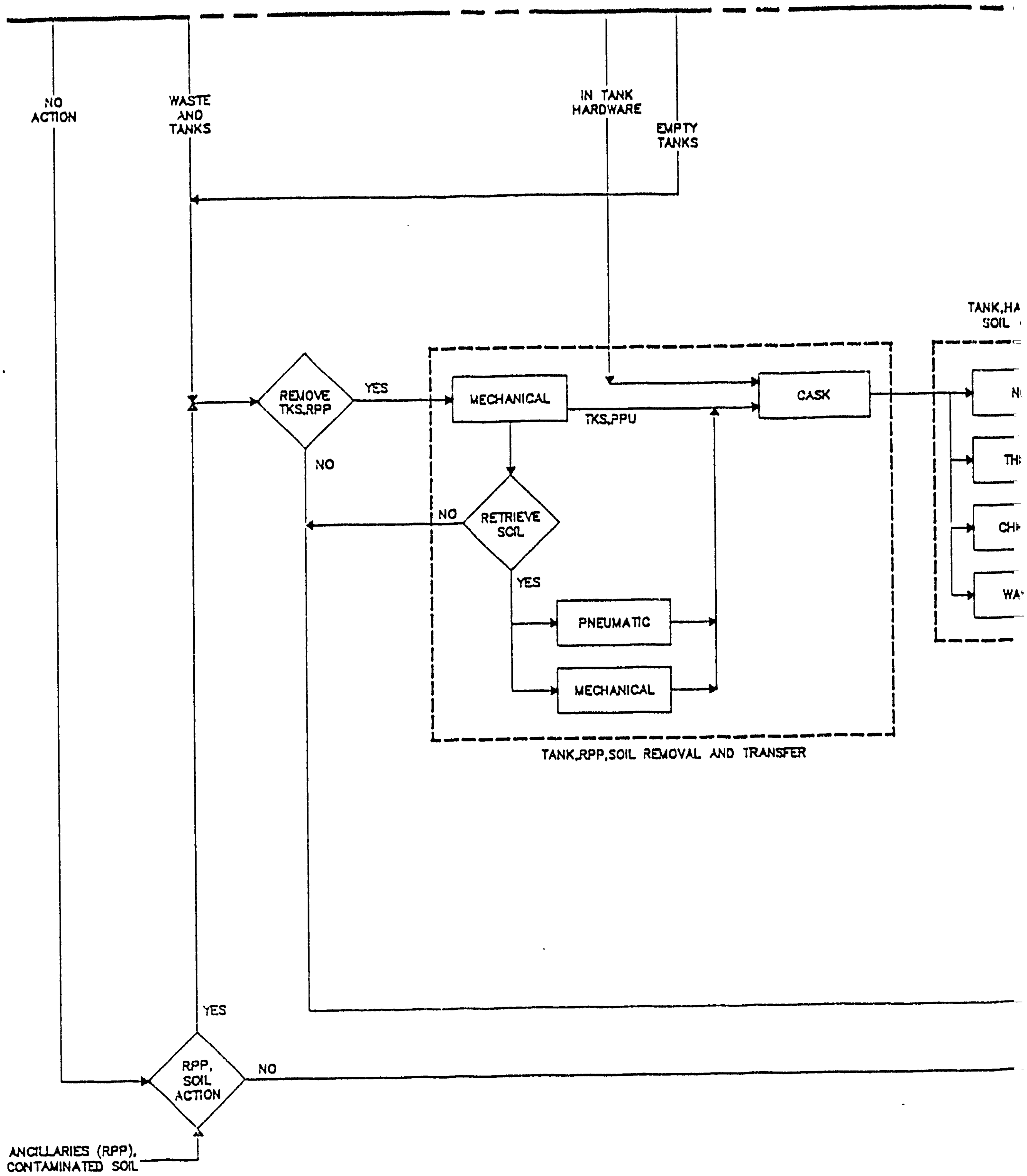

WASTE AND TANKS
TANK ACTION
NO
YES
STRONTIUM AND CESIUM CAPSULES
CHARACTERIZATION
HISTORICAL RECORDS
INSITU/FIELD ANALYSIS
CORE SAMPLE/ LAB ANALYSIS
SAFETY ACTION REQUIRED
YES
NO
SAFTEY MITIGATION
IN TANK DILUTE/MIX
RETRIEVE/ TREATMENT
WASTE RETRIEVAL AND TRANSFER
HYDRAULIC/ SLUICE PUMP
PNEUMATIC/ ARM
MECHANICAL/ ARM
SLURRY
CASK
RETRIEVE ALL WASTE
NO
YES
SELECTIVE RETRIEVAL
RETRIEVE SELECTED TANKS
NOT RETRIEVED
RETRIEVED
NO ACTION
WASTE AND TANKS
IN TANK HARDWARE
EMPTY TANKS
NOTES: • NO-SEPARATIONS
▬ REQUIRES WASHING
FOR LANDFILL, BAR
LEGEND: HLW - HIGH-LEVEL
LLW - LOW-LEVEL
RPP - RCRA PAST
TRU - TRANSURAN

FIGURE 2.2.



QUIRES NRC LICENSING OF ONSITE DISPOSAL
ON STATE DEPARTMENT OF ECOLOGY APPROVAL
IERS, AND MONITORING SYSTEM.

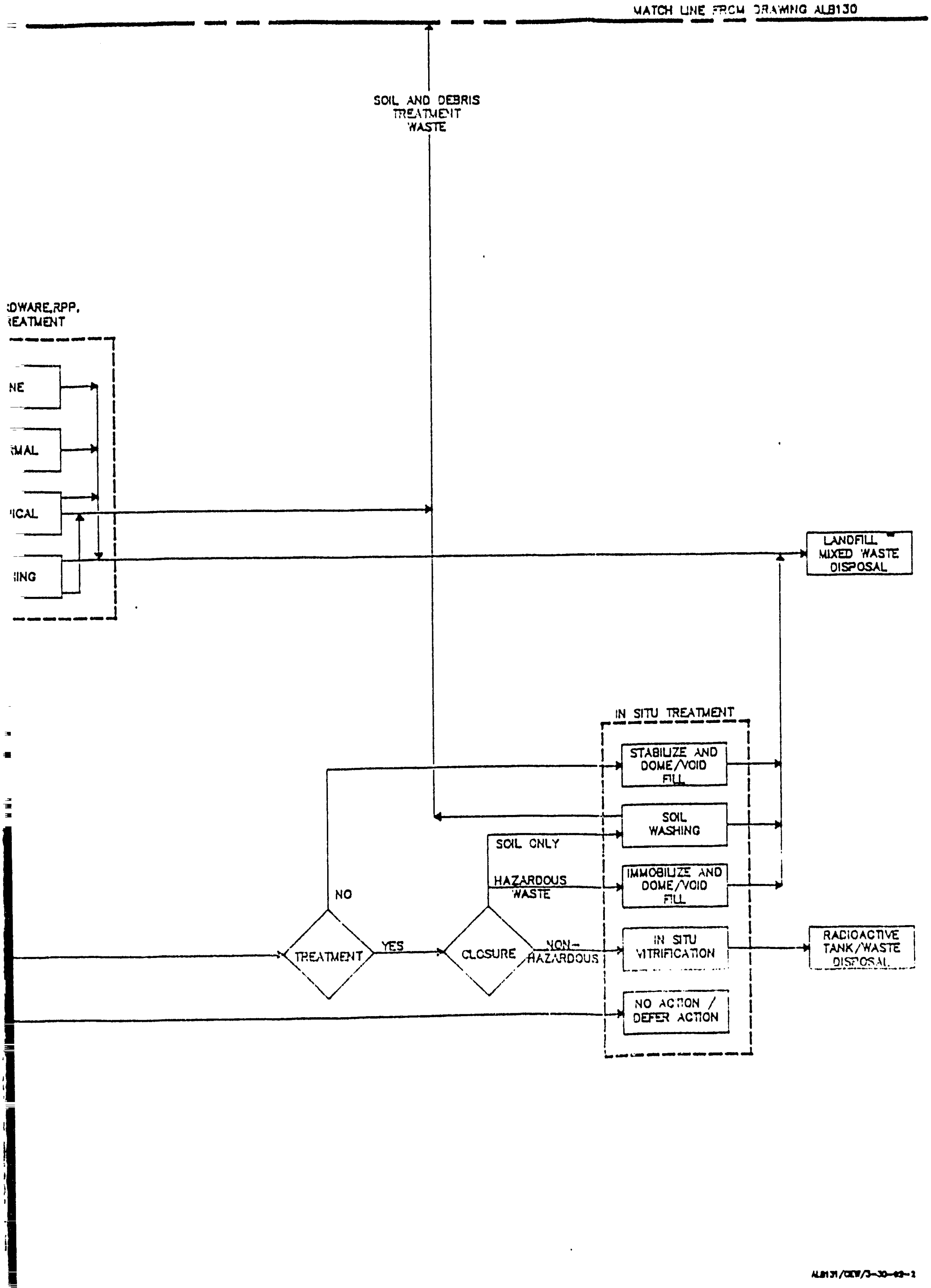
WASTE.
ASTE.
PRACTICE UNIT.



NOTES: * NO-SEPARATIONS REQUIRES NRC LICENSING OF ONSITE DISPOSAL
** REQUIRES WASHINGTON STATE DEPARTMENT OF ECOLOGY APPROVAL FOR LANDFILL, BARRIERS, AND MONITORING SYSTEM.

LEGEND:
HLW - HIGH-LEVEL WASTE.
LLW - LOW-LEVEL WASTE.
RPP - RCRA PAST-PRACTICE UNIT.
TRU - TRANSURANIC.

FIGURE



MATCH LINE FROM DRAWING ALB130
SOIL AND DEBRIS TREATMENT WASTE
LANDFILL MIXED WASTE DISPOSAL
IN SITU TREATMENT
STABILIZE AND DOME/VOID FILL
SOIL WASHING
SOIL ONLY
HAZARDOUS WASTE
IMMOBILIZE AND DOME/VOID FILL
NO
TREATMENT
YES
CLOSURE
NON-HAZARDOUS
IN SITU VITRIFICATION
RADIOACTIVE TANK/WASTE DISPOSAL
NO ACTION / DEFER ACTION

2. (contd)

TABLE 2.1. System Engineering Assessment of TWRS Waste Characterization Needs

Defer Action				
Primary Functions Interim Management	**Functions/Activities with Characterization Requirements**	**Process Alternatives**	**Characterization Needs**	**Specific Measurements**
Mitigate Safety Issues[(a)]	· Gas Generation and Retention	· Dilute Waste · Circulate/Mix Waste · Heat Tanks · Transfer Waste	· Composition of Major Constituents in Aqueous and Solid Waste Fractions · Physical Properties of Waste · Composition of Gaseous Effluents · Organic Speciation · Temperature Profile In Tanks · Organic Carbon Content · Waste Energetics	· Nitrate, Hydroxide, Sodium, Nitrite, Aluminum, Metal Oxides, Carbonate, Water · Viscosity, Thermal Conductivity, Temperature, Liquid Level, Rheological Properties, % Solids, Temperature Dependence of Viscosity · Hydrogen, Nitrous Oxide, Oxygen, Water, Volatile Organics · Semi-Volatile Organics, Low Molecular Weight Organic Acids · TOC, TIC, Total Complexants · Radionuclides
	· High Heat In SST	· Addition of Water · Transfer Waste and Dilute	· Composition of Major Constituents in Aqueous and Solid Waste Fractions · Physical Properties of Waste · Chemical Reactivity · Organic Carbon Content · Radiochemical Distribution	· Nitrate, Hydroxide, Sodium, Nitrite, Aluminum, Metal Oxides, Carbonate, Water · Viscosity, Thermal Conductivity, Temperature, Liquid Level Rheological Properties, % Solids, Temperature Dependence of Viscosity · DSC/TGA · TOC · Sr, Cs · Radionuclides · Thermal Output

(a) Characterization requirements of safety tanks are described in Tank Waste Remediation Plan, 1992. WHC-SD-PLD-047 (Draft).

TABLE 2.1. (contd)

Defer Action (contd)				
Primary Functions Interim Management	**Functions/Activities with Characterization Requirements**	**Process Alternatives**	**Characterization Needs**	**Specific Measurements**
Mitigate Safety Issues (contd)	· Ferrocyanide	· Homogenize Waste · Retrieve and Dilute	· Composition of Major Constituents in Aqueous and Solid Waste Fractions · Distribution and Concentration of Ferrocyanide Complexes · Physical Properties of Waste · Radiochemical Distribution · Waste Energetics	· Nitrate, Hydroxide, Sodium, Nitrite, Aluminum, Metal Oxides, Carbonate, Water · Ferrocyanide Speciation, Stratification, and Concentration · Viscosity, Thermal Conductivity, Temperature, Liquid Level Rheological Properties, % Solids, Temperature Dependence of Viscosity · DSC/TGA · Cs, Sr in Ferrocyanide Layer · Radionuclides
	· Organic	· In Tank Oxidation · Retrieve and Oxidize or Treat	· Composition of Major Constituents in Aqueous and Solid Waste Fractions · Physical Properties of Waste · Organic Speciation · Total Organic Carbon and Total Inorganic Carbon Content · Chemical Reactivity · Radiochemical Distribution · Waste Energetics	· Nitrate, Hydroxide, Sodium, Nitrite, Aluminum, Metal Oxides, Carbonate, Water · Viscosity, Thermal Conductivity, Temperature, Liquid Level Rheological Properties, % Solids, Temperature Dependence of Viscosity · Total Complexants, Volatile Organics, Semi-Volatile Organics · TOC, TIC, Total Organics · DSC/TGA · Radionuclides

TABLE 2.1. (contd)

Defer Action (contd)				
Primary Functions Interim Management	**Functions/Activities with Characterization Requirements**	**Process Alternatives**	**Characterization Needs**	**Specific Measurements**
Continued Waste Storage	· Leak Detection · Gaseous Effluents · Intrusions	· Monitoring	· Distribution of Contamination Around Leaking SS Tanks · Composition of Gaseous Effluents	· Contamination Profile · Hydrogen, Oxygen, Water, Volatile Organics
		· Transfer Waste	· Composition of Major Constituents in Aqueous and Solid Waste Fractions · Physical Properties of Waste · Radiochemical Distribution · Waste Energetics	· Nitrate, Hydroxide, Sodium, Nitrite, Aluminum, Metal Oxides, Carbonate, Water · Viscosity, Thermal Conductivity, Temperature, Liquid Level Rheological Properties, % Solids, Temperature Dependence of Viscosity · Radionuclides · DSC/TGA
Interim Stabilization	· Pump Liquid from SSTs · Leak Detection · Isolate Tanks · Transfer Liquids to DST · Intrusions		· Quantity of Pumpable/Leakable Liquids · Composition of Pumpable/Leakable Liquids · Physical Properties of Waste · Radiochemical Distribution · Waste Energetics	· Drainable Liquid, Solid-to-Liquid Ratio · Sodium, Nitrite, Hydroxide, Cs, Na, TOC · Porosity, Viscosity, Particle Size · Radionuclides · DSC/TGA

TABLE 2.1. (contd)

Retrieve and Dispose				
Primary Functions Interim Management	Functions/Activities with Characterization Requirements	Process Alternatives	Characterization Needs	Specific Measurements
Waste Retrieval	Waste Retrieval · Retrieval Technology	· Hydraulic/Sluice Pump	· Mechanical Properties of Waste · Waste Physical Characteristics	· Hardness, Viscosity, Shear Strength, Particle Size, Solubility, % Solids/Liquid, Compressive Strength, Abrasiveness, Density
			· Waste Stratification	· >10-20% Change in Physical or Chemical Composition
			· Equipment Compatibility	· pH, Radiation Levels, Corrosivity
			· Concentration of Reactive and Volatile Components	· Volatile Organic Compounds, Hydrogen, Ratio of Nitrate/Nitrite-to-Organic, or Ferrocyanide, Shock Sensitive Compounds >3-5%
			· Water/Moisture Content	· % Water, Drainable Liquids
			· Concentration of Radionuclides	· Gross Alpha, Beta, Gamma
			· Chemical Reactivity	· DSC and TGA
			· Heel Characteristics · Fissile Content by Location	· Hardness, Shear Strength, Particle Size, Solubility, % Solids/Liquid, Compressive Strength, Abrasiveness Density
		· Pneumatic/ARM	· Mechanical Properties of Waste · Waste Physical Characteristics	· Hardness, Viscosity, Shear Strength, Particle Size, Solubility, % Solids/Liquid, Compressive Strength, Abrasiveness, Density, Corrosivity
			· Waste Stratification	· >10-20% Change in Physical or Chemical Composition
			· Concentration of Reactive and Volatile Components	· Volatile Organic Compounds, Hydrogen, Ratio of Nitrate/Nitrite to Organic, or Ferrocyanide, Shock Sensitive Compounds >3-5%
			· Equipment Compatibility	· pH, Radiation Levels, Corrosivity
			· Concentration of TRU	· Gross Alpha, Beta, Gamma
			· Water/Moisture Content	· % Water, Drainable Liquids
			· Chemical Reactivity	· DSC and TGA
			· Heel Characteristics · Fissile Content by Location	· Hardness, Shear Strength, Particle Size Solubility, % Solids/Liquid, Compressive Strength, Abrasiveness Density

TABLE 2.1. (contd)

Retrieve and Dispose (contd)				
Primary Functions Interim Management	**Functions/Activities with Characterization Requirements**	**Process Alternatives**	**Characterization Needs**	**Specific Measurements**
Waste Retrieval (contd)	Waste Retrieval · Retrieval Technology (contd)	· Mechanical/ARM	· Mechanical Properties of Waste · Waste Physical Characteristics · Waste Stratification · Equipment Compatibility · Concentration of Reactive and Volatile Components · Chemical Reactivity · Heel Characteristics	· Hardness, Viscosity, Shear Strength, Particle Size, Solubility, % Solids/Liquid, Compressive Strength, Abrasiveness, Density, Corrosivity · >10-20% Change in Physical or Chemical Composition · pH, Radiation Levels, Corrosivity · Volatile Organic Compounds, Hydrogen, Ratio of Nitrate/Nitrite-to-Organic, or Ferrocyanide, Shock Sensitive Compounds >3-5% · DSC and TGA · Hardness, Shear Strength, Particle Size Solubility, % Solids/Liquid, Compressive Strength, Abrasiveness Density
	Waste Transfer · Fluidize/Slurry Waste · Waste Transfer System · Transfer Medium and Recycle	· Pipe Line and Fluid Recycle · Casks	· Solid/Liquid Content · Physical Characteristics, Pumping Properties · Composition of Major Liquid and Solid Components	· Ratio of Solids to Liquids, Water Content · Bulk Density, Settling Rate Particle Size, Particle Density, pH, Viscosity · TRU Content, Total Metal Oxides, Hydroxide, Nitrate, Nitrite, Aluminate
	Interim Waste Storage · LAG Storage Tanks · Mitigate Tank Safety Issues	· Segregate Waste Types · Blend Waste Types · Solid/Liquid Content · Solubility	· Solid/Liquid Content · Physical Characteristics, Pumping Properties · Chemical Composition of Interim Stored Waste-Key Components · Bulk Radioisotope Composite · Concentration/Distribution of Chemical Constituents Relative to Tank Waste Safety Issues	· Ratio of Solids to Liquids, Water Contents · Bulk Density, Settling Rate Particle Size, Particle Density, pH, Viscosity · Total Metal Oxides, Hydroxide Nitrate, Nitrite, Aluminate · TRU, Total Alpha, Beta, Gamma · Ferrocyanide, Acetate, TOC, TIC

TABLE 2.1. (contd)

Retrieve and Dispose (contd)				
Primary Functions Interim Management	**Functions/Activities with Characterization Requirements**	**Process Alternatives**	**Characterization Needs**	**Specific Measurements**
Waste Separation	• Waste Blending and Preconditioning	• Sludge Wash	• Solubility of Retrieved Waste in Water and Acid • % of Insoluble Fraction • Composition of Major Constituents in Aqueous and Solid Fractions • Radionuclide Content of Solid and Liquid Fraction	• % Solids Dissolved From Aqueous and Acid Wash • Ratio of Solids/Liquid After Sludge Wash • Nitrate, Hydroxide, Sodium, Nitrite, Aluminum, Metal Oxides, Carbonate • TRU, Total Alpha, Beta, and Gamma
	• Waste Treatment	• Cs Ion Exchange	• Composition of Major Constituents in Aqueous Feed Stream • Concentration of Interfering Ions for Separation Processes • Concentration of Cs in Feed Stream	• Sodium, Nitrate, Nitrite, Hydroxide • Cesium
		• Tc Ion Exchange	• Composition of Major Constituents in Aqueous Feed Stream • Concentration of Interfering Ions for Separation Processes • Concentration of Tc in Feed Stream	• Nitrate, Hydroxide, Sodium, Nitrite, Aluminum, Metal Cations, Carbonate • Ferrocyanide • Tc
		• Organic Destruction	• Organic vs Carbonate Analysis • Total Organic • Chemical Reactivity of Feed	• TOC and TIC • Total Acetate and Complexant • TGA/DSC • Semi VOA
		• Actinide and Sr SX	• Composition of Major Constituents in Aqueous Feed Stream • Concentration of Interfering Ions for Separation Processes • Concentration of TRU and Sr in Feed Stream	• Nitrate, Hydroxide, Sodium, Nitrite, Aluminum, Metal Oxides, Carbonate • Multivariant Metal Cations • Sr, Pu, U, TRU
		• U Recovery	• Composition of Major Constituents in Aqueous Feed Stream • Concentration of Interfering Ions for Separation Processes • Concentration of U in Feed Stream	• Nitrate, Hydroxide, Sodium, Nitrite, Aluminum, Metal Oxides, Carbonate • U

TABLE 2.1. (contd)

Retrieve and Dispose (contd)				
Primary Functions Interim Management	**Functions/Activities with Characterization Requirements**	**Process Alternatives**	**Characterization Needs**	**Specific Measurements**
HLW Form Conversion	· Blend and Precondition Waste Streams	· Vitrification	· Composition of Major Constituents in Aqueous Feed Stream	· Nitrate, Hydroxide, Sodium, Nitrite, Aluminum, Metal Oxides, Carbonate, Water
	· Cesium and Strontium Capsules Blending	· Glass/Sulfur	· Concentration of Hazardous or Limiting Constituents in Feeds and Products	· Hg, Sulfate, Phosphate, TOC, Fe, Ferrocyanide, Total Cyanide · I
	· Convert to HLW Form Suitable for Offsite Disposal	· Ceramic	· Distribution of Radionuclides in Feeds, Products, and Effluent Streams	· TRU, U, Tc, Sr
	· Package for Storage	· Calcine	· Physical and Mechanical Properties of Final Waste Forms · Regulatory	· Leachability, Hardness, Heat Content, TRU and Radioisotope Loading, Constituents Relative to Waste Designation
LLW Form Conversion	· Blend and Precondition Waste Streams	· Glass/Sulfur	· Composition of Major Constituents in Aqueous Feed Stream	· Nitrate, Hydroxide, Sodium, Nitrite, Carbonate, Water
	· Convert to LLW Form Suitable for Offsite Disposal	· Ceramic/Grout	· Concentration of Hazardous or Limiting Constituents in Feeds and Products	· Sulfate, Phosphate, TOC, Total Complexants
	· Pump/Transfer to Grout Vaults	· In Situ Vitrification · Containerized Glass · Mineral/Grout · Salt/Polymer · Salt/Grout	· Distribution of Radionuclides in Feeds, Products, and Effluent Streams · Physical and Mechanical Properties of Final Waste Forms	· Ca, Tc · Leachability, Hardness, Heat Content, TRU and Radioisotope Loading, Constituents Relative to Waste Designation
Treatment of Empty Tank and Site · Tank	· Decontaminate (DST)	· Sluice	· Composition of Major Constituents in the Waste Remaining in the Tank	· Nitrate, Hydroxide, Sodium, Nitrite, Water
	· In Situ Treatment	· In Situ Vitrification	· Concentration of Constituents that Interfere with Treatment/Stabilization Processes	· % Iron, Concrete, Moisture, Organics in Tank Structure
	· Dome/Void Fill · Retrieve Tank	· Gravel Fill · Grout Fill · Structural Properties	· Volume of Tank Space · Physical and Mechanical Properties Tank Structure	· LDR Requirements

TABLE 2.1. (contd)

Retrieve and Dispose (contd)				
Primary Functions Interim Management	**Functions/Activities with Characterization Requirements**	**Process Alternatives**	**Characterization Needs**	**Specific Measurements**
Treatment of Empty Tank and Site (contd) · Soil	· Treat Soil Contamination · Intrusion Barriers	· Soil Washing · In Situ Immobilize · In Situ Vitrification	· Characterization of Soil · Distribution of Contamination in the Soil · Physical Characterization of Soil · Chemical Characterization of Soil	· Porosity, Moisture, Particle Size, Density · Total Alpha, Beta, Gamma, TRU, Ca, Tc · Porosity, Moisture, Particle Size, Density · Dissolved Solids, TOC
· RCRA Past Practice	· In Situ Treatment	· Stabilize · Immobilize · In Situ Vitrification	· Composition of Major Constituents in PPU[(a)] · Concentration/Speciation of Hazardous/Radioactive Constituents in PPU (Waste Designation) · Potentially Volatile Constituents	· Iron, Concrete · Specific Metal and Organic Species for EHW Designation Including Radioisotopes · Organics, Moisture
· Site Closure	· Characterize Waste Site · Site Restoration		· Distribution and Concentration of Constituents at Closure Site (Waste Designation) · Physical Properties of Stabilized Tank Waste/Soil Contamination	· Waste and Radionuclide Constitutents for Waste Designation, and TRU · Leachability

(a) PPU is Past Practice Unit.

TABLE 2.1. (contd)

Treat and Close				
Primary Functions Interim Management	**Functions/Activities with Characterization Requirements**	**Process Alternatives**	**Characterization Needs**	**Specific Measurements**
In Place Treatment and Disposal of Tank Waste · Tank Waste	· In Situ Treatment	· Solidification · Immobilization · In Situ Vitrification	· Concentration/Speciation of Hazardous/Radioactive Constituents in Tank Waste (Waste Designation) · Composition of Major Constituents in the Waste · Composition of Constituents That Interfere with Treatment/ Stabilization Processes · Heat Output of Tank Waste · Physical Properties	· Specific Metal Ions and Organic Specifies for EHW Designation Including Radioisotopes, CN^{-1} · Al, Na, OH^{-1}, NO_3^{-1}, NO_2^{-1}, CO_3^{-2}, X^{-1}, Water · Fe, Si, Cr, TOC, Volatile Metals (In Situ) · Specific Heat · Density, TGA/DSC, Viscosity, Penetrometer, Porosity, Hardness, Moisture Content, Solids/Liquid Ratio, Waste Volume
· Tank	· Dome/Void Fill · In Situ Vitrification	· Grout · Gravel Fill	· Heat Output of Tank Waste · Physical Properties	· Specific Heat · Density, TGA/DSC, Viscosity, Penetrometer, Porosity, Hardness, Moisture Content, Solids/Liquid Ratio, Waste Volume
		· In Situ Vitrification	· Composition of Tank Structures	· % Iron, Concrete, Moisture, Organics in Tank Structure
· Soil	· Intrusion Barriers · Treatment Soil Contamination	· Soil Washing · In Situ Immobilize · In Situ Vitrification	· Physical Properties of Soil · Distribution of Contamination in the Soil · Composition of Major Constituents in the Soil · Potentially Volatile Constituents · Soil Characterization	· Porosity, Classification · TRU, Tc, Tritium, Nitrates, Cs · Water, Si, Al, TOC · TOC, Dissolved Soils
· RCRA Past Practice	· In Situ Treatment	· Stabilize · Immobilize · In Situ Vitrification	· Composition of Major Constituents in PPU · Concentration/Speciation of Hazardous/Radioactive Constituents in PPU (Waste Designation) · Potentially Volatile Constituents · Distribution and Concentration of Hazardous/Radioactive Constituents at Closure Site (Waste Designation)	· Iron, Concrete · Specific Metal and Organic Species for EHW Designation Including Radioisotopes · Organics, Moisture · Specific Metal Ions, and Organic Species for EHW Designation Including Radioisotopes, CN^{-1}

TABLE 2.1. (contd)

Treat and Close (contd)				
Primary Functions Interim Management	**Functions/Activities with Characterization Requirements**	**Process Alternatives**	**Characterization Needs**	**Specific Measurements**
Tank Farm Closure · Site Closure	· Characterize Waste Site · Site Restoration		· Regulatory · Physical Properties of Stabilized Tank Waste and Soil Contamination	· Hardness, Leachability · Well Monitoring

lower level of specificity (column 5). The intent of column 5 is to identify what specific physical measurements or chemical analyses are needed to support each process and function within the different management options--this is the ultimate objective of the task. For example, if the alternative is to destroy organics during pretreatment by employing standard thermal and/or oxidative processes, then the key characterization data required are 1) the quantities of organic carbon present; 2) the predominant organic species in the waste; and 3) the presence of elements other than carbon, hydrogen, and oxygen in the organic compounds. Any practical treatment method will be designed to handle the destruction/treatment of broad classes of organic compounds, not discrete species present as minor constituents.

Several assumptions are embodied in Table 2.1. First, from a systems perspective, the emphasis in the retrieve and dispose options is on the range and average concentration of material to be processed, rather than a tank-by-tank inventory. A tank-by-tank inventory will be required for waste designation at the time of tank closure and for alternatives involving in situ treatment of tank waste. Second, if the tank waste is retrieved (as in the current reference case), characterization of any residual waste could be based on analysis of samples of waste retrieved from that tank. Third, identification of a common measurement or analysis need across program elements or remediation alternatives does not imply 1) that the need must be met to the same level of performance or 2) that the same number of tanks or types of tank wastes need to be sampled to meet the need. A fairly safe assumption is that samples will be required for all tanks for the treat in place alternative. Fourth, the assessment addresses measurements required to support technology development for tank waste characterization and process design. The assessment does not address technology required for process monitoring and control. The latter cannot be addressed until user needs are more clearly identified, and most of the data will be derived from the feed tank(s) where waste from several tanks is likely to be stored in holding tanks. Finally, minor anions and cations are assumed to include only those that interfere with the process. The types of anions and cations of concern will vary between remediation alternatives and programs elements. However, similar types of technologies will likely be used to make these measurements.

2.1.3 Summary Observations

At this stage, the needs list is not completely specified. Additional effort is required to provide more definitive performance requirements (i.e., when the data are needed, how often the measurement must be taken, and how good it has to be). These data have yet to be identified by data users, who are still defining their baseline program and requirements. To anticipate more specific characterization data needs, an engineering effort beyond the scope of this study would be required. It may be argued that such an effort is not timely, given the present level of programmatic uncertainty. As additional process alternatives are identified and as engineering and design efforts advance, they can be readily incorporated along with their associated data needs.

Schedules and detection limits have yet to be specified even for needs that are known or can be reliably anticipated. This information is important for technology planning but is not currently available. As the TWRS matures, the framework in Table 2.1 should encourage participants to identify, justify, and further specify their characterization data needs.

In its present form, however, the framework provides some basis for prioritizing characterization needs for technology development by the UST-ID. This can be done by determining what needs are common across system alternatives, functions, and processes. Even at this preliminary stage, certain characterization elements or needs appear to be common to all disposal alternatives (Table 2.2):

- Information on the physical properties of the waste. Physical property measurements, such as viscosity, porosity, hardness, and solubility, are needed to evaluate and design retrieval alternatives; they are also required for addressing unresolved safety questions (USQs) and for evaluating in situ treatment and closure options.

- Data on the moisture content and the percentage of solids/liquids. These measures are needed for retrieval and pretreatment functions within the class of retrieve and dispose alternatives. They are also needed to evaluate and design in-tank treatment options, to resolve USQs, and for interim stabilization.

TABLE 2.2. Measurement

Measurement Needs	Remedial Action Alternati				
	Retrieve and Dispose				
	Retrieval	Pre-treatment	LLW Form Conversion	HLW Form Conversion	Post Retrie Site Cl
Physical Properties of Tank Wastes					
Thermal Conductivity		X			
Viscosity, Temperature, Temperature Dependence of Viscosity	X				
Porosity, Particle Size, Particle Density	X	X			
Hardness, Shear Strength, Compressive Strength	X				
Solubility	X	X			
Abrasiveness	X				
Density	X	X			
% Solids, % Moisture	X	X			
Drainable Liquids, Solid/Liquid Ratio, Liquid Level	X	X			
Heat Content					
Chemical Properties of Tank Wastes					
Chemical Reactivity, Shock Sensitive Compounds	X				
TOC, TIC, Organics, Ferrocyanide		X	X	X	
Composition of Tank Vapors, H_2, N_2O, VOC	X	X			
Major Constituents of Waste: Nitrate, Nitrite, Hydroxide, Sodium, Aluminum, Carbonates	X	X	X	X	
Minor Anions and Cations		X	X	X (Hg, sulfate, phosphate)	
pH, Corrosivity	X	X			
Radiological Properties of Tank Wastes					
Sr, Pu, U, TRU		X		X	
Cs, Tc		X	X		
Total Radiation Levels	X	X	X	X	X
Physical Properties of Final Waste Form					
Sr, Pu, U, TRU					
Cs, Tc					
Radiation Levels					
% Iron, Concrete, Moisture					
Leachability			X	X	X
Heat Content, Specific Heat			X		
Analysis for Hazardous Constituents					
Properties of Soils					
Porosity/Classification					X

Assumptions:
a. Identification of a common measurement or analysis need across program elements or remediation alterna of tank wastes need to be sampled to meet the need.
b. The assessment does not address technology required for process monitoring.
c. Minor anions and cations are assumed to include only those that interfere with the process.

Summary by Remedial Action

...es and Functions						Common Needs		
	Treat and Close		Delay Action					
...al ...ure	Treat in Tank	Closure of Site with Waste in Place	USQ	Waste Storage	Interim Stabilize	Across All 3 Alternatives	Across 3 or More Program Elements for Retrieve and Dispose	Type of Technology Development Required
								In Situ Methods:
	X		X			X		Heated Line Source
	X		X			X		Remote Viscometer
	X		X			X		Acoustic Methods
	X		X			X		Acoustic Wave Guide Fracture Resistant Probe
	X		X			X		Some Development Required
	X							
	X		X		X	X		Neutronics
	X		X		X	X		No Development Required
			X					No Development Required
								In Situ Methods:
	X		X			X		Unknown
	X	X	X			X	X	Remote Laser Techniques Remote Spectroscopy Fiber Optics Laser Diodes
	X	X	X			X		Chemical Sensors, FTIR
	X		X			X	X	No Development Required
	X		X			X	X	Specific Ion Electrodes Remote Spectroscopics
			X					No Development Required
								In Situ Methods:
			X					Neutron Activation w/ In Situ Foils
								No Development Required
			X					Fiber Optic Scintillation, GEA
		X						
		X						
	X	X						
		X						
		X					X	
	X		X					
		X						
							X	
		X	X			X		Unsaturated Flow Analyzer

...ives does not imply 1) that the need must be met to the same level of performance or 2) that the same number of tanks or types

- Composition of tank vapors. Regardless of the remediation alternative, it will be important to characterize (and potentially monitor) flammable concentrations of gasses (e.g., hydrogen or volatile organics), concentrations of inorganic (e.g., hydrogen cyanide acid or ammonia), and organic materials (e.g., acetone or halogenated hydrocarbons).

- Composition and concentration of the major anions and cations, as well as total fissiles, transuranics, gross alpha, beta, and gamma energy content. These are required for evaluating treatment alternatives across the board.

Other characterization needs tend to be dependent on the disposition alternative or process option being considered. In general, for example, the extent of sampling and analysis required to support the development and design of retrieval and post-retrieval activities is less than that needed to support tank waste designation and characterization for in situ waste tank treatment and tank closure. Similarly, the data required to support technology development and process design do not need to be as extensive or precise as that needed for waste designation. In addition, the following needs must be addressed.

- Data on percent solids dissolved in water and acid are of particular importance when considering hydraulic retrieval, sludge washing, and waste separation, but are not crucial for mechanical retrieval and in situ treatment alternatives.

- Detailed analyses for all radionuclides, hazardous constituents, metal cations, and anions are germane for leave alternatives but are of lesser importance for retrieval, pretreatment, and waste form conversion; such measurements are required on the final disposal form after waste form conversion.

- Data on mercury, sulfate, and isotopes of iodine may be required for the design of the vitrification process, but detailed data on minor cations and anions that do not affect or interfere with the process step are not needed.

- Measurements for organics, ferrocyanide, and hydrogen are required to resolve USQs, but may not be crucial for designing retrieval and pretreatment processes. Organic complexant concentrations may have a major impact on the need for organic destruction as a pretreatment option.

A second basis for determining priorities would be to focus on the current TWRS reference alternative. From this perspective, data needs associated with the retrieve and dispose alternatives are more likely drivers for technology development than the more detailed needs of the treat and close alternative (e.g., specific metal ions or organic speciation for Extremely Hazardous Waste [EHW] designation).[a]

2.1.4 Applications

Several purposes are served by gathering and applying these data. One is a check on characterization needs elicited directly from users (Section 2.2). If users are asking for very different characterization data, the drivers for those identified here and those uncovered in interviews must be compared and further evaluated. If the data needs uncovered in the direct user assessments coincide with those identified here, then these needs would appear even more reliable. Such agreement might provide one basis for prioritizing data needs when high levels of uncertainty exist about the relative importance of those needs.

A second application is directly relevant to technology development. Once characterization needs have been defined and can be attributed to a specific process and remediation alternative, the elements of a characterization program plan can be formulated and the technologies required to support the plan can be identified and prioritized. Proposed technology development can be matched against the characterization need to be addressed. If no match is apparent, the proposed technology may be irrelevant to UST characterization requirements. If a match is made, technical experts can judge whether the proposed technology development can satisfy the need.

The functionally driven characterization needs stressed in the preceding analysis do not provide an exclusively useful perspective for guiding technology development efforts. Measurement techniques, sample taking, sample transfer and preparation, data manipulation and verification, and in situ instrumentation are important elements of an overall characterization system. Useful technologies may either provide the measurement directly or support a

(a) Presently Washington State has permitted one site for disposal of EHW (RW 70:105). Measurements will be required to determine the disposal status of final waste forms.

characterization system that provides the final measurement. The UST-ID may select to support either or both types. This systems engineering assessment is particularly useful for identifying specific data needs; more "global" or "enabling" characterization needs are addressed in the following section.

2.2 DIRECT USER ASSESSMENT

The previous section described characterization needs based on a functional analysis of the Hanford TWRS. This section describes the UST technology development needs as assessed by characterization data users at Hanford and at other DOE sites.

2.2.1 Objective

The objective for this direct user assessment is to describe the demand for characterization data from the perspective of the programs who will use that data to support their decisions and operations. This assessment focused on Hanford; however, the Fernald, Idaho Falls, Oak Ridge, and Savannah River sites were also included.

2.2.2 Approach

The initial approach for assessing characterization data needs was to query the user organizations for decisions and/or requirements that depended on characterization data. This information was elicited initially from user organizations through an interview protocol that focused first on key decisions and requirements faced by the program and then elicited descriptions of characterization data needed to support those decisions and requirements. The interview protocol is described below:

- What key decisions or uncertainties must your program address in the next (1 to 3 years, 3 to 5 years, 5 to 10 years, 10 to 30 years)? What requirements (regulatory or other) does your program need to demonstrate compliance with (today, anticipate for the next 1 to 3 years, 3 to 5 years, 5 to 10 years, 10 to 30 years)? (Focus on those decisions or requirements that require characterization data.)
- What kinds of characterization data will support making the decision or meeting the requirement? List specific, measurable attributes (e.g., analytes, physical characteristics, etc.); the degree

of accuracy required or anticipated; and state when, relevant to the decision or regulation, you require that data.

- If you know of any, describe the tools, instruments, and/or devices that you believe would allow the characterization data to be obtained. Include any tank access, in situ, transportation, analytical, and other requirements for deploying these instruments.

- Given the decision/requirements listed, how often do you anticipate needing this measure?

- Are there any additional (i.e., prerequisite, concurrent, or subsequent) decisions that depend on this measure? List these and describe their relationship to the key decision already described. Identify any additional characterization data required to support these.

This approach proved inadequate. The user organizations were unable to assess their needs in this manner, as they had difficulty identifying key decisions and were generally unable to move from the decisions they could identify to characterization needs.

A revised approach was developed that began with previously identified characterization needs, i.e., a strawman needs list, summarized from existing characterization literature (Buck et al. 1991; Morris 1991; WHC 1992; Freeburg 1991; Opitz 1991), and sought to confirm or refute these needs. Additional qualifiers were requested to link each need to a specific driver. Theoretically, this would provide a basis for subsequent prioritization of the needs for technology development selection. The revised "needs driven" template is indicated by the subheadings in Table 2.3.

A strawman list was provided to each Hanford user organization in both the workshops and one-on-one sessions. Users were encouraged to eliminate irrelevant needs and to add needs that were missing from these lists.

With the exception of the retrieval program, the Hanford interviews were carried out with the managers or relevant staff associated with safety, pretreatment, low-level waste treatment, and high-level waste treatment. The retrieval assessment was derived from discussions with the analytical reporting and evaluation organization and was reviewed by the TWRS technology

TABLE 2.3. Direct Assessment of Waste Characterization Needs Requiring Technology Development

Data Need	Technical Issue	Programmatic Driver	Impact If Not Met[a]	Time Frame[b]	Applicable EM-30 Program
Noble Metals Ru, Rh, Pd	Hanford Analytical Method Development; Speciation	Technical Risk To HWVP Melter: Hydrogen Generation; Insoluble Precipitation In Melter; Feed Processability	Operations: Process Design (HWVP Feed Design, Melter Electrode Short Circuit); Regulatory	0-2 Years	Hanford HWVP
Iodine-129	Sample Preparation Problem	Design Of HWVP Offgas Abatement System	Schedule; Regulatory: Permit Requirements Operations: Process/Plant Development--Overdesigned HWVP Offgas System, High Cost	0-2 Years	Hanford HWVP
Mercury	Detection In Hot Samples	Vitrification Process Development	Schedule; Regulatory: Permit Requirements	0-2 Years	Hanford HWVP
Cyanide/ Ferrocyanide	Detection In Hot Samples		Safety; Regulatory: Permit Requirements	0-2 Years	Hanford Pre-treatment, HWVP; Waste Tank Safety
Organic Speciation	Speciation Specific Compound Identification	Vitrification Process Development For Various Waste Types	Regulatory: Permit Requirements-CAA, DW Regulations	0-2 Years	Hanford Pre-treatment, HWVP, Grout; Waste Tank Safety
Complete Dissolution Of Sample Material	Ability To Completely Dissolve Solids In Waste For Complete Analysis Of Constituents/Material Balance	Feed Processability: Identification Of Dissolved And Undissolved Solids	Operations: Process Design Data	0-2 Years	Hanford Pre-treatment; HWVP
Ni-63 Zr-93	Analytical Method Development	Waste Form Qualification	Regulatory: Regulatory Requirements	Before HWVP Feed Pretreatment	Hanford HWVP
Penetration Resistance	In Situ Measurement Method	Retrieval System Design: Need Accurate Range Of Physical Characteristics	Operations: Inadequate Retrieval Method Development	0-2 Years	Hanford Retrieval

TABLE 2.3. (contd)

Data Need	Technical Issue	Programmatic Driver	Impact If Not Met[(a)]	Time Frame[(b)]	Applicable EM-30 Program
Shear Strength	In Situ Measurement Method	Retrieval System Design: Need Accurate Range Of Physical Characteristics	Operations: Inadequate Retrieval Method Development	0-2 Years	Hanford Retrieval
Gross Abrasiveness	In Situ Measurement Method	Retrieval System Design: Need Accurate Range Of Physical Characteristics	Operations: Inadequate Retrieval Method Development	0-2 Years	Hanford Retrieval
Tensile Strength	In Situ Measurement Method	Retrieval System Design: Need Accurate Range Of Physical Characteristics	Operations: Inadequate Retrieval Method Development	0-2 Years	Hanford Retrieval
Settling Rates	In Situ Measurement Method	Retrieval System Design: Need Accurate Range Of Physical Characteristics	Operations: Inadequate Retrieval Method Development	0-2 Years	Hanford Retrieval
Thermophysical Properties (Specific Heat, Thermal Conductivity, Etc.)	In Situ Measurement Method	Retrieval System Design: Need Accurate Range Of Physical Characteristics	Operations: Inadequate Retrieval Method Development	0-2 Years	Hanford Retrieval
Representative Tank Waste Sampling	• Reticulated Arm Sampler, Easily Deconned, Collects Multiple Samples Vertically And Laterally Inside Tanks W/ Restricted Access (Opening Size)	Remediation Design Or Process Operation: Improved Representative Sampling	Operations: Decisions Are Currently Made With Reservations Based On Wide Confidence Intervals		Oak Ridge Site
			Operations: • Design Around Shortcomings • Complexity Of Operation Increased • Operations Slowdown • Intermediate Storage Areas And Tanks Must Be Constructed	0-2 Years	Fernald Site

TABLE 2.3. (contd)

Data Need	Technical Issue	Programmatic Driver	Impact If Not Met[a]	Time Frame[b]	Applicable EM-30 Program
Tank Vapor Space Sampling	• Routine Monitoring And Characterization Of Dome Space Vapor	Limited Information Received By Present Hanford Core Sample Methodology On The Following: • Flammable Gas Concentration (Hydrogen And/Or Volatile Organics) • Toxic Concentrations Of Inorganic Gasses (Hydrocyanic Acid, Cyanogen, Or Ammonia) • Toxic Or Hazardous Concentrations Of Organic Materials (Acetone Or Halogenated Hydrocarbons) • Quantitative Measurement Of Semi-volatile Organic Compounds (Potential For Fueling A Ferrocyanide Containing NO_2-NO_3 Radioactive Waste Reaction)	Safety: Threatens Safe Conduct Of Tank Operations	Prior To Intrusive Activities In Hanford "Watch List" Tanks	Hanford Waste Tank Safety
Tank Structure Sampling	Remote Structural Analysis	Improved Remediation Design Or Process Operation	Operations: • Currently Design Around Shortcomings • Operation Complexity Increased • Operations Slowdown • Intermediate Storage Areas And Tanks Must Be Constructed	June 1994	Savannah River Site Fernald Site

TABLE 2.3. (contd)

Data Need	Technical Issue	Programmatic Driver	Impact If Not Met(a)	Time Frame(b)	Applicable EM-30 Program
Volatile Organic Sample Collection	Improved Technique-both In Situ And Ex Situ-US EPA Accepted Methodology	Meet Regulatory Requirements	Regulatory: e.g., EPA Requirements		Oak Ridge Site
Sample Containment And Shielding	Improved Containment And Shielding Of Current Samples During Sample Retrieval And Transport	ALARA Tank Sample Retrieval -- Preservation Of Sample Integrity	Decisions Are Currently Made With Reservations Based On Wide Confidence Intervals		Oak Ridge Site
	Field Sample Preservation Methods	Improved Remediation Design Or Process Operation. Maintain Sample Purity (i.e., Phase Changes During Sampling, NOx, Change In Organics, Hydrogen, Nitrogen)	Decisions Are Currently Made With Reservations Based On Wide Confidence Intervals		Oak Ridge Site
Corrosive Damage To Tank Structure	• Ability To Measure Tank Structural Integrity And/Or Corrosive Damage To Tank • High Resolution Imaging For Better Corrosion Detection • NDE Equipment • Remote Structural Analysis • Repetitive Testing Of Tank Strength/ Stability	Improved Remediation Design Or Process Operation	Safety: Questionable Tank Integrity • Design Around Shortcomings • Complexity Of Operation Increased • Operations Slowdown • Intermediate Storage Areas And Tanks Must Be Constructed	Immediate	Savannah River Site Idaho Falls Site Fernald Site
Chemical Composition, Acidity, And pH Of Sludge	Sludge Sampling And Displacement Equipment Analytical Methods	Improved Remediation Design Or Process Operation	Safety		Idaho Falls Site

TABLE 2.3. (contd)

Data Need	Technical Issue	Programmatic Driver	Impact If Not Met[a]	Time Frame[b]	Applicable EM-30 Program
Tank Decontamination And Decommissioning Equipment		Improved Remediation Design Or Process Operation	Safety Operations: Efficiency Of Remediation Process		Idaho Falls Site Hanford Site
Faster Sample Turnaround	In Situ And/Or Online Measurement And Analysis	Improved Remediation Design Or Process Operation	Operations: · Design Around Shortcomings · Complexity Of Operation Increased · Operations Slowdown · Intermediate Storage Areas And Tanks Must Be Constructed	June 1994	Fernald Site

(a) This column is described in terms of four classes of impact: Safety, Schedule, Regulatory, or Operations (referring to impact on the effectiveness of process operations or design). These impacts are typically highly correlated; the table indicates those that users felt were of primary concern.
(b) Blank cells indicate that this information was not available.

Working Group WHC co-chair. Closure personnel were not interviewed because, compared to other programs, their characterization needs were longer term and their requirements less well defined programmatically. However, those data should be added to this assessment at the earliest possible date; as stated by other data users, the definition of contents left in the tanks will affect other aspects of remediation.

Information for the remaining DOE sites was obtained by telephone from individuals at each site. These individuals were identified from participants at the Underground Storage Tank Waste Characterization Needs Assessment Workshop; not all of these individuals had programmatic responsibility but each was familiar with the most prominent characterization data and technology development needs.

Results from these sessions are provided in Table 2.3. In contrast to the logic for identifying data needs in the systems engineering assessment, this assessment begins with a need and then indicates its driver(s). Additional qualifiers are provided in the columns of Table 2.3.

Column 1 describes the specific characterization Data Need. This column records UST waste data (i.e., measurement, specie, property, or characteristic) for which "technology development is required to allow your program to carry out its mission." Column 2 (Technical Issue) describes the technical issue(s) relevant to technology development. Column 3 (Programmatic Driver) describes the program requirement for the need (what decision is supported or requirement satisfied with these data). The interviewer then asked users to describe what happens to the program if the need is not met; how is the program's mission hindered? Their answers are recorded in column 4 (Impact) and are classified as Safety, Schedule, Regulatory, or Operations (efficiency and effectiveness). Column 5 (Time Frame) shows when (0 to 2 years, 3 to 5 years, or 5 to 10 years) the need must be met to benefit the program mission; when available, more descriptive information is provided. Finally, in column 6 (Applicable Program) the DOE site(s) and Hanford user organization(s) that recorded each need are shown, providing an indicator of how common the need is across the DOE complex.

2.2.3 Summary Observations

The data qualifiers in the table (driver, impact, time frame, and urgency/benefit) were elicited to discriminate between competing needs. In fact, many of these qualifying variables do not adequately discriminate among needs. For example, time frame data are either relatively similar or absent. Those that do discriminate are helpful for prioritizing within but not across program needs. For example, the impact qualifier (column 4) was added to allow users to indicate what would happen if they did not get the data they requested. The nature of adverse impacts provides a possible basis for setting technology development priorities; for example, safety impacts may indicate a higher priority for technology development investments than regulatory requirements (that might be negotiated) or operating inefficiencies (that could be designed around). At Hanford, the Hanford Waste Vitrification Plant (HWVP) notes that it cannot get a state permit to operate the facility without the ability to determine cyanide and ferrocyanide in hot samples. To ensure timely implementation of the system, this appears to require technology development. Cyanide and ferrocyanide may also present a safety problem. The same program also noted a need for data on Noble Metals, Ru, Rh, and Pd in order to reduce the operating risk of the HWVP melter. This may be a relatively lower priority need than the cyanide/ferrocyanide data. Again, however, it is impossible to determine relative priorities, system wide, from individual program impact assessments. At a minimum, this requires integrated scheduling information (e.g., when are retrieval characterization data needed relative to the HWVP), which is only now being developed at Hanford and will not be available for comparison to other sites for one to two years.

A last basis for prioritization might be commonality. Column 6 provides some indication of how common a data need is across programs and sites. For example, information on corrosive damage to tank structure was requested by three sites (Savannah River, Idaho Falls, and Fernald). Although this need was not explicitly identified at Hanford, it is closely related to assessing the tank wall integrity associated with the retrieval program. This then appears to be a fairly common need and hence may require technology development.

If questions were not specifically answered, either because they were irrelevant or because users could not provide the relevant information, the associated column cell was left blank (e.g., for Time Frame) or the general information available was recorded (e.g., "remediation process design or operation" for Programmatic Driver). This reflects an apparent inability of programs to clearly justify their characterization data needs, which is one of the most striking and perhaps most important observations of this work.

At Hanford, characterization needs identified by two or more programs include

- determination of cyanide and ferrocyanide concentrations
- speciation of organics
- complete dissolution of sample material.

Needs identified by two or more sites include

- better, more representative sampling methods
- tank structure sampling
- corrosive damage indicators
- tank decontamination and decommissioning.

2.2.4 Applications

The information provided through the direct assessment of user needs is a useful indicator of how programs judge their unfulfilled characterization data needs. Strictly speaking, if the UST-ID developed technologies to address these needs, it would be meeting a primary mission to support EM-30 and EM-40 programs. As site operations are further defined and new processes are identified, designed, and tested, the characterization needs recorded here will need to be updated.

One limitation of the direct user assessment is that the list of needs is based on the expert judgment of one to three individuals per program or site. The individuals interviewed were selected, where possible, as those most knowledgeable about their areas. It is possible, however, that different experts would provide different assessments, either in terms of different needs or with respect to the needs qualifiers (e.g., time frame or impact).

Iterative interviews within a given program, where each additional expert refines the previously elicited needs statements, would serve to reduce this limitation. A sufficient number of knowledgeable staff or managers were not available for this process during the time frame for this study. A second approach to dealing with expert bias is to concentrate on needs common across experts; this increases the reliability of a stated need.

Although Hanford needs were obtained from experts closely associated with each of the TWRS program elements, experts at other sites may have been less familiar with specific programs. Future work should attempt to obtain characterization needs from users with more specific knowledge of the needs at each of these sites.

2.3 NEEDS ASSESSMENT SUMMARY

Section 2.1 identified characterization data needs based on an engineering assessment of the Hanford TWRS. Section 2.2 listed needs that users (primarily programs within TWRS) perceive are not being adequately met by the current characterization program. Table 2.4 lists the needs from these two assessments and adds, in a third column, a general UST characterization need category derived from TWRS and HMP workshops. Only needs from the engineering evaluation and TWRS or HMP workshops that were judged, by workshop participants and technical reviewers of this report, to require technology development are included in the table. Needs from columns 1 and 2 are mapped into general need categories listed in column 3. They include

- analytical methods development
- in situ measurement of physical properties
- hot cell segment scanning
- process monitoring and control

TABLE 2.4. Summary, Comparison, and Consolidation of Characterization Needs

Engineering Assessment	Direct Assessment	Characterization Need Category[a]
Ferrocyanide And Organic Distribution And Concentration Organics - In Aqueous And Solids Chem Reactivity Organic Carbon (TOC) And Inorganic (TIC) Minor Anions And Cations; Species That Interfere With A Process Treatment (Concentration Of Ions) Chemical Reactivity; Shock Sensitive Compounds Major Constituents Of Waste	Noble Metals - Ru, Rh, Pd Method Development; Speciation Iodine-129 (And Other Isotopes) Better Sample Prep Method Hg (Mercury) Detection In Hot Samples Organics Speciation & Compounds Completely Dissolve Solids Better Constituent/Material Balance Results Ni-63, Zr-93 Method Development Sludge Chem. Comp., Acidity & pH Method Development, Equipment	Analytical Methods To Support Reference Case
Physical Properties Viscosity (& Temp. Dependency) Liquid Level, % Solids, Shear Strength, Particle Size, Abrasiveness, Solubility, Density, % Moisture, Drainable Liquids, Liquid Level Physical Properties Density 10-20% Change In Properties (Stratification) pH Leachability; Final Waste Form Leachability, Heat Content, Radiation Levels, % Iron, Concrete, Moisture) Temperature Profile: Rheological, Thermal Conductivity, pH Acidity, Solids/Liquids Ratio After Sludge Wash	Penetration Resistance In Situ Method Shear Strength In Situ Method Gross Abrasiveness In Situ Method Tensile Strength In Situ Method Settling Rates In Situ Method Thermophysical Properties (Sp Heat, Thermal Cond.) In Situ Method; Small Samples	In Situ Measurement Of Physical Properties
		Hot Cell Segment Scanning For Chemicals And Radionuclides
		Process Monitoring And Control
Soil Porosity, Classification		Soils Characterization
	Corrosive Damage To Tank Structure Sampling Tank Samples -NDE Methods -High Resolution Imaging	Tank Integrity Evaluations

TABLE 2.4. (contd)

Engineering Assessment	Direct Assessment	Characterization Need Category[(a)]
Heel Characteristics Waste Stratification	Tank Waste Sampling Methods, Better Sample Retrieval, Vertical And Lateral Arm Sampling In Limited Opening VOC Sample Collection (Improved In Situ And Ex Situ Method) Tank Vapor Space Sampling Sample Containment & Shielding Sample Preservation Improve Field Sample Purity Sludge Chem. Comp., Acidity & pH Method Development, Equipment	Representative Samples; Spatially Varied Samples; Samples Of Solids, Liquids, Vapors
	Faster (Results) Sample Turn-around	Increased Throughput
		Data Management System (LIMS)
	In Situ/On-Line Method & Analysis	In Situ Measurement Of Chemicals
TRU, Sr, Pu, U, Cs, Tc, Total Radiation Levels		In Situ Measurement Of Radiological Properties
	Tank Decommissioning And Decontamination	Decommissioning And Decontamination

(a) Derived primarily from needs identified within TWRS and HMP workshops and documents

- characterization of soils around tank
- tank integrity evaluations
- representative sampling, samplers, and sampler deployment
- increased throughput
- data management
- in situ measurement of chemical constituents
- in situ measurement of radiological properties
- tank decontamination and decommissioning.

Within a category, specific mentions of a need from each source were listed in the appropriate column. The most commonly mentioned characterization data needs were physical properties, tank sampling methods (particularly for solids, liquids, and gas vapors), and tank structural analysis. Specific analytes, especially ferrocyanide and organics, were identified in both the engineering assessment and the direct user assessment. In situ or on-line analytical methods, specifically hot cell segment scanning for chemicals and radiological properties, appear in the direct user, HMP Science and Technology, and TWRS UST needs assessments. Since the engineering assessment was the only task that considered tank closure here, that soils contamination is mentioned there only is not surprising.

While this summary provides a reasonable overview of characterization needs, it may obscure important differences in requirements associated with similar measures for different functions. For example, the criteria to provide mercury data to support the design of an off-gas scrubber for a glass melter are significantly different than the mercury data needed to support in situ treatment and closure of a specific tank. This point is not reflected in the results of the direct user assessment and is indicated but not quantified in the results of the systems engineering approach.

3.0 TECHNOLOGY RESPONSE ASSESSMENT

3.1 OBJECTIVES

The objectives of this chapter are to assess the availability of technology for characterizing UST waste (identifying possible technology gaps in the system), describe the system requirements associated with general categories of technology development, and use available information to generate possible funding options and criteria for evaluating the possible success of those options.

3.2 APPROACH

In Chapter 2.0 (Table 2.4) characterization needs based on a systems engineering assessment and a direct user assessment were summarized and supplemented by more global, or enabling, characterization program needs derived from TWRS and HMP documents and workshops. Table 2.4 consolidated and then compared results of different needs assessments to identify the most fundamental, or potentially reliable, set and to provide an organizing framework for specific data needs. That framework provides the basis for identifying classes of technology development options that must meet system requirements.

It is useful here to define system requirements as distinct from functional requirements. Functional requirements are the detailed specifications (e.g., sizing, allowable weight, radiation resistance) that ensure successful deployment. System requirements are the broader set of capabilities (e.g., data validation methods, decontamination apparatus) that ensure functions will perform together in a complete system, and that the system can meet its mission. For example, an instrument that successfully delivers in situ measurements would be useless if there were no means for translating its signals into reliable conclusions.

Technology development should anticipate and optimize a system's performance requirements, as well as the functional performance of its components (Meridith and Mantel 1989). This work defines preliminary system requirements. (Note that some functional requirements have already been developed by the UST-ID.) Detailed functional requirements must be determined through close collaboration between the EM-30 or EM-40 user organization and EM-50. Development of this information is important because it allows technology evaluators to better define needs and determine how completely a TTP meets these needs. Such requirements guide the proposers in their TTP development efforts.

Table 3.1 takes the next step in the progression from specific data needs to potential technology responses. Specific needs, derived directly from Tables 2.1 (Systems Engineering Assessment) and 2.3 (Direct User Assessment), are listed in the left-hand column. Needs are ordered as they appear in the original tables. Only needs requiring technology development are listed. A general characterization need category, derived from TWRS and HMP workshops, is shown in the middle column. These categories were developed by EM-30 and EM-50 participants in TWRS workshops to differentiate technology development having different system requirements. These categories are used in subsequent tables to group technology responses for additional evaluation. The right-hand column then lists promising technology development for addressing each need.

Technology responses were identified by reviewing currently funded TTPs, interviewing PIs, searching library literature and environmental market studies, and placing calls to relevant private industry sources. Detailed results are presented in Section 3.3. A first step toward evaluating how completely these technologies meet the needs of the user is to review the system and functional requirements for each category. This information is provided in Section 3.3.1, which focuses on system requirements but suggests sources for relevant functional requirements. A distinct type of "system requirements" schedule for development is review in Section 3.3.2. Descriptions of these requirements are not complete; however, this did not hinder the study due to the limited number of existing TTPs in the characterization area.

Section 3.3.3 discusses the match between specific needs, system and functional requirements, and technology development responses. Each need is

TABLE 3.1. Characterization Technology Needs Categorization

Data Needs	Characterization Need Category	Technology Development
Noble Metals Ru, Rh, Pd[a]	Method Development	ICP-MS Laser Ablation/ICP-MS
Iodine-129[a]	Method Development	Microwave Dissolution
Mercury[a]	Method Development	Cold Vapor Atomic Absorbance (CVAA)
Cyanide/Ferrocyanide[a]	Method Development	Ion Chromatography, Remote Laser Techniques, Remote Spectroscopy
Organic Speciation[a]	Method Development	Remote Spectroscopy
Complete Dissolution of Sample Material[a]	Method Development	Microwave Dissolution, Laser Ablation
Ni-63, Zr-93[a]	Method Development	ICP/MS
Penetration Resistance[a]	In Situ Measurement of Physical Properties	Shear Vane, Fracture Resistant Probe
Shear Strength[a]	In Situ Measurement of Physical Properties	Fracture Resistant Probe, Sludge Tensiometer
Gross Abrasiveness[a]	In Situ Measurement of Physical Properties	Not Known
Tensile Strength[a]	In Situ Measurement of Physical Properties	Fracture Resistant Probe, Sludge Tensiometer
Settling Rates[a]	Representative Samples, Samplers, and Deployment	Fluidized Bed Sampler
Thermal Conductivity, Specific Heat[a]	Representative Samples, Samplers, and Deployment	Heated Line Source

TABLE 3.1. (contd)

Data Needs	Characterization Need Category	Technology Development
Tank Waste Sampling[a]	Representative Samples, Samplers, and Deployment	Robotic Mole, Lightweight Utility Arm, End Affectors, Advanced Core Sampling Techniques, Hard Waste Sampler, Tank Heat Sampler
Tank Vapor Space Sampling[a]	Representative Samples, Samplers, and Deployment	Vapor Space Samplers
Tank Structure Sampling[a]	Tank Structural Analysis	Tank Sampler
VOC Sample Collection[a]	Representative Samples, Samplers, and Deployment	VOC Sampler
Sample Containment and Shielding[a]	Representative Samples, Samplers, and Deployment	Field Preservation Methods, Sample Containment and Shielding
Corrosive Damage to Tank Structure[a]	Tank Structural Analysis	Optical Viewing, Leak Detection, Delivery System for NDE, viewing equipment
Chemical Composition, Acidity, and pH of Sludge[a]	Representative Samples, Samplers, and Deployment	Sludge Sampler
Tank Decommissioning and Decontamination[a]	Tank Decommissioning and Decontamination	Long-Range Alpha
Faster Sample Turnaround[a]	Increased Throughput	Offsite Laboratory Services, Laboratory Upgrades, Shipping Containers, Laboratory Automation
Sr, Pu, U, TRU[a]	In Situ Measurement of Radiological Properties	Neutron Activation with In Situ Foils
Total Radiation Levels[a]	In Situ Measurement of Radiological Properties	GEA/Low-Energy GEA, Fiber Optic Scintillation

TABLE 3.1. (contd)

Data Needs	Characterization Need Category	Technology Development
Porosity, Classification of Soils[a]	Characterization of Soils Around Tanks	Unsaturated Flow Analyzer, Vadose Zone Monitoring
Not Identified	Process Monitoring and Control	Low-Energy GEA/GEA, Long-Range Alpha, Fiber Optics, Leak Detection, Flammable Gas Detection
Not Identified	Data Management	Laboratory Information Management System, Chemometrics
Not Identified	Hot Cell Segment Scanning	Laser and Radiological Scanning Techniques
Viscosity, Temperature, Temperature Dependance of Viscosity[b]	In Situ Measurement of Physical Properties	Remote Viscometer, Acoustic Methods
% Solids, % Moisture[b]	In Situ Measurement of Physical Properties	Acoustic Methods, Neutronics
Porosity, Particle Size, Particle Density[b]	In Situ Measurement of Physical Properties	Acoustic Methods
Chemical Reactivity, Shock Sensitivity[b]	In Situ Measurement of Chemical Constituents	Needs to be Determined
TOC, TIC, Organics[b]	In Situ Measurement of Chemical Constituents	Remote Spectroscopy, Chemical Microsensors, Remote Laser Techniques, Fiber Optics, Laser Diodes
Composition of Tank Vapors[b]	In Situ Measurement of Chemical Constituents	Remote Spectroscopies Chemical Microsensors, Thin Film Resonators
Minor Anions and Cations[b]	In Situ Measurement of Chemical Constituents	Selective Ion Electrodes

TABLE 3.1. (contd)

Data Needs	Characterization Need Category	Technology Development
Major Constituents of Tank Wastes[b]	Representative Samples, Samplers, and Sample Deployment	Laser Ablation ICP/MS Remote Spectroscopy

(a) Derived from both Table 2.1 (Systems Engineering Assessment) and Table 2.3 (Direct User Assessment).
(b) Derived from Table 2.1 only (Systems Engineering Assessment).

described in terms of the funding/deployment status of known relevant and current technology development at DOE facilities, DOE national laboratories, and private industry/universities.

Finally, a summary of possible technology gaps and development issues is provided in Section 3.3.4. A gap defined by a technology development need is not satisfactorily addressed within EM-50. These gaps represent areas that EM-50 might consider for possible funding.

3.3 OBSERVATIONS

3.3.1 Characterization System Requirements

More detailed definitions and system requirements for each need category presented in Section 2.3 are discussed below. They should not be considered complete. The purpose of including them is to illustrate the type of information that is needed to evaluate how completely or effectively a technology development activity will meet the user's needs, or what additional development may be required. However, the requirements are not considered complete. Activities are currently being funded within DOE to more completely capture this information. Once a technology is seriously considered for funding, functional requirements should be elicited in order to better determine whether the technology can meet specifications. In addition, functional requirements for tank environments have been published by the UST-ID (WHC 1992), including detailed data on the 332 USTs distributed among the five participant sites (e.g., waste type, tank leakage characteristics, and chemical and radiological characteristics). This document (WHC 1992) is a valuable adjunct to this section because it provides preliminary data on system requirements as well as functional requirements.

In Situ Measurement of Physical Properties

Recent guidance states that in situ technologies are most critical for measurements where the representativeness of the sample is irreversibly changed if samples are removed from the tank.[a] Laboratory equipment is in place at Hanford to measure physical properties (although not enough to meet demands), and existing technology in the laboratory could potentially be deployed in a field laboratory. However, most laboratory methods require that the sample be modified prior to measurement, which reduces the validity of the measurement.[b]

System requirements listed in WHC (1990) include the following:

- in situ probes
- ability to take point measurements in situ
- ability to be deployed remotely
- minimal in-tank preparation before equipment can be used
- minimal time required for equipment to yield satisfactory results.
- ability to validate results
- low cost for equipment.

(a) In situ physical measurements include physical property measurements needed particularly to support retrieval, system design, waste designation, and treatment process design. The types of physical properties necessary to choose and size appropriate retrieval equipment for retrieving waste from Hanford single-shell tanks (SSTs) were reviewed in an engineering study (WHC 1990). That study discusses required measurements and assesses the status of available methods to acquire the measurements.
(b) Information obtained from the "Characterization Technology Workshop," held in Richland, Washington, on September 3, 9, and 10, 1992.

Hot Cell Segment Scanning

Hot cell segment scanning allows programs to determine the "3-Dimensional" distribution of contaminants. Hot cell scanning systems might reduce the hot cell work load if samples can be preselected for additional analysis. According to onsite experts (Strong 1992), system requirements for hot cell scanning include:

- ability to scan for both chemical and radiological measurements
- availability of data interpretation software
- visual data display
- data and sample archiving capability.

Process Monitoring and Control

Process monitoring and control includes technologies required to ensure safe, effective operation of retrieval and treatment operations. Typical instrumentation requirements for production operations are listed below. These are functional specifications characteristic of equipment required to support process applications, such as:

- user-friendly calibration
- rugged design capable of high-quality measurements
- suitable for deployment in field conditions
- operable by a skilled technician
- low cost.

Characterization of Soils Around Tank

Characterization of soils around tanks is needed to support tank closure. System requirements have not been defined. Some obvious system requirements for technologies that have been described by characterization program staff at WHC include the following:

- minimal disturbance of soils around tank
- ability to detect radioactive and chemical constituents to depths of 150 ft

- ability to simulate or predict contaminant movement for long periods into the future (experts disagree about what that period should be, but it ranges from hundreds to thousands of years)
- ability to validate the measures.

Tank Integrity Evaluations

These evaluations include the ability to assess both existing and potential leaks as well as structural weaknesses that could lead to serious problems during retrieval or in-tank treatment. The basic system requirements include the following:

- ability to deploy NDE methods to inspect tank liner integrity[a]
- availability of sampling methods to assess physical sturdiness of tank structure (e.g., tank dome, tank liner, tank penetrations).[b]

Functional requirements for tank structural integrity are also described in the UST-ID technology needs statements.[c]

Representative Sampling, Samplers, and Sampler Deployment

The need at Fernald, Oak Ridge and Hanford is to obtain representative samples from multiple spatial locations within the tank. The types of wastes to be sampled include solids, liquids and vapors (both subsurface and in vapor space).

The system requirements to meet this need include the ability to:

- get out from underneath the riser
- have extrusion processes that do not distort the sample
- maintain the temperature, pressure, and other properties of the sample once it is removed from the tanks

---

(a) Pacific Northwest Laboratory. March 1992. Robotic Needs Assessment. Draft Report. Submitted to UST-ID in response to TTP RL321208.

(b) Tank Waste Remediation System (TWRS) National Workshop. June 29, 30, and July 1, 1992. Draft Proceedings of the "Retrieval Working Group." Westinghouse Hanford Company, Richland, Washington.

(c) UST-ID. March 1992. "Technology Needs Statements." Available from the UST-ID Coordinator at Westinghouse Hanford Company.

- obtain accurate vapor samples
- accurately place sampler
- retain representativeness of sample in transit and in the hot cell
- ensure that waste is contained at all times.

Increased Throughput

Technology to increase the throughput of waste characterization activities is needed at both Hanford and Fernald. The current Hanford plan assumes minimal characterization support from non-Hanford laboratories (WHC 1992); however, system requirements for offsite laboratories include the following:[a]

- ability to handle radioactive samples
- hot cell space
- standards program for waste material, synthetic or real
- ability to accept and transport radioactive samples
- waste disposal capabilities.[b]

System requirements that must be met by sites wishing to use these services include the following:

- sample containment and shielding during transport
- licensed shipping containers.

Laboratory automation might increase throughput; however, efforts are needed to identify the routine processes that should be automated.[c]

(a) System requirements are being defined by Curtis Stoup of Westinghouse Hanford Company.
(b) Atwood, J. M. July 1992. "Use of Alternative DOE Hot Cell and Laboratory Facilities in Support of Hanford Tank Waste Characterization." Correspondence No. A2049598 R1. Letter to J. R. Hunter, DOE Richland Field Office, Richland, Washington.
(c) Information obtained from the "Characterization Technology Workshop," held in Richland, Washington, on September 3, 9, and 10, 1992.

Data Management

Data management tools are the computational and procedural capabilities needed to track the vast numbers of samples and measurements that will be needed. Data management systems are in use in many laboratories. There are no standard systems, though some types of systems are more widely used. System requirements include the following:

- local area networks (LAN) access
- system responsive to onsite user needs
- user-friendly software.

The emphasis at DOE sites will include data gathering from appropriate sources and efforts to make software available and operational. Chemometrics is an essential effort to identify all the purposes for which the measurement of one analyte can be used and to ensure all possible information is obtained from signals and a combination of signals.

In Situ Measurement of Chemical Constituents

The "Technology Needs Statements"[a] contain definitions and information concerning requirements for in situ chemical characterization of waste tanks. System requirements for in situ measurements discussed there and in other sources include the following:

- availability of technology for placing detectors into a tank
- existing waste standards
- complete operator documentation prior to demonstration
- an understanding of matrix effects for DOE waste streams (important for spectroscopic techniques)
- ability of instrument to tolerate and be maintained in high radiation environment (i.e., optical fibers sensors may darken in the presence of radiation)
- ability to calibrate instruments.

(a) UST-ID. March 1992. "Technology Needs Statements." Available from the UST-ID coordinator at Westinghouse Hanford Company.

The underlying assumption for technology development in this area is that the regulator can be convinced that such measurements provide equivalent or superior data to support regulatory decisions, or that the data provide significant supplement core samples.

Several onsite experts have suggested that the hot cell and/or mobile laboratories can be the proving ground for later in-tank deployment. Hot cell deployment will be more timely and cost effective than going directly into a tank. Hot cell validation studies will reduce permitting concerns when the instrument is deployed into the tank. These same experts caution that need for in situ measurements should be carefully balanced against other alternatives. The difficulty in obtaining approvals for deployment must be considered. Today, any entry or modification to the tanks takes many months for approvals and may severely limit accessibility to in-tank instrumentation.[a]

In Situ Measurement of Radiological Properties

The "Technology Needs Statements" contain definitions and information concerning requirements for in situ radiological characterization.[b] System requirements for in situ chemical measurements discussed above should also be considered. Hanford should be considered as only one of many sources of technology for other DOE sites, but a demanding test bed in the area of radiological measurements. Technology transfer across sites may be the prime focus for this need.

Tank Decommissioning and Decontamination (D&D)

Measurement technology for tank D&D is needed to verify that tank structures and hardware are decontaminated to acceptable levels. System requirements have not been defined.

(a) Tank Waste Remediation System (TWRS) National Workshop. June 29, 30, and July 1, 1992. Draft Proceedings of the Characterization Working Group. Westinghouse Hanford Company, Richland, Washington.

(b) UST-ID. March 1992. "Technology Needs Statements." Available from the UST-ID coordinator at Westinghouse Hanford Company.

3.3.2 Time Frame for Resolving Needs

Most of the technology development listed in Table 3.1 would be useful if available today. Many of these same measurements will still be required in 10-20 years to support process monitoring and control, and a smaller set of measurements will be required for closure monitoring. Hence, the demand for certain capabilities, such as in situ measurement, will continue until closure; however, the measurement techniques, detection levels, and adaptations required to deploy the technologies will likely continue to evolve as the various materials handling and treatment functions become operational.[a] Some useful schedule information relevant to technology development at Hanford is listed below:[b]

- Operations and safety concerns for watch-list tanks will likely be resolved over the next 3 to 5 years.
- Retrieval and pretreatment are scheduled to begin activities to support grout campaigns by 1994.
- Fourteen grout campaigns must be completed by 1996.
- Conversion to high-level and low-level waste disposal forms must be completed by the year 2018.
- Post-closure monitoring will be required for at least 30 years after the site is cleaned up.[c]

3.3.3 Technology Development Assessment

Detailed results of a technology development assessment are provided in the Appendix. Characterization needs are listed in the upper left-hand corner of Table A.1. These needs and technology development options are from Table 3.1 (columns 2 and 3). The technology development options and their associated deployment status are listed from left to right. These working tables provide the background information for the assessment discussed below.

(a) Information obtained from the "Characterization Technology Workshop," held in Richland, Washington, on September 3, 9, and 10, 1992.
(b) These are current Tri-Party Agreement milestones.
(c) Westinghouse Hanford Company. 1992. Draft Tank Waste Remediation System (TWRS) Decision Plan. Revision OB.

The technology development options listed in the Appendix were obtained from conversations with onsite experts, the proceedings of the TWRS National Technology Workshop, characterization documents (Winters 1990 et al.; Bovay Northwest),[a] and technical reviewers. The information on characterization technologies being funded by EM-50 was gleaned from UST-ID TTPs and the EM-50 Directory of Principal Investigators.[b] The status of these technologies was determined from interviews with principal investigators and users, library literature searches, discussions with private industry representatives, and environmental market studies. The company or person able to provide additional information is provided in the Appendix. References offering additional information are cited where available.

3.3.4 Technology Gaps Assessment

Table 3.2 shows possible characterization technology development gaps and uncertainties. The 12 technology development categories identified in previous tables are listed in the left-hand column; specific technology development options (including specific technologies and general needs where no apparent technology exists) are listed in column 2; the funding status (funded or not) for the technologies is shown in the center three columns; and major uncertainties associated with these technologies are summarized in the right-hand column. More detailed funding information is provided in the Appendix.

All FY92 TTPs funded by the UST-ID address identified needs. In fact, of the approximately 50 specific technology development options listed in

(a) Bovay Northwest (BN). 1991. Draft Underground Storage Tank Waste Characterization Workshop Report and Plan. Prepared for Westinghouse Hanford Company, Richland, Washington.

(b) Office of Technology Development (OTD). July 1992. Principal Investigator Directory. Obtained from "Characterization, Sensing, and Monitoring Technologies" information meeting on July 15-16, 1992 in Dallas, Texas.

TABLE 3.2. Technology Responses to Systems Needs: Status and Uncertainties

Characterization Need Category	Specific Technology Development Option	Funding Status			Uncertainties[c]
		EM-30	EM-50	Other[b]	
In Situ Measurement of Physical Properties[a]	Abrasiveness				No methods available.
	Acoustic Methods	X	X	X	Probe waste coupling to waste.
	Heated Line Source	X			Only works with non-convecting or homogeneous dry samples.
	Neutron Scattering	X		X	Needs to be validated on Hanford Wastes - Probe size reduction.
	Cone Penetrometer		X		
	Remote Viscometers	X		X	
	Sludge Tensiometer and Fracture Resistant Probe				No in situ methods available to measure rheology of sludges and hard wastes.
Hot Cell Segment Scanning	Scanning Techniques ·XRF ·Laser Raman ·Raman/Laser Fluorescence		X	X	Interference from background radiation.
Process Monitoring and Control	Long-Range Alpha		X		Promising technology but further development needed.
	Low-Energy GEA/GEA	X		X (EM-40)	· Requires proof-of-principle. · Interference from background radiation
	Fiber Optic Spectroscopy		X	X	Requires technology transfer and adaptations of methods used in industry.
	Leak Detection	X		X	Existing technology may not be suitable for use during retrieval.
Characterization of Soils[a]	Unsaturated Flow Analyzer		X		
	Vadose Zone Monitoring	X	X	X	
Tank Structural Analysis[a]	Leak Detection	X		X	No viable on-line technology for leak detection for SSTs.
	NDE Equipment	X		X	Needs to be tested.
	Optical Viewing	X		X	Not sensitive to very small penetrations.
	Tank Sampler				Difficult to obtain representative data.

TABLE 3.2. (contd)

Characterization Need Category	Specific Technology Development Option	Funding Status			Uncertainties[c]
		EM-30	EM-50	Other[b]	
Method Development	ICP/MS LA/ICP/MS		X	X	Zn-129 interferes with I-129
	Microwave Dissolution	X			Need to validate that all I-129 is retrieved from sample
	Cold Vapor Atomic Absorption (CVAA)	X		X	Field methods not available
	Laser Raman Spectroscopy/FTIR	X		X	Needs to be validated on Hanford waste matrixes
	Laser Ablation	X		X	Transport lines become contaminated
	Ion Chromatography	X		X	Not suitable to low levels of detection
Representative Samples, Samplers, and Sampler Deployment[a]	Samplers ·Tank Heel Sampler ·Vapor Space Sampler ·Hard Waste Sampler ·Fluidized Bed Sampling ·VOC Sampler ·Sludge Sampler	X (some types)		X (some types)	Real difficulty is deploying samplers into tank environment.
	Robotic Sampler Deployment ·Lightweight Utility Arm ·Robotic Mole ·End Affecters		X	X	Functional requirements and adaptations for sampling in situ need to be determined interactively with robotic arm developers.
	Advanced Core Sampling Techniques (e.g., Slant Drilling, other)	X (some)	X (some)		Cost-effective alternatives need to be investigated.
	Field Preservation Methods	X			Feasibility of alternatives needs to be investigated.
	Sample Containment and Shielding	X		X	OTD role uncertain
Increased Throughput[a]	Laboratory Automation	X	X (BWID)	X	• Functional requirements for hot cells, mobile units, in tank are not understood. • Need to identify routine, repetitive operation for first trials.
	Shipping Containers	X		X	Modifications to existing technology.
	Offsite Laboratory Services	X		X	Limited capabilities.
Data Management	LIMS	X		X	• LAN capability needed that cuts across program elements and makes data available to users. • Existing systems at Hanford cannot handle tank wastes.

TABLE 3.2. (contd)

Characterization Need Category	Specific Technology Development Option	Funding Status EM-30	Funding Status EM-50	Funding Status Other[b]	Uncertainties[c]
Data Management (contd)	Chemometrics		X	X	
In Situ Measurement of Chemical Constituents[a]	Thin Film Resonator for Monitoring of Gaseous Components			X	· Coating materials need to be developed. · These types are very sensitive to their environment (e.g., may give incorrect responses). · Never been used with hot materials.
	Selective Ion Electrodes		X	X	Interference effects may be considerable.
	Fiber Optic Spectroscopy		X	X	Fiber optics darken in high radiation environment.
	Remote Spectroscopy ·IR ·Near IR ·Long Path IR ·Laser Raman ·Laser Fluorescence ·XRF		X	X	Need to integrate systems with fiber optics or other means for light transmission.
	Chemical Microsensors		X (other IDs and IPs)	X	· Fiber optic sensors are very difficult to mass-produce, so costs may be high. · Sensitivity and range is limited.
	Laser Diodes for Single Species Monitoring	X	X	X	· Useful for ferrocyanide, nitrates, phosphates, and sulfates, but could be extended to other species. · Sensitivity too limited for some applications (.01 wt% to .1 wt% for species listed above).
	Flammable Gas Detection		X	X	
	Remote Laser Techniques ·LA/MS ·LA/ICP/MS ·LA/AES ·LA/LIBS ·Raman/Laser Fluorescence		X	X	· Impacts of laser anomalies must be resolved, such as fluctuation in laser signal and focusing difficulties. · Matrix effects of tank wastes need to be determined. · Radiation susceptibility of instrument needs to be proven.
	Chemical Reactivity/Shock Sensitivity Measurements				No method available.

TABLE 3.2. (contd)

Characterization Need Category	Specific Technology Development Option	Funding Status			Uncertainties[c]
		EM-30	EM-50	Other[b]	
In Situ Measurement of Radiological Properties[a]	Neutron Activation and In Situ Foils for Fissiles	X	X	X	• Interference from background radiations degrades measurements. • It currently activates several elements (fissiles, water, metals). • May be very difficult to use in high radiation environment.
	Fiber Optic Scintillation			X	Equipment exists but needs to be tested on Hanford matrices.
	GEA/Low-Energy GEA	X		X	• Tests planned in hot cell, but requires proof-of-principle in tank. • Needs to be incorporated in the scanning hot cell testbed. • Needs to be integrated into scanning platform.
Tank Decommissioning and Decontamination[a]	Long-Range Alpha		X (BWID)		• Limited range. Best use is to survey equipment coming out of tank. • Need to adapt LANL instrument to other sites.

(a) Technology development categories representing one or more specific characterization data needs, derived from the systems engineering or direct user assessments. Other categories represent technology development needs derived from TWRS or HMP workshops.
(b) The "other" category refers primarily to industry, but includes universities, other government agencies, and EM-40 funded activities.
(c) Uncertainties based on conversations with onsite "experts," TWRS (1992), and Bovay Northwest (1991).

Table 3.2, 17 (approximately 30%)[a] were addressed by UST-ID FY92 TTPs. However, there are still several gaps. Neither EM-30, EM-40 nor EM-50 is funding the following types of technologies: sludge tensiometer and fracture resistant probe, in situ measurement of abrasiveness, tank structure samplers, thin film resonator for monitoring gaseous components, and chemical reactivity/shock sensitivity measurements.

Technology is apparently available in the private sector that at least partially addresses the technology development options shown in Table 3.2, except in the following areas: some in situ measurement of physical properties (abrasiveness and heated line sources), long-range alpha measures, tank structure samplers, advanced core sampling techniques, sample retainment and preservation systems, and chemical reactivity/shock sensitivity measurements. However, two key prerequisites for existing technologies include:

- testing equipment in a high-radiation environment
- validating measurements on DOE waste streams. These may be difficult and costly activities, and should be considered when planning the development of any of these technologies.

3.4 CONCLUSIONS AND RECOMMENDATIONS

Table 3.3 summarizes highly uncertain and/or currently unfunded characterization technology development options from Table 3.2. The characterization need category is presented to the left. Specific technology development options are listed in the next column. The center columns indicate the number of identified technology development options that are funded (or not funded) by different organizations. The far right-hand column lists a coded status summary, indicating the relative adequacy of currently funded development efforts. These judgments reflect the combined expertise of experts from EM-30

(a) This study recognizes that each technology development option represents a different sized problem, benefit, and investment of resources: the fact that 15% of the identified technologies are being addressed does not mean that 15% of the characterization need is being met. The purpose of citing a number is to give some type of quantitative indicator of how well the current UST-ID characterization technology development program is targeted at identified needs.

TABLE 3.3. Summary Technology Development Funding Status

Characterization Need Category	Identified Technology Development Options	Number of Recommended Technology Development Options: Total	Not Funded by EM	Funded by EM-30	Funded by EM-50: UST-ID	Funded by EM-50: Other ID	Private Sector Options	Status Summary
Method Development		6	0	5	3	1	5	
In Situ Measurement of Physical Properties	Abrasiveness	7	2	1	2	0	3	B
	Settling Rates							C
	Heated Line Source							A
Hot Cell Segment Scanning		1	0	1	1	0	1	
Process Monitoring and Control	Long-Range Alpha	4	0	1	1	1	3	A
	Low-Energy GEA/GEA							A
	Neutron Activation for Fissiles							A
Characterization of Soils		2	0	1	0	1	1	
Tank Structural Analysis	Tank Sampler	4	1	3	0	0	3	B
Representative Samples, Sampling, and Sampler Deployment	Advanced Core Sampling Techniques, Vapor and Head Space Samplers	5	0	4	1	1	3	C
Increased Throughput	Laboratory Automation	3	0	3	0	1	3	A
Data Management		2	0	1	1	0	2	
In Situ Measurement of Chemical Constituents	Chemical Microsensors	9	2	4	3	2	8	A
	Chemical Reactivity							B
	Specific Ion Electrodes							A
	Thin Film Resonator							B
In Situ Measurement of Radiological Properties	Fiber Optic Scintillation	3	1	2	0	1	3	A
	Neutron Activation for Fissiles							A
Tank Decommissioning and Decontamination	Long-Range Alpha	1	0	0	0	1	0	A

KEY:
A: Technology response funded by EM-30, EM-40 or EM-50 (not UST-ID), but problem is long-term and technically difficult.
B: Technology response not funded by any EM Division.
C: Existing TTP does not completely address requirements for technology response.

(TWG members), EM-50 (TSG members), and technical reviewers. Some technology options are so complex that additional funding is recommended regardless of current funding status (reason A in the last column of Table 3.3). Technologies not funded by EM as indicated in column 3 of Table 3.3 are all recommended for funding consideration by EM-50 (designated for selection using reason B). If a TTP exists within EM-50 but does not completely address the UST-ID need, it is also recommended for funding consideration (reason C).

Table 3.3 shows that experts believe current technology development is generally inadequate to meet users' UST waste data needs. Although not shown here, even relatively mature technologies "available" in industry may require expensive adaptation.

In addition to these apparent funding gaps, more funding may be directed to development areas that are unlikely to meet needs under current funding levels. These include:

Characterization Need Category	Technology Development Issue
Increased throughput	Sampling technologies or in situ probes to measure settling rates of the waste
In situ measurement of chemical constituents	The CdTe detector may have applications for process monitoring and control
In situ measurement of radiological properties	Some specific advanced core sampling methods have been identified as needs (e.g., slant drilling). However, the greatest area of uncertainty is the development of sampler deployment apparatus. This area is currently being addressed by the UST-ID.
Process monitoring and control	Laboratory automation
Representative samplers, sampling methods, and sampler deployment apparatus.	Specific ion electrodes chemical microsensors
In situ measurement of physical properties	Fiber optic scintillation long-range alpha neutron activation for detection of fissiles

Characterization Need Category	Technology Development Issue
Tank decommissioning and decontamination	Long-range alpha has a limited range; need to adapt CANL instrument to other sites

Additional technology development should address these uncertainties. The following funding criteria should be considered:

- Does the technology development activity resolve important uncertainties?
- Will the technology fulfill functional requirements? Will associated system requirements be met so the technology can be effectively deployed?
- Will the technology meet the need within an acceptable time frame?
- Can the data be validated?

Cost savings are important and should be included in any assessment, but it is imperative that serious consideration be given to whether the technology can be effectively deployed and the data validated.

4.0 REFERENCES

Buck, J. W., et al. 1991. Preliminary Recommendations on the Design of the Characterization Program for the Hanford Site SSTs - System Analysis. PNL-7573, Pacific Northwest Laboratory, Richland, Washington.

Freeburg, R. D. 1991. Hanford Site Single-Shell Tank Characterization and Assessment Program Update Meeting #10 for National Academy of Sciences. DOE-010-VA, U.S. Department of Energy, Richland, Washington.

Mayberry, J. L., W. J. Quapp, F. Feizollahi, and J. C. Del Signore. 1991. Preliminary Systems Design Study Assessment Report. EGG-WTD-9989, Idaho National Engineering Laboaratory.

Meridith, J. R. and S. J. Mantel, Jr. 1989. Project Management. John Wiley & Sons, New York.

Morris, K. L. 1991. In-Tank Waste Physical Property Measurement Study. WHC-SD-ER-WP-004, Westinghouse Hanford Company, Richland, Washington.

Opitz, B. E., et al. 1991. Single-Shell Tank Systems Technical Support Program Plan, WHC-EP-0288-002, Westinghouse Hanford Company, Richland, Washington.

Strong, K. E. 1992. "In Process Hot Core Sample, Storage, Justifications and Requirements." In-Tank Waste Characterization Plan. WHC-SD-WM-PLN-047, Westinghouse Hanford Company, Richland, Washington.

von Winterfeldt and Edwards. 1976. Design Analysis and Behavioral Research. Cambridge University Press, Cambridge.

Westinghouse Hanford Company (WHC). 1992. Underground Storage Tank Integrated Demonstration Functional Requirements. WHC-EP-0566, Westinghouse Hanford Company, Richland, Washington.

Westinghouse Hanford Company (WHC). 1990. In-Tank Physical Property Measurement Study. WHC-SD-ER-WP-004. Westinghouse Hanford Company, Richland, Washington.

Winters, W. I., L. Jensen, L. L. Sasaki, et al. 1990. Waste Characterization Plan for the Hanford Single Shell Tanks. WHC-EP-0210, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

APPENDIX

CHARACTERIZATION TECHNOLOGY ACTIVITY WORKSHEETS

TABLE A.1. Functional Need:

Technology	EM-30 or EM-40 Activities	EM-50 Ac
ICP ICP/MS LA/ICP/MS	ICP/MS has been tested on hot cells at Hanford. Plans are to establish noble metals analysis measurement techniques onsite in FY 1994. Meanwhile samples are sent to SRL.[a] ICP/MS unit planned to be installed in 222S in FY 1992.[b] PNL has an instrument.	CH101101 Mobile Coupled Plasma O Emission Spectro Improvements in Spectra/CH121202 on ICP
Microwave Dissolution	Wet chemistry is being used at Hanford for analysis of ^{129}I, but it is difficult to prove that all of the sample is in solution. PNL (contact Monty Smith at 376-8459) is developing techniques.	
Cold Vapor Atomic Absorption (CVAA)	Capability for cold vapor analysis by atomic absorption (CVAA) to detect mercury being requested for laboratories.	
Laser Raman Spectroscopy/FTIR	Wet chemistry methods are currently being used to determine cyanoferrate complexes. Solid-state infrared spectroscopy has been demonstrated for determining cyanide species.[c] SRL has used remote Raman capabilities to speciate nitrates in hot samples. Florida state is looking at matrix effects using IR.	RL401206 Waste A Laser Raman Spec
Laser Ablation		
Ion Chromatography	IC methods can separate ferrocyanide complexes in aqueous solution. Methods need to be developed further to allow quantitative determinations.[c]	

(a) Atwood, J. M. 1992. "Use of Alternative U.S. DOE Hot Cells and Laboratory Fa dated July 1992.
(b) Integrated Sampling and Analysis Plan. March 1992. WHC-EP-0533.
(c) Pacific Northwest Laboratory. 1992. Ferrocyanide Safety Project Task 3.5 Cya Westinghouse Hanford Company, Waste Tank Safety Program.

Analytical Methods Development

ivities	Industrial Activities	Foreign Activities
nductively tical eter/CH101103 CP Mass Paper Study	ICP/MS instruments are off-the-shelf and available.	
	Catholic University studying methods for ^{129}I.	
	CVAA equipment is commercially available. Other alternatives: P.S. Analytical Ltd. (U.S. 609-587-6898) (atomic fluorescence of Mercury vapor to determine mercury level), Arizona Instrument Corp. (800-528-7411) (Mercury vapor analyzer)	Swedish Linkoping and Lund Universities (sensors for mercury II)
alysis using roscopy	Instruments are commercially available.	
	Equipment can be purchased on a piece-by-piece basis.	
	Instruments are commercially available.	

ilities in Support of Hanford Waste Tank Characterization." Letter to J. R. Hunter,

ide Species Analytical Methods Development FY 1992 Annual Report. Prepared for

TABLE A.2. Functional Need: In S

Technology	EM-30 or EM 40 Activities	
Neutron Scattering (Moisture)	Some testing and use. PNL is developing technique;[a] SRL may be using technology.	
Acoustic Methods (Viscosity, Density, Temp., Adhesiveness)	Laboratory capabilities to obtain these measurements exist. In situ methods are not available. Initial work at Ames Laboratory shows that Ultrasonic NDE techniques can be used to locate sludge layers.	CH1 Cha Und Fun
Cone Penetrometer	Cone penetrometer is being tested by VOC-ID.	RL4 Dem
Remote Absolute Viscometer (Cylinder with Cylinder)		
Remote Relative Viscometer (Shear Vane)	Rheology measurements are taken with direct and diluted samples at hot cell temperature and 95°C.[c]	
Sludge Tensiometer and Impact Type Fracture Resistant Probe		
Heated Line Source	PNL is testing methods.[b]	
Rheological Waste Simulants	Simulants exist but they do not represent tank waste rheology.	RL Sim

(a) Telephone interview. Larry Morgan, PNL, October 1, 1992.
(b) Telephone interview. Joel Tingey, PNL, October 2, 1992.
(c) Tank Waste Characterization Plan. August 1992. WHC-SD-WM-PLD-047, Rev. 0, Dra

tu Measurement of Physical Properties

EM-50 Activities	Industrial Activities	Foreign Activities
1201/CH121103 Physical acterization of Contents of rground Storage Tank (Note: ing Stopped in FY 93)		
1201 Cone Penetrometer nstration		
1205 Define and Prepare Waste lants		

t.

TABLE A.3. Technology Development

Technology	EM-30 or EM-40 Activities	EM-5
Hot Cell Segment Scanning Techniques - XRF - Laser Raman - Raman/Laser Fluorescence	First use is in the hot cell on extruded samples. Instrumentation is available, but the scanning systems must be developed and validated on Hanford samples. EG&G in Santa Barbara, California is using scanning system on soil samples.	

ess Monitoring and Control

Industrial Activities	Foreign Activities
Fiber optic sensors to measure temperature, pressure, acceleration, flow of liquids and gases, and liquid level are commercially available; Metricor (plug-in fiber optic probes for T & P); Hughes Research Laboratory (high-temperature optical fiber) - (203-797-5000); and Battelle (distributed fiber to detect "hot spots").	Standard Telecommunications Laboratories in Great Britain (sensors for flow, pressure, machine vibration; many FOC development programs are underway in Japan, Europe, and North America
Commercially available.	
Technologies for leak detection exist due to a need for remediating underground storage tanks. The majority of USTs owned by industry are used for petroleum product storage. About 50% of the tanks are owned by gas stations, and the remainder are owned by private companies and government facilities. Private companies selling equipment include Arizona Instruments (800-528-7411) (Leak Detection Sensors) and MDA Scientific (404-242-0977) (Laser-Based Leak Detection).[a]	

The Environmental Protection Agency sponsors research to clean up USTs. Some of the
plicable to the UST-ID.
ial Practices." Battelle Today, p.47.

TABLE A.5. Functional Need: Ch

Technology	EM-30 or EM-40 Activities	EM-50 Acti
Vadose Zone Monitoring		A number of technol potential applicati funded by the Chara Monitoring Integrat FY 92 MWLID TTP AL2 cally develops an a nique for detecting beneath tanks.
Unsaturated Flow Analyzer		Technology funded b

TABLE A.6. Functional Nee

Technology Response	EM-30 or EM-40 Activities	EM-5
Optical Viewing		OR113201 Robotics UST structured light sourc surface of waste)
NDE Equipment		ID41302 Remote Tank In
Tank Sampler		

aracterization of Soils Around Tank

vities	Industrial Activities	Foreign Activities
ogies with ons are being cterization and ed Program. 21114 specifi- dvanced tech- fluid losses	The Environmental Protection Agency operates an Environmental Monitoring Systems Laboratory in Las Vegas, NV (702-798-2525). Major programs exist in the areas of advanced analytical methods, advanced monitoring methods, and radiological monitoring and analysis.	
y VOC-ID.	Beckman Instruments is developing prototype.	

l: Tank Integrity Evaluations

D	Industrial Activities	Foreign Activities
(includes e for mapping		
spection System		

TABLE A.7. Functional Need: Represen

Technology	EM-30 or EM-40 Activities	
Sampler Deployment - Robotic Arm - Mole Deployment Device - End Affectors	Biggest need is for coordination and interaction with robotics program to ensure adaptations implemented for deployment of samplers and in situ instruments.	SF 221204 Ro Toxic Waste Funding Stop RL 332002 Li Effector (US
Advanced Core Sampling Techniques (e.g., Slant Drilling)	Only vertical core samples can be taken.	Directional soil samplin Mike Hagood)
VOC Sampler (Robotic Arm)	Existing samplers are somewhat gas tight.	
Fluidized Bed Sampling	Technology is needed to stir up particles and transport them to sampler.	
Vapor Space Samplers Hard Waste Samplers Sludge Samplers	Work is underway to develop vapor space samplers.[a] Real difficulty is deploying samplers into tank environment.	
Field Preservation Methods	Core samples are handled at ambient temperatures.[a]	
Sample Containment & Shielding		

(a) Tank Waste Characterization Plan. August 1992. WHC-SD-WM-PLD-047, Rev. 0, Dra tative Sampling, Samplers, and Deployment

EM-50 Activities	Industrial Activities	Foreign Activities
otic Mole Development for Site Inspection (Note: ped for FY 93) ght Duty Arm Sampling End TID)	Petroleum industry uses truck-mounted articulated boom technology to clean sludge from petroleum tanks.	
drilling is being funded for g by the VOC-ID (contact		
	Samplers have been developed for water quality measurements. Stack gas samplers marketed by companies such as Anderson Instruments (404-691-1910).	
	See above.	
	See above.	
	Nuclear Packaging, Inc., (206-874-2235) Radioactive materials packaging.	
t.		

TABLE A.8. Functional N

Technology	EM-30 or EM-40 Activities	EM-50 Activities
Laboratory Upgrades	Several laboratory upgrades are being considered to increase onsite capacity.[a]	
Offsite Laboratory Services	WHC has sent dried HTWC samples to Savannah River for a trial run with noble metals.[b] WINCO, LANL, and SRL have the capability to analyze solid waste samples.	
Shipping Containers	No offsite shipping containers are licensed to transport sludges. Shipping containers exist for dried samples.[a] Commercially available and being used by pharmaceutical companies.	
Laboratory Automation	Lab automation requires making systems robust. Should be considered for routine processes only.	SF 213202 Microstructure In mentation Application for L tory Automation. RL3113201 Robotics Contamin Analysis Automation ID413203/AL 113204 /AL213203/ID413203 Robotics Lab Automation Note: Mike Dodson at PNL de an automation system for OT delivered it to Idaho Falls

(a) Tank Waste Characterization Plan. August 1992. WHC-SD-WM-PLN-047, Rev. 0, Draft.
(b) Atwood, J. M. 1992. "Use of Alternative U.S. DOE Hot Cells and Laboratory Facili July 1992.

ed: Increased Throughput

	Foreign Activities	Industrial Activities
		Laboratories that can handle radioactive samples include International Technology (IT) Analytical Services (509-375-3131); Alpha Analytical Laboratories in Westborough, MA (508-898-9220); DataChem Laboratories in Salt Lake City, UT (1-800-356-9135); and CompuChem Laboratories, Inc. in Research Triangle Park, NC (1-800-833-5097). IT recently purchased a testing facility on the Hanford Site. There is limited capability for nonroutine analysis. Westinghouse Environmental Systems and Services Division (412-937-4066) offers environmental assessment services for radioactive waste sites, which includes some mobile laboratories for onsite characterization services.
		Westinghouse Environmental Services is developing a shipping cask.
tru- bora- nt eloped and ID.	Repetitious lab automation procedures are being done by NIST. CPAC looking at automated sample preparation procedures.	Amersham Corp. uses robots to calibrate radiopharmaceuticals; Zymark Corp., laboratory robots; IBM 7565 laboratory robot; real-time expert system from Gensym Corp. (617-547-9606).

ies in Support of Hanford Waste Tank Characterization." Letter to J. R. Hunter, dated

TABLE A.9. Functiona

Technology	EM-30 or EM-40 Activities	
LIMS	Hanford Environmental Information System (HEIS) is being developed, but tank information has not yet been integrated. Other strategy is to integrate existing databases. A commitment has been made to purchase LIMS by WHC. PNL is also considering purchasing a PC-based LIMS.	
Chemometrics	DQO process is being implemented at Hanford.	This work i RL401206.

l Need: Data Management

EM-50	Industrial Activities	Foreign Activities
	Thermo Analytical (818-357-3247) Design of sampling programs.	
s being consider under UST-ID		

TABLE A.10. Technology Development Category

Technology	EM-30 or EM-40 Activities	EM-50 Act
Remote Spectroscopy - IR - Near IR - Long Path IR - Laser Raman - Laser Fluorescence - XRF	Raman IR system planned to be installed in 222 S (contact David Dodd). SRL has used Raman/IR techniques in hot cell and for process monitoring (Contact Pat O'Rourke). WHC (contact Fred Reich at 376-4063) and PNL are developing laser Raman techniques. PNL is evaluating the integrity of fiber optic probes in high radiation environments (contact Greg Exharhos at 375-2440). LANL (contact Robert Donahoe at 505-665-6794) is working on Raman spectrographic techniques using fiber optics	RL421206 Surface Chara Mapping of Tank Waste Transform Infrared Spc Not funded in FY93). RL321114 Detection anc High-Z Metals at the S Landfill by XRF SF211203 Advanced Fibe Spectroscopy
Laser Diodes Single Species Monitoring	Goal is in situ deployment, but will likely be tested and validated in the hot cell. Work done in 222S by UST-ID (contact David Dodd of WHC). PNL is conducting studies to understand sensitivity of various techniques.	
Chemical Microsensors - Spectroscopic - Passive - Ion selective		

In Situ Measurement of Chemical Constituents

vities	Industrial Activities	Foreign Activities
cterization/ Jsing Fourier ctroscopy (Note: Quantification of NL Mixed Waste r Optic	Raman, XRF, and Laser Fluorescence IR instruments are commercially available. Raman and IR are well-established techniques that provide qualitative measurements about the chemistry of a sample. The addition of a laser source increases selectivity and allows time-resolved measurement.	
	Univ. of WA CPAC (contact Betsy McGrath at 206-543-3430) developing techniques. Toshiba produces laser diodes (contact Pete Todd); Hewlett Packard (tunable laser diode package); ND State University (701-237-8244) (tunable wavelength light source to discriminate BTX); Tufts University (contact Johnathon Kenny at 617-628-5000) (excitation-emission matrix [EEM] sensor for aromatics); Georgia Institute of Technology (contact Rick Browner at 404-894-4020) IR linked with LC; and Spectral Sciences (617-273-4770) Species selective IR devices for small hydrocarbons.	
	Sensors are available but sensitivity and range are limited: Microsensor Systems, Inc. (502-745-0099) SAW sensor with portable GC; Integrated Chemical Sensors Corp. (617-965-7255).	

TABLE A.

Technology	EM-30 or EM-40 Activities	EM-50 Act
Flammable Gas Detection	LLNL developing Surface Acoustic Wave (SAW) devices. PNL developing hydrogen sensor (contact Art Janata at 375-6492). Hydrogen monitors are being used.	Sandia National Labor developed miniaturize flammable gas detecti
Chemical Reactivity Measurement		
Remote Laser Techniques -LA/MS -LA/ICP/MS -LA/AES -LA/LIBS -Laser Raman -Raman/Laser Fluorescence	May not be safe for combustible tanks (e.g., laser fluorescence has the potential to energize tank contents). PNL (contact Steve Colson at 375-6882) developing Mobile Analysis Reconnaissance System (MARS). It will include a laser ablation system, a mass spectrometer system, and computer control and analysis. Laser ablation would actually take the small amount of material out of the hot cell for analysis.	
Fiber Optic Spectroscopies	Fiber optics darken in high radiation environments. A light pipe may be an acceptable alternative.	SF211203 Advanced Fib copy for Inorganic Co
Thin Film Resonator for Monitoring of Gaseous Components	PNL has done work with thin film coatings over piezo-electric crystals.	

Q. (contd)

...vities	Industrial Activities	Foreign Activities
...tories has ... sensor systems for ...n.[a]	Femtometrics, Inc. (714-722-6239) (chemical vapor sensors); Transducer Research, Inc. (708-357-0004); Center for Nuclear Studies, Grenoble, France (solvent vapor detector); University of Kent, United Kingdom (fiber optic sensor for detection of flammable gases).	
	Laser ablation methods are well-established, but may not be quantitative. Organizations marketing or developing laser systems include: - Leybold-Heraeus Gmbh produces LAMMA (Laser Microprobe Mass Analyzer) instruments - Spectra-Physics Corp., Laser Analytics Division (415-961-9100) - Ultrafast laser systems being studied by University of Pennsylvania (contact Robin Hochstrasser at 215-898-8410) - Coherent, Inc., Laser Products Division (415-493-2111) - Hughes Corp. (203-797-5000) - ORNL SERS (surface enhanced Raman spectroscopy); EIC Laboratories manufactures fiber optic SERS probe (617-769-9450).	
...r Optic Spectros-...taminants.	Fiber Chem, Inc. (702-361-9873) (pH, carbon dioxide, and oxygen).	
	Commercially available. University of WA CPAC is developing a piezoelectric type.	

TABLE A.1

Technology	EM-30 or EM-40 Activities	EM-50 Act
Selective Ion Electrodes for Single Species Monitoring	PNL and Sandia are developing technologies in this area. Selective ion electrodes are used in the laboratory.[(b)]	Being funded by VOC Ar

(a) Sandia National Laboratories. 1992. "Have Lab Will Travel." Energy and Envir
(b) Tank Waste Characterization Plan. August 1992. WHC-SD-WM-PLN-047, Rev. 0, Dr

0. (contd)

vities	Industrial Activities	Foreign Activities
id ID.	Industry used technology to measure pH. Swedish Linkoping and Lund Universities (sensors for mercury II); Dublin City University (ion-selective electrodes using ionophores); Locite Ltd, Ireland (contact Dermit Diamond at 37007) (ion-selective electrodes using ionophores); NM State University (chromium VI sensor based on adsorptive strip).	
onment, P.O. Box 5800, Albuquerque, NM 87185. ft.		

TABLE A.11. Need: In Situ Meas

Technology	EM-30 or EM-40 Activities	EM-
Low-Level GEA/GEA	325 Laboratory has a scanning system in the hot cell. It must be designed not to give spurious data in high-radiation environments. LANL developing improved gamma energy analysis (contact Cal Moss at 505-667-5056).	
Fiber Optic Scintillation	Work is being done at PNL for DOD clients (contact John Hartman at 375-2771).	ID at Fernald fund scintillation.
Neutron Activation and In Situ Foil for Neutron Fissile Measurement[a] Thin Film Detector for Actinides.	SRL is using technology. Work is being discussed (contact Ron Brodzinski, PNL, at 376-3529. In the past, a neutron source has been used in Z-9 crib to measure reactivity for fissiles. WHC used a neutron source in tank to look for plutonium. LANL developing fissile assay system (contact George Auchampaugh at 505-667-7739).	AL921101 Neutron A for Fissiles (SNL N SF223301 Remote Se Organics, Toxic Me Actinides

(a) Telephone interview with Larry Morgan, PNL, October 1, 1992.

TABLE A.12. Technology Development Catego

Technology	EM-30 or EM-40 Activities	EM-50 Activities
Long-Range Alpha	Instrument has been developed by LANL. Applications being studied to support decontamination.	WHC/LANL TTP with BWID to te conveyor belt.[a]

(a) Telephone interview with Gary Troyer, WHC, October 1, 1992.

urement of Radiological Properties

;0	Industrial Activities	Foreign Activities
	Instruments are available for low cost.	
d development of	Used extensively for national security applications. Contact Don Oakley and Ed Vanevanhout (505-667-1960) of National Security Committee for information on remote sensing technologies for radioisotopes.	
tivation Logging WLID) sors for als, and	Instruments are available from General Activation Analysis, Inc. (619-755-5121), but they are not very portable.	

·y: Tank Decommissioning and Decontamination

	Industrial Activities	Foreign Activities
st on		

END

DATE FILMED

8/31/93