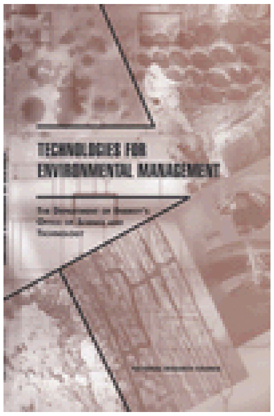

Technologies for Environmental Management: The Department of Energy's Office of Science and Technology

Board on Radioactive Waste Management, National Research Council

ISBN: 0-309-56288-0, 84 pages, 6 x 9, (1999)

TECHNOLOGIES FOR ENVIRONMENTAL MANAGEMENT

THE DEPARTMENT OF ENERGY'S OFFICE OF SCIENCE AND TECHNOLOGY

Board on Radioactive Waste Management
Commission on Geosciences, Environment, and Resources
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C.

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

This work was sponsored by the U.S. Department of Energy, Contracts No. DE-FC01-94EW54069 and DE-FC01-99EW59049. All opinions, findings, conclusions, and recommendations expressed herein are those of the authors and do not necessarily reflect the views of the Department of Energy.

International Standard Book Number 0-309-06647-6

Additional copies of this report are available from:

National Academy Press
2101 Constitution Ave., NW
Box 285
Washington, DC 20055
800-624-6242
202-334-3313 (in the Washington Metropolitan Area)
http://www.nap.edu

Printed in the United States of America

THE NATIONAL ACADEMIES

National Academy of Sciences
National Academy of Engineering
Institute of Medicine
National Research Council

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

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William. A. Wulf is president of the National Academy of Engineering.

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

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

www.national-academies.org

BOARD ON RADIOACTIVE WASTE MANAGEMENT

MICHAEL C. KAVANAUGH, *Chair,* Malcolm Pirnie, Inc., Oakland, California[1]
JOHN F. AHEARNE, *Vice-Chair,* Sigma Xi, The Scientific Research Society, and Duke University, Research Triangle Park and Durham, North Carolina[2]
ROBERT J. BUDNITZ, Future Resources Associates, Inc., Berkeley, California[1]
MARY R. ENGLISH, University of Tennessee, Knoxville[1]
DARLEANE C. HOFFMAN, Lawrence Berkeley Laboratory, Berkeley, California
JAMES H. JOHNSON, JR., Howard University, Washington, D.C.
ROGER E. KASPERSON, Clark University, Worcester, Massachusetts
JAMES O. LECKIE, Stanford University, Stanford, California
JANE C.S. LONG, University of Nevada, Reno
CHARLES McCOMBIE, International Consultant, Wettingen, Switzerland
WILLIAM A. MILLS, Oak Ridge Associated Universities (retired), Olney, Maryland
D. WARNER NORTH, NorthWorks, Inc., Belmont, California[1]
MARTIN J. STEINDLER, Argonne National Laboratory (retired), Argonne, Illinois
JOHN J. TAYLOR, Electric Power Research Institute (retired), Palo Alto, California
MARY LOU ZOBACK, U.S. Geological Survey, Menlo Park, California

NRC Staff

GREGORY H. SYMMES, Study Director
SUSAN B. MOCKLER, Research Associate
TONI GREENLEAF, Administrative Associate
LAURA D. LLANOS, Project Assistant

[1]Member of Committee on Environmental Management Technologies (CEMT) Working Group
[2]Chair of CEMT Working Group

COMMISSION ON GEOSCIENCES, ENVIRONMENT, AND RESOURCES

GEORGE M. HORNBERGER, *Chair,* University of Virginia, Charlottesville
RICHARD A. CONWAY, Union Carbide Corporation (retired), South Charleston, West Virginia
THOMAS E. GRAEDEL, Yale University, New Haven, Connecticut
THOMAS J. GRAFF, Environmental Defense Fund, Oakland, California
EUGENIA KALNAY, University of Maryland, College Park
DEBRA KNOPMAN, Progressive Policy Institute, Washington, D.C.
KAI N. LEE, Williams College, Williamstown, Massachusetts
BRAD MOONEY, J. Brad Mooney Associates, Ltd., Arlington, Virginia
HUGH C. MORRIS, El Dorado Gold Corporation, Vancouver, British Columbia
H. RONALD PULLIAM, University of Georgia, Athens
MILTON RUSSELL, Joint Institute for Energy and Environment and University of Tennessee (emeritus), Knoxville
THOMAS C. SCHELLING, University of Maryland, College Park
ANDREW R. SOLOW, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts
VICTORIA J. TSCHINKEL, Landers and Parsons, Tallahassee, Florida
E-AN ZEN, University of Maryland, College Park
MARY LOU ZOBACK, U.S. Geological Survey, Menlo Park, California

NRC Staff

ROBERT M. HAMILTON, Executive Director
GREGORY H. SYMMES, Associate Executive Director
JEANETTE SPOON, Administrative and Financial Officer
DAVID FEARY, Scientific Reports Officer
SANDI FITZPATRICK, Administrative Associate
MARQUITA SMITH, Administrative Assistant/Technology Analyst

Preface

The Department of Energy's Environmental Management Program (DOE-EM) is one of the largest environmental cleanup efforts in world history (the analogue in Greco-Roman mythic tradition being the cleanup of the Augean stables). The EM division charged with developing or finding technologies to accomplish this massive feat, its Office of Science and Technology (OST), has been reviewed extensively, including six reports from committees of the National Research Council's (NRC's) Board on Radioactive Waste Management (BRWM) that have been released since December 1998. These committees examined different components of OST's technology development program, including its decision-making and peer review processes and its efforts to develop technologies in the areas of decontamination and decommissioning, waste forms for mixed waste, tank waste, and subsurface contamination.

Gerald Boyd, head of OST, asked the BRWM to summarize the major findings and recommendations of these reports and synthesize any common issues into a number of overarching recommendations to EM and OST. Such an overarching assessment is timely because it occurs soon after the appointment of a new Assistant Secretary for Environmental Management.

This report was written by a working group formed from members of the BRWM.[1] The working group developed a work plan, prepared a background paper and detailed summaries of the six reports reviewed, and held a meeting in early February with representatives of the committees that prepared the reports. The working group prepared drafts of this report, which were subsequently discussed by the entire board at its June 1999 and November 1999 board meetings. The report has been approved by all BRWM members.

[1] The following BRWM members serve on this working group: John Ahearne (chair), Robert Budnitz, Mary English, Michael Kavanaugh, and Warner North.

The working group thanks those representatives of BRWM committees who participated in the meeting in February: Martin Steindler, Tanks Committee; John Fountain, Peer Review and Subsurface Contaminants Committees; Ray Wymer (chair), Decision Making Committee; Sol Burstein, D&D Committee; and Paul DeJonghe (chair), Mixed Waste Committee. In addition, the board gratefully acknowledges the assistance of NRC staff involved in this study. In particular, Toni Greenleaf did an exceptional job organizing the meeting and overseeing the preparation of drafts of this report. Susan Mockler assisted in preparing meeting summaries, performed research tasks for the study, and edited various drafts of the report. Laura Llanos prepared the camera-ready copy of this report. Gregory Symmes, who served as study director for this project, made major contributions in helping shape the board's ideas into a coherent report and in assisting the board to respond to extensive reviewer comments. Kevin Crowley provided helpful suggestions throughout the study.

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

Corale Brierley, Brierley Consultancy, LLC
Thomas A. Cotton, JK Research Associates, Inc.
Allen G. Croff, Oak Ridge National Laboratory
Lloyd Duscha, U.S. Army Corps of Engineers (retired)
Harold Forsen, Bechtel Corporation (retired)
John Fountain, State University of New York, Buffalo
William Kastenberg, University of California, Berkeley
Milton Levenson, Bechtel International (retired)
Frank Parker, Vanderbilt University
Bruce M. Thomson, University of New Mexico, Albuquerque
Detlof von Winterfeldt, University of Southern California, Los Angeles

While the individuals listed above have provided constructive comments and suggestions, it must be emphasized that responsibility for the final content of this report rests entirely with the authoring committee and the institution.

John Ahearne
Chair, CEMT Working Group

Contents

SUMMARY 1

1 INTRODUCTION 8
This Report 10
Background 14

2 CLARIFY THE ROLE AND MISSION OF OST 18
Strategic Planning and Prioritization 20
Long-Term Objectives 21

3 PUT DISCIPLINE INTO DECISION MAKING 22
Framing Decisions 22
Making Decisions 27
Prioritizing Needs and Measuring Results 34

4 EXPAND OST'S REACH OUTSIDE DOE 36
Recommendations 37

5 ADDRESS CONSTRAINTS TO TECHNOLOGY IMPLEMENTATION 38
Constraints Within DOE 38
Constraints External to DOE 39
Conclusion 42
Recommendations 42

REFERENCES 44

APPENDIXES

A List of Recommendations from *A Review of Decontamination and Decommissioning Technology Development Programs at the Department of Energy* 49

B List of Recommendations from *Peer Review in Environmental Technology Development Programs: The Department of Energy's Office of Science and Technology* 52

C List of Recommendations from *An End State Methodology for Identifying Technology Needs for Environmental Management, with an Example from the Hanford Site Tanks* 55

D List of Recommendations from *The State of Development of Waste Forms for Mixed Wastes: U.S. Department of Energy's Office of Environmental Management* 58

E List of Recommendations from *Groundwater and Soil Cleanup: Improving Management of Persistent Contaminants* 62

F List of Recommendations from *Decision Making in the U.S. Department of Energy's Environmental Management Office of Science and Technology* 65

G Acronyms and Abbreviations 72

H Organizational Structure of Relevant Parts of the Department of Energy's Office of Environmental Management as of August 1999 73

Summary

The Department of Energy's Environmental Management Program (DOE-EM) is one of the largest environmental clean up efforts in world history. The program is estimated to cost over $100 billion (some estimates exceed $200 billion) and is expected to continue for decades (DOE, 1998c). The EM division charged with developing or finding technologies to accomplish this massive task,[2] its Office of Science and Technology (OST), has been reviewed extensively, including six reports from committees of the National Research Council's (NRC's) Board on Radioactive Waste Management (BRWM) that have been released since December 1998 (see Box 1 in Chapter 1). These committees examined different components of OST's technology development program, including its decision-making and peer review processes and its efforts to develop technologies in the areas of decontamination and decommissioning, waste forms[3] for mixed waste, tank waste, and subsurface contamination.

Gerald Boyd, head of OST, asked the Board on Radioactive Waste Management (BRWM) to summarize the major findings and recommendations of the six reports and synthesize any common issues into a number of overarching recommendations (see Box 2 in Chapter 1 for the complete Statement of Task). Such an assessment is timely because it occurs soon after the appointment of a new Assistant Secretary for Environmental Management. The board believes that DOE leadership will find this report useful as it works

[2] Significant effort also is done by industry. Much DOE-EM cleanup can use technologies appropriate for non-DOE remediation activities. Recently, DOE has moved to allowing contracts that require the contractor to provide all the initial funding and develop the technologies to be applied. This is often called “privatization.”

[3] A “waste form” is considered a solid material that is the product of one or more treatment processes (Mixed Waste report, p. 2).

to improve EM's efforts to research, develop, and demonstrate technologies for environmental remediation and restoration of DOE sites.

Although some of the six reports were released recently, most of the authoring committees completed their information gathering and deliberations months ago. Therefore, the reports may not take into account recent changes that are being made by OST management in response to criticisms by Congress, the General Accounting Office, and the BRWM. To better understand these recent changes, the board received from OST two briefings, written responses to three of its recent reports (DOE, 1999b,c; 1998d), and a summary of changes made in response to the 1996 report from the BRWM's Committee on Environmental Management Technologies (CEMT) (DOE, 1999a). The board has reviewed these documents and, where appropriate, acknowledges where progress has been made. It is clear that OST also has begun, or is planning, to make a number of changes to address the issues raised in the subject reports. In many cases, however, it is simply too early to judge the efficacy of the changes. A credible evaluation of these anticipated changes and their possible impacts would entail an extensive study that is beyond the scope of this synthesis effort.

The board identified four themes from its analysis of the six reports: (1) clarify the role and mission of OST, including effective use of strategic plans; (2) put discipline into decision making; (3) expand the reach of OST's efforts outside DOE; and (4) address constraints to technology implementation. **The board's overall conclusion is that OST has made some progress since the BRWM's most recent overall assessment of its technology development program (NRC, 1996). However, the board believes that additional efforts are needed.** Many factors have hindered progress, including conflicting directions given by regulators, Congress, and other parts of DOE; reduced funding; interagency conflicts; and that a decade or longer is often required to develop and implement truly innovative technologies. The board believes that a lack of management leadership in OST, EM, and DOE also has been a factor. The board offers upper-level DOE management and Congress the following recommendations to address these issues.

CLARIFY THE ROLE AND MISSION OF OST

The lack of well-defined strategic goals for OST is one of the most consistent themes of the six reports.[4] Some areas within OST (e.g., the Mixed

[4] Detailed references to the individual reports are not included in this Summary. References to the individual reports that form the basis of the board's conclusions and recommendations are provided in the corresponding section of the body of this report.

Waste Focus Area) have done reasonably well in defining strategic plans. The implementation of many of OST's programs has suffered, however, because there existed no formal strategic plan on which to base discussions, select alternatives, and manage the program, and because OST strategic goals have not been sharply focused.[5] Despite these problems, the board believes that there is a role for centralized research, development, and demonstration (RD&D) activities in providing economical, effective, acceptable, and practicable technologies for use in DOE-EM site cleanups.[6] Although OST accounts for only a small part of the DOE-EM budget, its work can have substantial and beneficial impact in reducing the costs (and the risks) of environmental remediation activities.

To achieve this potential role, the board recommends that OST managers, in conjunction with other top-level EM managers, produce strategic goals and plans that define explicitly the technical problem areas that OST program units will and will not address. Any top-level strategic goals developed by OST should be consistent with the EM mission and be derived in concert with technology user plans and needs. It is important to recognize that ten years or more is a realistic time frame for development, demonstration, and deployment of truly innovative technologies. Such long-term efforts should target both site-specific and complex-wide problems that are either intractable or very difficult (e.g., expensive) with current technologies.

Lists of major recommendations from all of the individual reports also are provided in Appendix A through F.

[5] The board notes that DOE-EM recently released a Research and Development Program Plan (DOE, 1998a) and a Strategic Plan for Science and Technology (DOE, 1998b). Due to the limited time available to prepare this report, the extensive study that would be required to evaluate the efficacy of these new plans, and the board's task (i.e., to summarize and synthesize recent NRC reports), the board did not conduct a detailed evaluation of these documents or their possible impacts.

[6] The Decision Making Committee recommended that “A centralized RD&D function within DOE-EM should be maintained because of its potential advantage in coordinating potentially duplicative technology development efforts needed at DOE-EM sites and because it is in a better position to address important broader issues (e.g., alternative technologies in the baseline functional flowsheets and alternative functional flowsheets) than more specifically directed RD&D” (Decision Making report, p. 74).

PUT DISCIPLINE INTO DECISION MAKING

The recent reports point to a lack of discipline as a significant problem in OST's decision-making processes. In particular, the committees found that often OST's decision-making process has been ad hoc and frequently has varied from site to site and from decision to decision.

To be effective, a technology development program must begin by defining and specifying particular problems to be solved, rather than by developing a solution and then looking for a problem. Another theme from the six reports is that such an approach generally has not been used by DOE-EM to manage its technology development activities. Sound decision making also demands that, in the face of technical uncertainty, multiple paths be explored to achieve intended goals. **The board recommends that DOE-EM implement an end state based methodology**[7] **(similar to that described in the Tanks report) to identify the technology needs and research and development required to achieve specific remediation goals. As part of this approach, DOE management and legislative decision makers should allow for consideration of a wider range of alternative end states that may be needed in the future, and this should be reflected in the DOE remediation and technology development programs. Alternative end states and scenarios should be considered for remediation scenarios that involve high uncertainty or high risk.**

OST has elements of a decision-making process throughout its organizational parts but it has not had a process that is applied universally and systematically across the entire organization.[8] **The board recommends that, for decisions involving the allocation of significant resources, OST institute a decision-making structure in which projects and proposals are evaluated**

[7] In this conceptual approach, the term “end state” does not necessarily connote a *final* disposition of the waste or waste site; that is, further phases with new end states may occur.

[8] OST recently pilot tested a new system (its Work Package Ranking System) to create an integrated priority list of “work packages” (i.e., a group of related projects) at the OST headquarters level. The new process employs five criteria to rank the work packages: site needs, project value/need, future technology deployments, technological risks, and technology cost savings (DOE, 1999a,d). In this new system, a numerical score for each work package is produced through a process stated to be based on multiobjective decision analysis methodology. Beyond this generality, the processes used to determine the scoring criteria, ranking factors, and weighting factors have not been specified (Decision Making report, p. 48). The Decision Making Committee noted that, in principle, this prioritization process could be used to set budget targets for OST program units. However, the committee also pointed out that this system was not yet developed to a point where OST staff could use this process as the sole basis for prioritization (Decision Making report, p. 48).

against consistently defined criteria such as project cost, probability of technical success, probability of implementation, potential cost savings, and human health risk reduction. The recommended decision-making process should be transparent, include participation from relevant interested and affected parties,[9] incorporate adequate documentation, involve peer review, and lead to setting priorities.

There have been no general OST-wide guidelines applied to OST programs for setting criteria for the selection and prioritization of technology development needs, although individual OST program units have developed their own guidelines. **The board recommends that OST (with input from its various organizational elements) establish general selection and prioritization criteria, and guidelines for applying these criteria, including allowance for instances where exceptions to the guidelines may be necessary.**

EXPAND OST'S REACH OUTSIDE DOE

A criticism in the 1996 CEMT report (NRC, 1996a) and repeated in several of the recent six reports is that OST does not adequately search for technologies in the international community nor in the domestic industrial and, to a lesser extent, academic communities. Based on OST responses to recent NRC reports, it appears that DOE has made some progress in creating data systems for environmental management technologies. However, most of these efforts so far appear to be focused on DOE-developed technologies, rather than as a mechanism to search and identify relevant technologies that have been developed external to DOE. **DOE-EM should be more aware of technologies developed in the private, academic, and foreign sectors. OST should establish a better coordinated, less duplicative, and less cumbersome system for integration of technology procurement activities. OST should improve its formal linkages to demonstrated technologies from outside DOE, perhaps by expanding its existing databases. Doing so will require improving OST's (or DOE's) outreach and ability to identify and use non-DOE technology.**

[9] See *Understanding Risk: Informing Decisions in a Democratic Society* (NRC, 1996c) for definition of the term “interested and affected parties” which is used throughout this report rather than the term “stakeholders.”

ADDRESS CONSTRAINTS TO TECHNOLOGY IMPLEMENTATION

The board recognizes that OST's actions are constrained by legal and regulatory requirements and other non-OST constraints, both within and external to DOE. Successful implementation of new and innovative technologies will require OST to identify these constraints, evaluate their validity and importance and, in some cases, take a more proactive role in effecting change. It is clear that merely identifying a promising technology will not result in implementation at DOE sites. Many other actions are necessary; some can be done by OST itself, but most will require OST to work with other elements in DOE. Some will also require DOE to work with other federal and state agencies. Because of the historical autonomy of individual DOE sites, there is currently no mechanism to ensure implementation of successful[10] OST-developed technologies. As long as authority for technology deployment and responsibility for technology development continue to reside in different entities, centralized development of technologies to be deployed throughout the DOE complex will not, in the board's view, be effective.

The board recommends that when contracts allow, agreements be developed between the sites and OST that, if certain agreed-on conditions are met, then OST-sponsored technology will be implemented at the site(s). The sites and OST would agree on technical requirements (e.g., throughput and contamination reduction percentages of processing equipment), schedules (e.g., when testing of equipment or full scale equipment will begin), and deployment costs. If these targets are met, then the sites would be required by DOE to deploy the technologies. If they are not met, the sites would be allowed to deploy any alternative that meets the targets, including those developed independently of OST. (Some flexibility, however, would be necessary to accommodate changes in regulations or multiparty agreements.) If not allowed by current contracts, DOE should consider adding such provisions to future contracts. For current contracts, DOE should consider developing incentives to encourage use of OST-developed technologies, when these meet the above conditions.

In addition, DOE-EM should work to promote consensus among the U.S. Environmental Protection Agency (EPA), the U.S. Nuclear Regulatory Commission (USNRC), the U.S. Department of Energy (DOE), and the scientific community on waste form testing methods that will be generally acceptable for providing at least a qualitative evaluation of long-term waste performance in disposal environments. DOE-EM should work with EPA and the USNRC to agree on clear guidelines that define acceptable waste

[10] Including economic as well as technological success.

forms for disposal of mixed waste in future near-surface disposal facilities. Well-documented decisions and sound technical reviews should be used by OST to earn the confidence of Congress and members of the public.

1

Introduction

In November 1989, the US Department of Energy (DOE) established its Office of Environmental Management (EM). The primary goal of the EM program is to clean up the legacy of environmental pollution at DOE facilities throughout the nation while reducing hazards to the environment and human health posed by the generation, handling, treatment, storage, transportation, and disposal of DOE waste. The undertaking was projected to cost billions of dollars each year for many decades to come and to require the application and development of new remediation technologies. It was further expected that because of the magnitude and complexity of the undertaking, if new technologies were available, cleanup could be achieved "faster, cheaper, and better." An Office of Technology Development (EM-50) was charged with carrying out an aggressive national program of technology development to meet some of the environmental restoration and waste management needs within the DOE complex (see Appendix H for EM-50's organizational structure as of August 1999).

Almost from the beginning, the Office of Technology Development (later renamed Office of Science and Technology, OST) was criticized by a number of external groups, including Congress, the General Accounting Office (GAO) and the National Research Council (NRC) (particularly, committees of its Board on Radioactive Waste Management, BRWM). Its history of turmoil and change (see section entitled "Background") reflects these criticisms, and by the mid 1990s, the Office of Science and Technology (OST) had been viewed by many as ineffective (NRC, 1996a; GAO, 1996).

As part of OST's efforts to become more effective, OST asked the NRC's BRWM to address six specific issues related to technology development activities in DOE-EM. The NRC established two panels and four subcommittees of its Committee on Environmental Management Technologies

(CEMT) in early 1997 to address these issues (Table 1).[11] Since December 1998 these committees have completed six reports on various aspects of OST's program (Box 1).

In late 1998 Gerald Boyd, head of OST, asked the BRWM to summarize the major findings and recommendations of these reports and synthesize any common issues into a few overarching recommendations to EM and OST[12] (see Box 2 for the Statement of Task). Such an assessment is timely because it is occurs soon after the appointment of a new Assistant Secretary for Environmental Management. The board believes that DOE leadership will find this report useful as it works to improve EM's efforts to research, develop, and deploy technologies for environmental remediation and restoration of DOE sites.

BOX 1: RECENT NRC REPORTS ON ASPECTS OF DOE'S OFFICE OF SCIENCE AND TECHNOLOGY

A Review of Decontamination and Decommissioning Technology Development Programs at the Department of Energy (NRC, 1998a) - December 1998 (the D&D report)

Peer Review in Environmental Technology Development Programs: The Department of Energy's Office of Science and Technology (NRC, 1998b) - December 1998 (the Peer Review report)

An End State Methodology for Identifying Technology Needs for Environmental Management, With an Example from the Hanford Site Tanks (NRC, 1999b) - February, 1999 (the Tanks report)

The State of Development of Waste Forms for Mixed Wastes: U.S. Department of Energy's Office of Environmental Management (NRC, 1999a) - June 1999 (the Mixed Waste report)

Groundwater and Soil Cleanup: Improving Management of Persistent Contaminants (NRC, 1999c) - June 1999 (the Subsurface report)

Decision Making Related to the U.S. Department of Energy's Environmental Management Office of Science and Technology (NRC, 1999d) - July 1999 (the Decision Making report)

[11] These panels and subcommittees were re-organized as ad hoc committees in August 1997 when the BRWM discontinued the Committee on Environmental Management Technologies.

[12] In the body of this report, recommendations taken directly from one of the subject reports include references to the subject reports (no references to the subject reports are included in the Summary). Recommendations in the body of the report with no references reflect the board's synthesis of the recommendations and analyses in the subject reports.

BOX 2: STATEMENT OF TASK

The BRWM will prepare a brief summary report on DOE-EM's efforts to research, develop, and deploy technologies for environmental remediation and restoration of DOE sites. The report will be based on the conclusions and recommendations from a series of BRWM reports to be completed after November 1998 that address different aspects of DOE-EM's technology development activities. The BRWM will summarize the most significant conclusions and recommendations from these reports, and will attempt to synthesize and generalize these issues, if possible, into a few major recommendations for the DOE. In preparing this summary report, the board may also use the findings of these reports to document how OST has addressed specific issues noted in the NRC's most recent assessment of DOE-EM's technology development program, “Environmental Management Technology-Development Program at the Department of Energy: 1995 Review.”

The board recognizes that the deployment of OST-developed technologies is, in many cases, decided by individuals and organizations with little or no connection to OST. Legislative and regulatory programs, as well as DOE policy decisions and funding constraints, play a major role in determining environmental management technology needs. Often these constraints play a more important role in environmental management technology selection than the performance of the technology (see Chapter 5).

THIS REPORT

BRWM committees have produced six reports since December 1998 (see Box 1) that address aspects of OST's technology development program. The advice offered in these reports ranges from recommendations addressing the management of OST to recommendations on specific technologies and R&D programs (the major recommendations from each of these reports are included as Appendix A, Appendix B, Appendix C, Appendix D, Appendix E through Appendix F). Much of this advice is program or context specific and is not readily generalized to OST as a whole. Nevertheless, the board has observed that there are several themes that pervade the discussions and recommendations in these reports—themes that, for the most part, address what the board considers high-level or first-order program management issues for OST and for DOE as a whole. The objective of the present report (see Box 2) is to provide a synthesis and discussion of these issues for action by upper-level DOE management and Congress.

In preparing the present report, the board has relied heavily on recent reports of its committees that have focused on technology development and deployment efforts within OST (see Box 1). Although some of these reports have only recently been released, most of the authoring committees completed their information-gathering and deliberations well before publication. Therefore, these reports may not take into account more recent changes that are being made by OST management in response to congressional, GAO, and BRWM criticisms. To better understand recent changes, the board received two briefings from OST in July *1998* and February 1999. The board also received written responses from OST to three of its recent reports (DOE, 1999b,c; 1998d) and a summary of changes made in response to the 1996 CEMT report (DOE, 1999a). The board reviewed these documents and, where appropriate, acknowledges where progress has been made. It is clear from these documents that OST has begun or is planning to make a number of changes to address the issues raised in the subject reports and to accomplish other programmatic goals. In many cases, however, it is too early to judge the efficacy of the changes. Moreover, a credible evaluation of these anticipated changes and their possible impact would entail extensive study, which is beyond the scope of this effort. The board believes that the conclusions and recommendations of this synthesis report will be useful to DOE leadership as it continues to address these challenges.

The present report does not supersede or substitute for the six committee reports, which provide more detailed assessments of the management and conduct of specific parts of OST programs. The six reports include extensive discussions and analyses to support many of the conclusions and recommendations presented in this report. The six reports also provide valuable primers on aspects of OST programs—including peer review, decision making, and "systems-based" approaches for conducting technology development programs—essentially to correct what the committees viewed as poor practices that have occurred within OST. The board does not reproduce any of this material in this synthesis report but commends this material, as well as all of the findings and recommendations in the six reports (see Appendix A, Appendix B, Appendix C, Appendix D, Appendix E, and Appendix F for the major recommendations from the reports), to OST and upper-level DOE management for review and action.

TABLE 1 Summary of Tasks and Study Milestones for BRWM Committees

Committee Name	Summary of Statement of Task	Committee Formed	Information Gathering Completed	Report(s) Completed
Decontamination and Decommissioning (D&D)	• Review OST's technology development and demonstrations relevant to alternative D&D approaches and their effects on different end-state scenarios, focusing on OST's Large Scale Demonstration Projects (LSDPs). • Review the applicability of the experience gained from the LSDPs to D&D throughout the DOE complex.	4/97*	12/97	12/98
Peer Review	• Evaluate the effectiveness of OST's new peer review process and make specific recommendations to improve it, based on a comparison of OST's practices to generally accepted norms for scientific and technical peer review.	2/97	4/98	10/97 (interim) 12/98 (final)
Tanks	• Provide recommendations for an approach to identify technology requirements for remediating high-level waste tanks across the DOE weapons complex. To illustrate the committee's approach, consideration will be given to a select number of site-specific remediation scenarios. • Identify and review selected process steps within each of the scenarios. • Review technologies being developed by DOE that support remediation of high-level waste tanks to determine whether the right needs are being addressed and the right technologies are being pursued.	4/97	early 1998	3/99

Mixed Waste	• Provide an independent review and recommendations on the state of development of final waste forms for mixed wastes. • Identify technology development options for the DOE to consider in producing final waste forms for the treatment of mixed wastes.	4/97	12/97	6/99
Subsurface Contaminants	• Assess alternative technologies for the characterization, containment, and cleanup of dense nonaqueous phase liquids and metals in the subsurface and the potential applicability of the technologies at DOE facilities.	4/97	5/98	6/99
Decision Making	• Evaluate the effectiveness of OST's decision-making processes by addressing: – the appropriateness and effectiveness of decision-making processes to select, prioritize, and fund R&D activities; – technical factors appropriate to consider in the development of cleanup technologies and the adequacy with which these factors can be measured; – recommendations for improvement; and – the role and importance of an effective peer review.	3/97	4/98	7/99

* Date last committee members were appointed. Information gathering by continuing members of the D&D subcommittee began in December 1996.

BACKGROUND

In 1994, the GAO issued a report (GAO/RCED-94-205) that evaluated the internal and external barriers that inhibit the use of new and innovative technologies in environmental cleanup. GAO concluded that after five years of effort and the expenditure of hundreds of millions of dollars by its Office of Technology Development, DOE lacked a well coordinated and fully integrated technology development program. In response to this report, the Assistant Secretary for Environmental Management announced a new approach to environmental research and technology and changed the name of the Office of Technology Development to the Office of Science and Technology (OST). According to OST, an awareness of the needs of customers, users, regulators, and other interested and affected parties[13] was integral to OST's new, solution-oriented approach. Some of the key features of this new approach were stated to be:

- establishing five focus areas to address DOE's most pressing problems;
- teaming with customers in the Office of Waste Management (EM-30), the Office of Environmental Restoration (EM-40), and the Office of Nuclear Material and Facility Stabilization (EM-60) to identify, develop, and implement needed technology;
- focusing technology development activities on major environmental problems;
- involving industry and academia to stimulate technological breakthroughs; and
- enhancing the involvement of regulators and stakeholders in the implementation of technology development (GAO, 1996).

In late 1994, DOE asked the NRC to form a committee (Committee on Environmental Management Technologies [CEMT]) to provide continuing independent advice to DOE-EM on its technology development program. In 1995, CEMT formed five subcommittees corresponding to OST's five focus areas. In March 1996, CEMT published its report *Environmental Management Technology-Development Program at the Department of Energy 1995 Review,* which noted that only limited progress had been made by OST. CEMT concluded that “major improvements are needed in the fundamental management processes if the EM research and technology development program is to meet its responsibilities to the DOE and the public” (NRC, 1996a, p. 2).

[13] See *Understanding Risk: Informing Decisions in a Democratic Society* (NRC, 1996c) for definition of the term “interested and affected parties,” which is used throughout this report rather than the term “stakeholders.”

CEMT further concluded that a "great deal more needs to be done before the DOE-EM has a vital, focused, and coordinated technology-development program sufficient to support the technically and organizationally complex waste-remediation program effectively" (NRC, 1996a, p. 1).

The report included five recommendations to DOE:

1) develop and implement quantitative criteria by which technology development efforts can be prioritized and success can be measured;
2) carefully consider the waste streams in determining adequate technology development needs;
3) systematically assess and document previous and current efforts to develop and apply technologies using the quantitative criteria mentioned above;
4) apply effective external peer review in the selection, evaluation, and prioritization of projects; and
5) improve the system for information gathering and documentation of technologies that are available or under development at other organizations in the United States and abroad.

In the fall of 1996, the conclusions expressed in another GAO report, "Energy Management: Technology Development Program Taking Action to Address Problems" (GAO, 1996), generally confirmed the CEMT recommendations.

In late 1996, DOE asked the CEMT to address six issues related to DOE-EM technology development activities. The NRC established two panels and four subcommittees of the CEMT in early 1997 to address these issues. To streamline its oversight structure, in August 1997, BRWM discontinued CEMT, reorganized its subcommittees and panels into ad hoc committees, and formed a working group from its own membership to oversee the committees. (See Table 1 for the tasks and major milestones for each activity.)

In September 1998, the GAO issued another report on EM's technology development efforts, "Nuclear Waste: Further Actions Needed to Increase the Use of Innovative Cleanup Technologies" (GAO, 1998). The GAO estimated that, as of January 1998, OST had an overall deployment rate of 12-18 percent, which was less than the 21 percent estimated by OST (GAO, 1998, p. 5). The GAO found that DOE-EM had addressed several obstacles to using innovative technologies (e.g., federal and contractor staff had become better informed about relevant innovative cleanup technologies and DOE and its regulators had improved their working relationships). Despite this progress, however, the GAO identified three matters that continued to hinder the deployment of OST-developed technologies: (1) OST has not involved users when technologies are being developed; (2) EM policy does not clearly state who should pay for modifications often required to fit a specific site's needs; and (3) OST has not provided enough technical assistance to sites during technology selection and implementation.[14] GAO also questioned EM's commitment to its efforts to increase deployment through the formation of the Technology Acceleration Committee, the identification of performance metrics, and the requirement for site deployment plans. Again, lack of “user involvement” in OST projects was cited as a significant barrier to OST's deployment initiatives.

Table 2 summarizes DOE-EM's budget for technology development and related activities from fiscal year (FY) 1990 to FY 1999. The data for DOE-EM, OST, and most of OST's major budget categories show a steady increase over the first 5 years (through FY 1994), then a plateau (FY 1994-1996), followed by reductions. EM's budget experienced a 6.5 percent reduction in FY 1997, followed by relatively stable funding through FY 1999. OST's budget, however, has experienced a significant reduction every year since FY 1996, decreasing by a total of approximately 40 percent relative to its peak funding in FY 1995. OST funding as a percentage of DOE-EM funding also has decreased from over 6 percent in FY 1997 to approximately 4 percent in FY 1999. The two technical areas most affected by the budget cuts in OST have been the Mixed Waste and Subsurface Contaminants focus areas. Another notable change in OST's budget occurred in FY 1996, when Congress mandated the Environmental Management Science Program (EMSP) to stimulate basic research and technology development for cleanup of the nation's nuclear weapons complex (NRC, 1997a). Approximately $50 million has been appropriated to the program annually. See NRC (1997b) for an assessment of the EMSP.

[14] “GAO recommended in 1994 that EM give OST a formal role in technology selection decisions. However, the recommendation was not implemented because site personnel lack confidence in OST's ability to provide expert technical advice and assistance and are therefore reluctant to allow OST a formal role in their technology selections.” (GAO, 1996, p. 8)

TABLE 2 DOE-EM Budget (Budget Authority, in millions of dollarsa)

	FY90	FY91	FY92	FY93	FY94	FY95	FY96	FY97	FY98	FY99
EM	2274	3601	4287	5520	6175	6280	6100	5700	5600	5800
OST Total[b]	183.5	236.0	303.4	362.2	393.8	409.6	396.1	351.9	269.2	243.1
(% of EM)	(8.1)	(6.6)	(7.1)	(6.6)	(6.4)	(6.5)	(6.5)	(6.2)	(4.8)	(4.2)
OST Focus Areas										
Mixed Waste	-	26.9	23.6	43.0	56.5	29.6	49.8	43.7	16.5	11.0
Tanks	-	8.3	19.8	18.8	23.5	23.1	30.9	37.2	38.4	34.6
D&D	-	8.5	13.9	5.5	4.5	12.9	15.5	13.5	18.0	15.3
Subcon	-	54.6	49.5	68.7	82.1	63.7	55.1	35.7	18.6	24.9
OST Crosscutting Areas										
Characterization	-	3.1	6.1	9.2	25.1	19.5	14.5	13.3	10.5	9.6
Efficient Separations	-	4.9	1.8	10.8	13.3	14.7	12.7	12.2	5.5	2.0
Robotics	-	20.0	17.5	27.3	21.4	22.3	15.0	12.1	7.1	6.2
Other OST Programs										
Industry/University		29.7	54.7	33.5	48.0	61.1	60.2	62.9	60.9	37.1
EM Science	-	-	-	-	-	-	48.9	48.7	46.1	47.0

[a] Then-year (i.e., not constant) dollars.

[b] Total budget for OST includes funding for activities not provided in this table, including other program units (e.g., Risk Program Technology Systems Applications), management, education, and program support. Funding levels for OST program units therefore do not sum to the total for OST. This table also does not include R&D funding for remediation projects by other DOE-EM offices (e.g., EM-30, EM-40).

2

Clarify the Role and Mission of OST

In 1998, DOE Office of Environmental Management (EM) published its Strategic Plan for Science and Technology,[15] which includes the following mission statement for its science and technology efforts (DOE, 1998b, p. 3):

> Provide the full range of science and technology resources and capabilities, from basic research to development, to demonstration and deployment to technical assistance, that are needed to deliver and support fully developed, deployable scientific and technological solutions to EM cleanup and long-term environmental stewardship problems.

However, an overarching issue raised in the six reports is how the role and mission of EM's Office of Science and Technology (OST) should be defined, and how OST's role and mission relate to those of other parts of DOE-EM. There are several possibilities, which are not mutually exclusive:

- develop new technologies,
- find applicable technologies,
- adapt existing technologies to address DOE-EM problems,
- communicate or negotiate with users and other interested and affected parties, and

[15] DOE-EM also released a Research and Development Program plan in late 1998 (DOE, 1998a). Due to the limited time available to prepare this report, the extensive study that would be required to evaluate the efficacy of these two new plans, and the board's task (i.e., to summarize and synthesize recent NRC reports), the board did not conduct a detailed evaluation of these documents or their possible impacts.

- market OST-developed technologies.

Several of the committees have provided insights on this issue. The Subsurface Contaminants Committee recommended that DOE-EM continue to invest in developing groundwater and soil remediation technologies because existing technologies are not adequate for cleaning up large quantities of contaminated groundwater and soil, as required by federal law (Subsurface report, p. 13). The Mixed Waste Committee recommended that waste form[16] development no longer be the primary focus of the Mixed Waste Focus Area (MWFA) because currently available waste forms are sufficiently developed to enable proper disposal of DOE's known and expected mixed waste inventory. Instead the committee recommended that the MWFA emphasize engineering design, integration, and scale-up of its proposed treatment processes and their demonstration and deployment at the DOE sites (Mixed Waste report, p. 98). The D&D Committee questioned whether simply testing and providing information about commercially developed technologies is a suitable role for the DDFA (D&D report, p. 25). The board did not attempt to settle the matter, but believes that to be effective, OST's role should be clear, and it has not been. It is also not clear how the OST mission relates to that of EM, DOE, and the sites.

The board concludes that there is a role for centralized research, development, and demonstration (RD&D) activities in providing economical, effective, acceptable, and practicable technologies for use in DOE-EM site cleanups. Although OST accounts for only a small part of the DOE-EM budget, its work can have substantial beneficial impact in reducing the cost (and risk) associated with environmental remediation activities, which are estimated to be over $100 billion (Decision Making report, p. 74, 86).[17]

To realize this potential role, the committees offered a number of findings and recommendations to improve OST's strategic planning and prioritization processes (including ways to enhance participation by the sites) and to target its mission to short-term and long-term objectives.

---

[16] A “waste form” is a solid material that is the product of one or more treatment processes (Mixed Waste report, p. 2).

[17] The Decision Making Committee did not consider other possible organizational structures to accomplish the RD&D needed in DOE-EM. Therefore this conclusion from the Decision Making report (and others) are specific to the context and associated challenges provided by the DOE-EM organizational structure examined in the course of this study (Decision Making report, p. 10).

STRATEGIC PLANNING AND PRIORITIZATION

A consistent theme in the six reports is the lack of well-defined strategic goals for OST.[18] Program implementation has suffered because there existed no formal strategic plan on which to base discussions, select alternatives, and manage the program, and because strategic goals developed by OST have not been sharply focused in the past.[19] Such criticisms were not universal, however. For example, the Mixed Waste Committee complimented the Mixed Waste Focus Area (MWFA) and recommended continuing the practice of identifying, prioritizing, and responding to technology deficiencies (Mixed Waste report, p. 99). The committee also recommended that OST integrate treatment technologies into a mixed waste treatment strategy (Mixed Waste report, p. 102). In addition, as pointed out by the Decision Making Committee, this issue is not solely an OST problem, because the strategic goals for OST must be guided and constrained by priorities established by other DOE-EM offices—priorities that also have varied over the years (Decision Making report, p. 80). The committee also found that OST's strategic goals do not provide an adequate level of guidance for program managers as they attempt, in collaboration with users, to assign priorities to technology needs (Decision Making report, p. 79). The board recommends the following actions to address this issue:

- **OST managers, in conjunction with other top-level EM managers, should produce strategic goals and plans that define explicitly the technical problems that OST program units will and will not address (Decision Making report, p. 6).**
- **Any top-level strategic goals developed by OST should be consistent with the EM mission and be derived in concert with technology user plans and needs (Decision Making report, p. 80).**

[18] "OST's strategic goals do not provide an adequate level of guidance for program managers as they attempt, in collaboration with users, to assign priorities to technology needs" (Decision Making report, p. 79).

"The overall goals of SCFA's [Subsurface Contaminants Focus Area] technology development program have to be better defined in order to evaluate success" (Subsurface report, p. 214).

[19] "There is a lack of top-down evaluation and prioritization of DDFA activities." (D&D report, p. 2)

"SCFA should identify key technical gaps and prepare a national plan for developing technologies to fill these gaps" (Subsurface report, p. 214).

LONG-TERM OBJECTIVES

Due to the time generally required to research, develop, and deploy new technologies, it is unrealistic to expect unproven, truly innovative technologies to affect major cleanup tasks by 2006 (D&D report, p. 22). **Ten years or more is a realistic time frame for development, demonstration, and deployment of truly innovative technologies. Such long-term efforts should target both site-specific and complex-wide problems that are either intractable or very difficult (e.g., expensive) with current technologies (D&D report, p. 22).**

3

Put Discipline into Decision Making

DOE-EM has spent billions of dollars to introduce technologies to remediate environmental problems at DOE's weapons complex sites and yet has continued to be subjected to strong criticism for lack of performance (i.e., few deployed technologies) (GAO, 1996, 1998).[20] BRWM reports have pointed to a lack of discipline in DOE-EM and OST's decision-making processes as a significant cause of this problem. In particular, the reports indicate that the decision-making process often has been ad hoc and frequently has varied from site to site and from decision to decision. Unless decision making can be improved significantly, criticism likely will intensify. The findings and recommendations from these reports address three components of an effective decision-making process: (1) framing decisions, (2) making decisions, and (3) prioritizing needs and evaluating results.

FRAMING DECISIONS

The six reports emphasize two broad issues related to framing decisions about technology development: defining goals and considering alternatives. The reports provide three main examples of how OST's technology development

[20] The Subsurface Contaminants Committee pointed out that DOE is not alone in its limited application of innovative technologies. For example, the committee cited an EPA estimate that innovative remedies have been selected for contaminated ground water at just 6 percent of all CERCLA sites as of 1995 (Subsurface report, p. 203). The committee also noted that despite slow progress in deploying innovative remediation technologies, the SCFA has helped to develop a number of technologies that have shown considerable promise (Subsurface report, p. 11).

goals could be better defined: (1) through the use of an end state based methodology, (2) through consideration of waste forms, and (3) through the use of baseline functional flowsheets.[21] The reports also emphasize the importance of developing alternative technologies and alternatives to baseline functional flowsheets.

Defining Goals

To be effective, a technology development program must begin by defining and specifying particular problems to be solved,[22] rather than by developing a solution and then looking for a problem (D&D report, p. 24). An important theme from the six reports is that such an approach had not been used by DOE-EM to manage its technology development activities. For example, the Tanks Committee concluded that DOE's process for screening and formulating technology needs lacks a systematic basis (Tanks report, p. 1). Similarly, the D&D Committee found that the prospective uses of facilities that will undergo decontamination and decommissioning have not been defined adequately, and this has prevented OST from assessing the technology needs, cost, and schedule for D&D projects (D&D report, p. 3). The committee found no evidence of significant progress in defining or even proposing goals to be targeted by new technologies (D&D report, p. 3).

End State Based Methodology

Both of the aforementioned reports (the Tanks report and the D&D report) make frequent reference to the concept of "end states." As used in the Tanks report, "an end state can be expressed as the desired composition, configuration, performance, and location of a particular waste product at the completion of remediation activities, frequently wastes emplaced in a disposal facility. *If the phased-decision approach previously recommended by the National Research Council (1996b) were to be used, the end state may be that associated with the end state of one of the phases*" (Tanks report, p. 15-16, emphasis added). As the italicized passage makes clear, within this conceptual approach an end state is not necessarily a final state. In other words, further phases with new end states may occur.

[21] A baseline functional flowsheet is the sequence of steps that comprise the waste treatment process from the initial waste configuration to the final state.

[22] Of course, the technology program must base these problems on technology needs identified by the sites (see discussion on "Input from Sites/Users").

The Tanks Committee recommended that DOE adopt a systems engineering approach for identifying technology requirements to remediate stored tank wastes (Tanks report, p. 7). The recommended approach involves the analysis of remediation scenarios[23] to identify the technologies needed to achieve specified goals. The committee concluded that such an approach would serve two fundamental objectives: (1) greatly facilitate the efficiency and visibility of EM's efforts to provide the technologies required to remediate high-level waste tanks throughout the DOE complex, and (2) clearly expose the underlying basis of the technology development program (including the ability to reach a prescribed end state in a cost-effective manner), which is critical to gaining public understanding and support for the program (Tanks report, p. 2, 6). The committee argued that this can be done even though substantial uncertainties exist in the end states (Tanks report, p. 6). The committee further suggested that such an approach should be generally applicable to any of the waste tank farms throughout the DOE nuclear weapons complex and possibly other DOE-EM problems (Tanks report, p. 1).

Waste Forms

As an example of how OST should better define goals, the board uses the results of the Mixed Waste Committee. In its report, the committee evaluated the state of development of waste forms for mixed wastes and found that currently available waste forms are adequate (sufficiently developed) to enable proper disposal of DOE's known and expected mixed waste inventory. These waste forms resulted mainly from the intensive worldwide efforts and experience in developing waste forms for high- and low-level radioactive waste, and include grout, glass, ceramics, polymers, and compacted waste (Mixed Waste report, p. 3).[24] The committee therefore recommended that waste form development no longer be a primary focus of the Mixed Waste Focus Area (MWFA) (Mixed Waste report, p. 98). Instead, the committee recommended that the MWFA emphasize engineering design, integration, and scale-up of its proposed treatment processes and their demonstration and deployment at the DOE sites (Mixed Waste report, p. 98).

[23] For this report, a scenario is loosely defined as the sequence of events that takes wastes in their current status to desired end states.

[24] The Mixed Waste report did not give explicit credit to new OST technology development. A similar conclusion was reached in the 1996 report: “The MWFA has determined that 90 percent of the mixed-waste streams can be treated with technologies that currently exist or that can be modified” (NRC, 1996a, p. 69).

The Mixed Waste Committee also concluded that conceptual design of treatment processes and waste form selection can proceed, but the upfront characterization is inadequate for detailed engineering design of treatment processes or process optimization (Mixed Waste report, p. 100). To address this issue, the committee recommended that the MWFA: (1) develop simplified methods to characterize the waste up front, with emphasis on nondestructive examination and assay techniques; (2) continue to develop and implement techniques and procedures to ensure that all new waste streams are characterized adequately; and (3) strive for a balance between the effort and cost of up-front characterization and the effort and cost to develop more robust technologies (Mixed Waste report, p. 100). The MWFA assigned improved waste characterization first priority in its list of technology needs.

Flowsheets

The Decision Making Committee discussed the use of baseline functional flowsheets (i.e., the sequence of steps that comprise the waste treatment process from the initial waste configuration to the final state) as fundamentally important to determining technology needs.[25] The committee found that one major problem with the system has been that OST has had no direct role in establishing such flowsheets, which have been developed at the sites by the site remediation problem owners (Decision Making report, p. 75). The committee concluded that the expertise of OST and its contractors could be valuable to the site problem owners in formulating and maintaining technically sound and practicable cleanup functional flowsheets and recommended that efforts be made to have substantial involvement of OST and OST contractors in reviews of functional flowsheets (Decision Making report, p. 75). The committee argued that such OST participation would have the dual benefits of (1) ensuring that OST technology developers fully understand the sites problem owners' technical needs and their bases, and (2) increasing the sites' confidence in OST's dedication and ability to meet their needs (Decision Making report, p. 75-76).

[25] For OST-developed technologies to be adopted at the sites, OST must persuade site managers and contractors to adopt different technologies from those they are already committed to use (i.e., its baseline technologies). OST therefore needs to undertake studies that compare existing baseline technology costs with more favorable costs of OST-proposed technologies (Decision Making report, p. 75).

Alternatives

In the face of technical uncertainty, sound decision making demands that multiple paths to achieve goals be explored. The importance of considering alternatives in technology development was emphasized in both the Tanks and Decision Making reports, as well as other recent NRC reports (e.g., NRC, 1996b). The Tanks Committee found that one major weakness of EM's approach to technology development for the Hanford Site tanks was a lack of consideration of end states other than those baseline scenarios codified in various site-specific compliance agreements (Tanks report, p. 6). The committee concluded that scenarios involving alternative end states may need to be considered for such reasons as life cycle costs, technical failures, and delays in meeting schedules when originally selected end states present problems (Tanks report, p. 5). The committee did recognize that such an approach would require a major change in DOE-EM technology development philosophy because alternative end states are outside the present plans of both the remediation programs and the technology development organization (Tanks report, p. 5). Indeed it could require either renegotiation of some of DOE's current legally binding agreements, or legislation by the Congress. For this reason, recommendations related to alternatives (in the Tanks report and included in this report) are directed primarily to the Assistant Secretary for EM and the Secretary of DOE.

The Decision Making Committee found that good decision making practices (e.g., hedging against technical uncertainty and insisting on alternatives) imply that DOE-EM should plan for alternatives to the site baseline functional flowsheets, especially when the baseline flowsheet involves high cost, high or poorly defined risk, and/or substantial probability of technical failure (Decision Making report, p. 76). To address this issue, the committee recommended that EM seek out and acknowledge the potential vulnerabilities—in cost, risk, and technological failure—of the baseline functional flowsheets and processes, and with OST's assistance, develop alternative flowsheets as appropriate. The committee recommended that OST encourage this course of action and seek to collaborate in it. In particular, the committee recommended that OST identify specific technology development opportunities aimed at supporting alternative functional flowsheets and processes designed to enhance the overall probability of remediation successes and to minimize program delays (Decision Making report, p. 76).

Recommendations

DOE-EM should implement an end state based methodology[26] (similar to that described in the Tanks report) to identify the technology needs and research and development required to achieve specific remediation goals. Such an approach would include the following characteristics:

- **DOE management and legislative decision makers should allow for consideration of a wider range of alternative end states that may be needed in the future, and this should be reflected in the DOE remediation and technology development programs (Tanks report, p. 5).**
- **Alternative end states and alternative scenarios should be considered for remediation scenarios that involve high uncertainty or high risk.**
- **OST should be allowed to commit a portion of its resources to developing technologies to address needs derived from alternative functional flowsheets, in addition to developing technologies to meet the needs derived from the baseline flowsheets (Decision Making report, p. 76).**
- **If initial conditions cannot be adequately characterized and end states cannot be adequately specified, a plan leading to the timely resolution of open items should be prepared and executed. In the interim, assumptions that allow scenario development and identification of technology needs to proceed should be emplaced and clearly stated, preferably by problem owners, but by technology providers if necessary (Tanks report, p. 7).**

MAKING DECISIONS

The Decision Making Committee found that, as OST's decision-making process has matured, it has functioned reasonably well to prioritize technologies for funding at individual sites and to make decisions for funding among sites within OST's operational framework. However, some of the process steps are

[26] As noted previously, with this conceptual approach, the term “end state” does not necessarily connote a *final* disposition of the waste or waste sit; further phases with new end states may occur.

cumbersome and ill conceived. Furthermore, there has been little effort to apply a carefully considered process uniformly throughout OST (Decision Making report, p. 87).[27] Other committees, including the Peer Review Committee, the Mixed Waste Committee, the Subsurface Contaminants Committee, and the D&D Committee, also analyzed parts of OST's decision-making process. Based on its review of these reports, the board has identified four main areas where OST can improve its decision-making process: (1) adequate documentation and communication of results; (2) use of independent, external expert review; (3) use of input from sites and other affected parties; and (4) increased transparency.

Documentation and Communication of Results

The importance of adequate technical documentation and communication of results has been emphasized in several recent board reports. For example, the Decision Making Committee noted that the type and quality of information provided to Congress and other interested review groups are critically important to OST. The committee recommended that OST ensure that the decisions underlying the technologies it develops are well documented and supported by sound technical reviews (Decision Making report, p. 79). The Peer Review Committee commended OST's peer review program for modifying the documentation required for peer reviews to focus on technical issues. However, the committee pointed out that the program does not require a detailed technical proposal or statement of work, and recommended that such a document be required for every peer review (Peer Review report, p. 10). The Subsurface Contaminants Committee found that Subsurface Contamination Focus Area (SCFA) periodic technology summary reports were not sufficiently detailed to evaluate potential technology performance and effectiveness relative to other technologies, and recommended that such reports include well-documented

[27] OST recently pilot tested a new system (its Work Package Ranking System) to create an integrated priority list of “work packages” (i.e., a group of related projects) at the OST headquarters level. The new process employs five criteria to rank the work packages: site needs, project value/need, future technology deployments, technological risks, and technology cost savings (DOE, 1999a,d). In this new system, a numerical score for each work package is produced through a process stated to be based on multiobjective decision analysis methodology. Beyond this generality, the processes used to determine the scoring criteria, ranking factors, and weighting factors have not been specified. The Decision Making Committee noted that in principle, this prioritization process could be used to set budget targets for OST program units. However, the committee also pointed out that this system was not yet developed to a point where OST staff used it as the sole basis for prioritization (Decision Making report, p. 48).

performance data, detailed cost estimates, design information useful to practitioners, and lessons learned (Subsurface report, p. 246). The committee also recommended that a key future role for the SCFA be the development of design manuals for technologies that could be used across the DOE weapons complex (Subsurface report, p. 216). In addition, the D&D Committee concluded that one factor that limited the acceptance of OST-demonstrated technologies was the lack of prompt dissemination of technical and cost data on these projects (D&D report, p. 2). The committee recommended that the D&D Focus Area communicate its program results in a more effective manner (D&D report, p. 4).

Independent, External Expert Review

The Peer Review Committee conducted a detailed evaluation of the peer review[28] process that OST established in 1996 to perform independent technical assessments of technology projects. During the course of the study, OST continued to change its peer review procedures, partly in response to comments in the committee's interim report. The changes were intended to improve the peer review program and were generally found by the committee to be steps in the right direction. In particular, OST (1) revised its review criteria to focus on four technical issues; (2) developed a more systematic approach for selecting projects to be reviewed; and (3) modified its list of documentation required for peer reviews (Peer Review report, p. 6). The committee also noted that OST senior management appears to be committed to this improvement process (Peer Review report, p. 7). Based on this report and its contrast with prior critical reviews of OST's peer review efforts (NRC, 1996a), it appears that OST has made significant improvements in this program.

Despite these improvements in the procedures used to conduct peer review, however, the Peer Review Committee identified several important issues that remain to be addressed: peer reviews are not being incorporated adequately into decision making (Peer Review report, p. 7); OST is overwhelmed with a backlog of needed peer reviews (Peer Review report, p. 11);[29] for peer reviews to make a difference, new procedures, while important, are not enough—instead a culture change also is needed (Peer Review report, p. 13); and unless OST uses peer reviews judiciously, it runs the risk of adding yet more reviews and paperwork, even as its budget continues to shrink (Peer Review report, p. 13).

[28] Peer reviews are defined as evaluations by technical experts who are independent of, and external to, the program of work being reviewed.

[29] As of May 1998, only 43 of 226 active projects had been peer reviewed.

The committee made a number of recommendations to address these issues. First, OST program managers should be required to clearly identify the upcoming decision or milestone for which the peer review results will be used, before a project is chosen to be reviewed (Peer Review report, p. 7). Second, prioritization should be applied to the selection of projects for peer review and how the peer reviews are conducted; for example, OST should consider adopting a triage approach[30] to allow more effective in-depth reviews (Peer Review report, p. 11). Third, OST leadership should develop a strategy to accomplish a change in its organizational culture so that OST staff recognize and accept the value of independent expert advice (Peer Review report, p. 14).

The Decision Making and Subsurface Contaminants Committees also considered the role of independent external review in OST's decision-making process. The Decision Making Committee concluded that independent expert reviews are a vital part of a credible decision-making process (Decision Making report, p. 76), and that peer reviews of technology projects should be part of OST's decision-making process. The committee also pointed out that the evaluation of technology development projects is but one step in OST's decision-making process (Decision Making report, p. 8). The Subsurface Contaminants Committee recommended that the SCFA significantly increase the use of peer review for determining technology needs and for evaluating projects proposed for funding (Subsurface report, p. 9).

Both the Peer Review and Decision Making Committees identified additional areas to which external independent reviews could be applied usefully. The Peer Review report included a detailed discussion on how peer reviews could be used to assess the technical merit of programs (Peer Review report, p. 46-47). The Decision Making Committee recommended that OST use an external independent body to review the bases of annual decisions that establish budget targets for OST program units (Decision Making report, p. 8). The committee also recommended that OST have a role in reviewing site remediation functional flowsheets (Decision Making report, p. 3). Both committees cautioned, however, that before adding any more reviews, OST should carefully assess the purpose and value of the many reviews already being used (Decision Making report, p. 77; Peer Review report, p. 13). The Decision Making Committee pointed out that peer reviews of projects should not require an overly burdensome commitment of OST resources, and therefore

[30] Such an approach involves a formal prescreening of projects by peer reviewers based exclusively on the project's written documentation. The results of this prescreening review could then be used to determine (1) highly ranked low-budget projects that should be considered for funding without additional review; (2) highly ranked projects that should receive a more detailed evaluation; and (3) technically weak projects that should not be considered for funding (Peer Review report, p. 11-12).

recommended that the peer review of projects be streamlined by reducing the number and types of reviews based on an analysis of the objectives being served by each (Decision Making report, p. 77).

Input from Sites and Users

The necessity of incorporating input from sites and users in OST's decision-making process also has been a prominent theme in recent board reports (Decision Making, D&D, Mixed Waste, Subsurface reports), as well as GAO's recent report.[31] OST has had limited success in getting the technologies it developed or procured deployed at the sites with cleanup problems. The Decision Making committee pointed out that this problem is due in part to conditions outside OST's control (see Chapter 5). However, the committee found that the problem also was the result of the way OST operated in the past when it developed technologies without adequate input from site problem owners (Decision Making report, p. 9). In more recent times, these site inputs have been obtained through Site Technology Coordination Groups (STCGs)[32] (Decision Making report, p. 9), but the Decision Making committee found weaknesses in the STCG structuring of criteria and in the STCG evaluative and prioritization methods (Decision Making report, p. 3)[33]. To address this issue, the committee recommended that OST use the best available information on DOE-EM site technology needs as a guide to tailoring program goals and RD&D projects. As one way to acquire this information, the committee recommended that OST establish (or increase) its direct contact with site personnel at the problem-solving and decision making levels (Decision Making report, p. 3). The Decision Making Committee also concluded that longer-term technology needs be derived from OST's consideration of the functional flowsheets for site remediation that other DOE-EM offices already develop, use

[31] In its evaluation of the extent to which innovative technologies developed by OST have been deployed, GAO concluded that lack of user involvement is one of the major remaining obstacles to more widespread use of technologies developed by OST (GAO, 1998).

[32] OST has formed STCGs at each major DOE-EM site to interact with local contractor personnel and others to obtain that site's environmental restoration and waste management technology needs (Decision Making report, p. 2). STCGs are responsible for developing and prioritizing a list of site problems and technology needs based on the environmental management issues relevant to a specific site (Decision Making report, p. 105). Each STCG evaluates and prioritizes (i.e., ranks or rates) technology needs according to a set of criteria established by the STCG (Decision Making report, p. 3).

[33] The criteria were different at each site and at some sites were not rigorously constructed (Decision Making report, p. 3).

in their planning, and subject to reviews (Decision Making report, p. 3). At present, OST has no direct role in establishing or reviewing these flowsheets, which are activities conducted by other EM organizations and contractors at the site level. The committee recommended that, in conjunction with the other DOE-EM offices responsible for site cleanups, OST participate to the extent possible (e.g., by establishing a role for its contractors) in a review of site remediation functional flowsheets. OST's technology development projects should be responsive to technology needs identified from baselines remediation plans and their alternatives (Decision Making report, p. 3).

Similarly, the Mixed Waste Committee recommended that OST continue to address technology deficiencies identified by the STCGs (Mixed Waste report, p. 69). The Subsurface Contaminants Committee found that a major barrier to deployment of SCFA's technologies is a lack of demand from individual DOE sites (Subsurface report, p. 7), and that one important factor in limiting demand for SCFA technologies (among other factors) is insufficient involvement of technology end users in setting SCFA's technology development priorities (Subsurface report, p. 9). The committee recommended that the SCFA strive to increase the involvement of technology end users in planning the technology demonstrations it funds (Subsurface report, p. 12).

Transparency

The Tanks Committee concluded that although DOE has a participatory process for screening and formulating technology needs, this process lacks transparency (in terms of being easily understood by all concerned decision makers and other interested and affected parties[34]) (Tanks Report, p. 1). The Peer Review Committee discussed at some length the pros and cons of conducting peer reviews in an “open” manner (i.e., identifying reviewers, fully informing the public of the nature of the reviews, and employing a known process) (Peer Review report, p. 35-36). The committee concluded that the strengths of open reviews (e.g., enhanced credibility of the process, the potential for more constructive evaluations) far outweigh the potential weaknesses (e.g., possible lack of candor by some reviewers when evaluating weak proposals), especially for the peer review of projects or programs (Peer Review report, p. 79). The committee emphasized that openness does not imply

[34] “Interested and affected parties” can include members of the public, technology users, the affected state or tribal nation, and regulators. All of these should, on a selective case-by-case basis, have the opportunity to be involved in decisions concerning remediation technologies. See *Understanding Risk: Informing Decisions in a Democratic Society* (NRC, 1996c).

that all deliberative sessions are held in public, however. The ability of an evaluating body to discuss frankly the merits and weaknesses of a project and to reach consensus in a closed session is an important attribute of some open reviews (Peer Review report, p. 36). The committee encouraged OST to continue to promote openness of its peer reviews and to fully inform members of the public and others attending the reviews of their nature (Peer Review report, p. 11). The importance of transparency to OST's decision-making process also was noted by the Decision Making Committee, which recommended that OST ensure that the decisions underlying the technologies it develops are well documented, traceable to customer needs, and supported by sound technical reviews (Decision Making report, p. 79). The board believes that such transparency should be a standard characteristic of much of DOE's decision-making processes.

Recommendations

- **OST's decision-making process should be transparent; include participation from relevant interested and affected parties (such as the technology users, the surrounding community, the affected states and tribal nations, and regulators); incorporate adequate documentation; involve peer review; and lead to setting priorities.**
- **The decision points at which (1) budget allocations are made and (2) user-defined technology needs are established are important to shaping the OST program and are therefore opportunities for independent external review (Decision Making report, p. 8). Before adding any additional reviews, however, OST should carefully assess the purpose and value of the many reviews already being conducted (Decision Making report, p. 77, Peer Review report, p. 13).**
- **OST should use the best available information on DOE-EM site technology needs as a guide to tailoring program goals and RD&D projects. As one way to acquire this information, OST should establish (or increase) its direct contact with site personnel at the problem-solving and decision making levels (Decision Making report, p. 3).**

- **OST should continue to address technology deficiencies identified by the Site Technology Coordination Groups, but prioritized among the sites by upper-level DOE-EM management.**

PRIORITIZING NEEDS AND MEASURING RESULTS

There have been no general OST-wide guidelines applied among the OST programs for setting criteria for the selection and prioritization of technology development needs, although individual OST program units have developed their own guidelines (Decision Making report, p. 84). The Decision Making Committee recommended that OST establish general selection and prioritization criteria, and guidelines for applying these criteria, to include allowance for instances when exceptions to the criteria may be appropriate (Decision Making report, p. 84). Similarly, the D&D Committee recommended that OST and the D&D Focus Area (DDFA) develop and apply a consistent approach to comparative technology assessment across all projects (D&D report, p. 31).

The Decision Making Committee emphasized that the decisions underlying the technologies OST develops should be traceable to user needs (Decision Making report, p. 79). However, this does not mean that all RD&D needs should be derived from user requests. For example, alternative technical approaches to site remediation baseline flowsheets are another important source of technology development needs (see " Alternatives" earlier in this Chapter). The committee therefore concluded that there is a need for exploratory RD&D to meet the needs of alternatives to baseline flowsheets (Decision Making report, p. 79). Moreover, the Decision Making Committee emphasized that the general criterion that technologies should be applicable to multiple sites, while useful, is flawed when applied without exception because it may lead to a failure to develop technologies for potentially very important problems that exist at only one or two sites (Decision Making report, p. 84).

The Decision Making Committee also emphasized the importance of establishing quantifiable attributes and follow-up procedures to measure (and hopefully improve) organizational results (Decision Making report, p. 3-4). Based on its review of private sector decision-making practices, the committee recommended that OST adopt relevant principles of private sector decision making, including the need to agree on clear and measurable goals and to measure and evaluate results as a guide to resource allocation (Decision Making report, p. 7). The committee found that OST's stage-and-gate system for monitoring ongoing projects has more development stages than necessary, and it does not seem to assist effectively in making decisions to select a project for funding or to terminate a project. The committee therefore recommended that OST use the minimum number of stages and gates needed to track a project and use peer reviews at key decision points (gates), especially in the selection of a new project (Decision Making report, p. 5).

Recommendations

- **For decisions involving the allocation of significant resources, OST should institute a decision-making structure wherein projects and proposals are evaluated against consistently defined criteria, such as project cost, probability of technical success, probability of implementation, potential cost savings, and human health risk reduction (Decision Making report, p. 80).**
- **To the extent practicable and with input from its various organizational elements, OST should establish general selection and prioritization criteria, and guidelines for applying these criteria, including allowance for instances where exceptions to the guidelines may be necessary (Decision Making report, p. 84).**
- **Although the technology development projects should be based primarily on specific site needs, some should be of an exploratory research nature (Decision Making report, p. 79).**
- **OST should establish measurable goals that can be used to quantify its success in meeting organizational objectives (Decision Making report, p. 7).**

4

Expand OST's Reach Outside DOE

A criticism in the 1996 CEMT report (NRC, 1996a) and repeated in several of the six reports is that OST had not adequately searched for technologies in the international, domestic industrial, and to a lesser extent, academic communities. For example, the D&D Committee found that capabilities in the private, academic, and foreign sectors for providing advanced D&D technologies were not being identified or used by OST effectively (D&D report, p. 3). The committee recommended that the DDFA be more aware of technologies developed in the private, academic, and foreign sectors and that it establish a better connection between university and industry programs and prioritized long-term needs (D&D report, p. 4). The Subsurface Contaminants Committee recommended that the SCFA improve its collaborations with leaders in the field of remediation technology development from outside DOE to avoid duplication of their work and to leverage SCFA funding (Subsurface report, p. 248). The Decision Making Committee found that OST's approach to technology procurement—wherein both OST's Industry Program and other OST organizational units perform some aspects of technology selection and procurement from industry—is cumbersome and duplicative and impairs OST's deployment initiatives (Decision Making report, p. 84). The committee recommended that OST establish a better coordinated, less duplicative, and less cumbersome system for integration of technology procurement activities, which would involve the use of a comprehensive database of demonstrated and commercially available technologies for assessments (Decision Making report, p. 84).

The committees also expressed concerns about some of OST's efforts to involve external parties. For example, the Mixed Waste Committee criticized the MWFA's privatization efforts, finding that the division of responsibility for technology development among MWFA and its contractors is not clear, nor are the mechanisms for sharing results of technology development efforts well defined (Mixed Waste report, p. 65-66). Similarly, the D&D Committee was critical of the economic analyses provided by DOE and the U.S. Army Corps of Engineers, finding that there is a lack of standard methodology, a failure to specify baseline costs, and uncertainties associated with comparative analyses because of different end states (D&D report, p. 26-27). As a result, the committee recommended that OST adopt a cost estimating approach that could provide a basis for prioritization (D&D report, p. 31).

In its response to the D&D report, OST pointed out that the DDFA maintains a database of over 700 D&D technologies, which incorporates information from a number of international partners (DOE, 1998d). OST also has a database (its World Wide Web-based Technology Management System) to track and manage OST-developed technology projects and programs (DOE, 1999a) and DOE has a database that includes over 12,000 research and development projects currently underway in DOE (DOE, 1999b). Based on these responses, it appears that OST has made some progress in creating data systems for environmental management technologies. However, most of these efforts so far appear to be focused on DOE-developed technologies, rather than as a mechanism to search and identify relevant technologies that have been developed external to DOE.

RECOMMENDATIONS

- **DOE-EM should be more aware of technologies developed in the private, academic, and foreign sectors (D&D report, p. 3).**
- **OST should establish a better coordinated, less duplicative, and less cumbersome system for integration of technology procurement activities (Decision Making report, p. 84).**
- **OST should improve its formal linkages to demonstrated technologies from outside DOE, perhaps by expanding its existing databases. Doing so will require improving OST's (and DOE's) outreach and ability to identify and use non-DOE technology.**

5

Address Constraints to Technology Implementation

The committees recognized that OST's ability to promote implementation of new technologies is constrained by legal and regulatory requirements and other non-OST factors, both within and external to DOE. Successful implementation of new and innovative technologies will require OST to identify these hindrances, evaluate their validity and importance, and in some cases, take a more proactive role in effecting change. Although some of these changes can be made by OST itself, most will require working with other elements in DOE, and some will require working with other federal and state agencies, Congress, and state legislatures.

CONSTRAINTS WITHIN DOE

OST operates in a complex, ever-changing environment. As pointed out by the Decision Making Committee, an important complication for OST is that the sites and EM offices responsible for overseeing waste management and cleanup activities (e.g., EM-30, EM-40) have a great deal of autonomy in selecting baseline remediation processes and technologies to deploy, consistent with current legally enforceable agreements. Furthermore, they are under no obligation to use OST-developed technologies and often pursue their own technology deployment[35] (Decision Making report, p. 9). In fact, contractors and managers at DOE installations have in some cases resisted efforts by DOE

[35] The D&D Committee, as well as others, recognized the “not invented here” syndrome (i.e., whereby one site is reluctant to accept technologies developed by another site) at some DOE sites (D&D report, pg. 27).

headquarters and OST to "push" use of innovative technologies (Subsurface report, p. 204). One potential disincentive to the use of innovative technologies has been that rapid cleanup could lead to loss of revenue for the DOE site management contractor and loss of local jobs once the cleanup is completed and the site is closed (GAO, 1994). Another barrier to deployment of innovative technologies is the potential liability to the user and embarrassment to DOE if the innovative technology were to fail (NRC, 1994, 1997b). Moreover, as new cleanup and waste management problems are found at the sites, new technology needs arise. This makes it difficult for OST to keep abreast of technology needs and to have its technologies accepted and deployed. Another problem relates to remediation contracts, which generally do not allow DOE to specify the technology to be used. In its review of OST's decontamination and decommissioning technology development program, the D&D Committee concluded that the Large Scale Demonstration Project (LSDP) was unable to overcome important institutional barriers to the deployment of new technologies (D&D report, p. 2).

OST and DOE-EM have initiated several efforts to address internal (to DOE) barriers to deployment. For example, in 1997 OST management initiated the Accelerated Site Technology Deployment (ASTD) program in which OST provides funding to a site for the first on-site deployment of a fully demonstrated technology if the site can show the potential for multiple uses of the technology in DOE-EM and an associated cost benefit. In 1997, OST received many more site proposals under these terms than could be funded (Decision Making report, p. 9). Also in 1997, DOE-EM established an upper level management committee, the Technical Acceleration Committee (TAC), to help deploy technologies (Decision Making report, p. 26). The Decision Making Committee found that the use of financial incentives such as those provided by the ASTD program were not desirable but appeared to be necessary at the time (Decision Making report, p. 74) The Decision Making Committee also recognized that the lack of strong incentives to deploy OST-developed technologies is largely out of OST's control, and recommended that DOE-EM seek ways to assist OST in getting its developed technologies deployed at the sites (Decision Making report, p. 74).

CONSTRAINTS EXTERNAL TO DOE

Political

Although other EM offices such as EM-30 and EM-40 are obvious users of OST technology developments, OST has other "customers" to satisfy. For example, the U.S. Congress must be satisfied that a reasonable fraction of OST products are useful and worth their cost. Furthermore, some OST expenditures are congressionally mandated. Consequently, the type and quality of the information provided to Congress (and to other interested review groups) is critically important to OST (Decision Making report, p. 3). The Subsurface Contaminants Committee recognized that political pressures to meet federal and state groundwater and soil remediation requirements (e.g., at the Hanford Site) have created problems for DOE. In particular, DOE faces a major challenge in cleaning up large quantities of contaminated groundwater and soil with a suite of inadequate baseline technologies (Subsurface report, p. 248).

Regulatory

The Subsurface Contaminants Committee noted that regulatory problems have interfered with deployment of innovative remediation technologies. The committee cited as especially problematic the slow, linear nature of the regulatory process and inconsistencies in the way the process has been applied from site to site. Such problems can delay selection of remediation technologies and can result in the use of outdated technologies chosen years before site cleanup begins. In addition, regulatory inconsistencies create uncertainties about whether a technology proven at one location will meet the regulatory requirements at another location, making contractors hesitant to take the risk of using an alternative technology (Subsurface report, p. 10).

For example, the committees identified differing approaches to waste management and disposal by the U.S. Environmental Protection Agency (EPA) for hazardous waste, the DOE for its own radioactive waste, and the U.S. Nuclear Regulatory Commission (USNRC) for commercial radioactive waste. EPA requires that all DOE mixed waste sites be designed to comply with RCRA. The Mixed Waste Committee criticized the approach recommended by EPA to determine toxicity, the Toxicity Characteristic Leaching Procedure (TCLP), because it requires grinding the material before a leach test, thereby destroying any protective coating put around the material by a treatment process. The report describes this test as bearing “little resemblance to the environmental conditions experienced by disposed waste” (Mixed Waste report, p. 72). The committee reviewed the methods available to characterize the chemical and physical stability of waste forms for mixed waste and found that no test methods are accepted by the technical and regulatory authorities to demonstrate the long-term (greater than a few hundred years) behavior of a waste form in the disposal environment (Mixed Waste report, p. 80). No waste form leachability criteria have been established for radioactive waste by either the DOE or the USNRC.

As another example, EPA's facility design regulations are site independent and hence cannot take into account the advantages one site may have over another. The EPA facility approval process does take into account site characteristics but not waste form. The USNRC performance objectives are for the entire disposal system and do include consideration of site and waste form characteristics (Mixed Waste report, p. 39). In the area of containment, EPA requires containment for only 30 years after closure, whereas the USNRC recommends performance assessment for at least 1,000 years. Many hazardous components are either stable elements (e.g., Cd, Be, Ba, Pb, Sb) or very persistent organic constituents.

The Mixed Waste Committee concluded that a major driver in technology selection and development by the MWFA has been EPA hazardous waste regulations, whereas other factors such as economics have received less attention (Mixed Waste report, p. 65). The committee recognized that technical issues pertaining to waste management are often overshadowed by nontechnical (e.g., political and social) issues (Mixed Waste report, p. 99). Controlling regulations are complex, confusing, and subject to change and interpretations (Mixed Waste report, p. 4).

The OST's Technology Integration Systems Application (TISA) Domestic Program (formerly known as the Office of Technology Integration) is intended to facilitate knowledge, communication, and acceptance of new technology applied to DOE-EM problems among interested and affected parties (Decision Making report, p. 15). OST investments in these activities show that attention to nontechnical barriers, such as regulatory acceptance of new technology ready for demonstration, has been a program priority, at least until the program's budget was cut in FY 1998 (Decision Making report, p. 150).

The Public

Several of the reports observed that public concerns can be an obstacle to deployment of new technologies. For example, the Tanks Committee wrote that (Tanks report, pg. 5):

> At present, many public stakeholders at Hanford apparently want DOE to follow the current compliance-driven Hanford baseline approach, and they view investment of significant resources in technology development for alternative scenarios as a diversion from that effort. Some stakeholders do apparently recognize that readjustments to the Hanford baseline may become necessary if a particular approach proves to be infeasible for whatever reason (whether technical, programmatic, economic, or political). However, stakeholders generally appear to prefer DOE to limit such

> investments. Nevertheless, more explicit consideration of alternatives as proposed herein and greater organizational commitment to a risk-based approach could make the overall DOE program more robust with respect to unexpected developments, as well as provide a more transparent rationale for a particular approach to eventually be adopted from among the candidate approaches.

The Decision Making Committee also identified an unwillingness to jeopardize established agreements with interested and affected parties (including the public) as a barrier to innovative technology use (Decision Making report, p. 27).

CONCLUSION

It is clear from the six reports reviewed for this synthesis, that merely identifying a promising technology will not lead to its implementation at DOE sites. Many other actions are necessary. Some can be done by OST itself, but most will require working with other elements in DOE. Some will also require DOE to work with other federal and state agencies. Because of the historical autonomy of DOE sites, there is no mechanism to ensure implementation of successful[36] OST-developed technologies. As long as authority for technology deployment and responsibility for technology development continue to reside in different entities, centralized development of technologies to be deployed throughout the DOE complex will not, in the board's view, be effective.

RECOMMENDATIONS

Internal to DOE

- **When contracts allow, agreements should be developed between the sites and OST that, if certain agreed-on conditions are met, then OST-sponsored technology will be implemented at the site(s). The sites and OST would agree on technical requirements (e.g., throughput and contamination reduction percentages of processing equipment), schedules (e.g., when testing of equipment or full scale operation will begin), and deployment costs. If these targets are met, then the sites would be required by DOE to deploy the technologies. If they are not met, the sites would be allowed to deploy any alternative that meets the targets, including those**

[36] Including economic as well as technological success.

developed independently of OST. (Some flexibility, however, would be necessary to accommodate changes in regulations or multiparty agreements.) If not allowed by current contracts, DOE should consider adding such provisions to future contracts. For current contracts, DOE should consider developing incentives to encourage use of OST-developed technologies, when these meet the above conditions.

External to DOE

- **DOE-EM should work to promote consensus among EPA, USNRC, DOE, and the scientific community on waste form testing methods that will generally be acceptable for providing at least a qualitative evaluation of long-term waste performance in disposal environments (Mixed Waste report, p. 104).**
- **DOE-EM should work with EPA and the USNRC to agree on clear guidelines that define acceptable waste forms for disposal of mixed waste in future near-surface disposal facilities (Mixed Waste report, p. 105).**
- **The well-documented decisions and sound technical reviews recommended earlier in this report should be used by OST to earn the confidence of Congress and members of the public.**

References

DOE (U.S. Department of Energy). 1998a. Environmental Management Research and Development Program Plan: Solution-Based Investments in Science and Technology. November.

DOE. 1998b. Environmental Management Strategic Plan for Science and Technology. November.

DOE. 1998c. Accelerating Cleanup: Paths to Closure. Office of Environmental Management. June.

DOE. 1998d. DOE Response to National Research Council Report "A Review of Decontamination and Decommissioning Technology Development Programs at the Department of Energy." Prepared by the Office of Environmental Management's Office of Science and Technology. December

DOE. 1999a. Office of Science and Technology Progress Since 1996 in Response to the National Research Council Report, *Environmental Management Technology Development Program at the Department of Energy 1995 Review*. Prepared by the Office of Environmental Management Program's Office of Science and Technology.

DOE. 1999b. Response Report to the National Academy of Science on the National Research Council Report "Peer Review in Environmental Technology Development Programs." Prepared by the Environmental Management Program's Office of Science and Technology.

DOE. 1999c. Letter from Gerald G. Boyd to Michael Kavanaugh in response to National Research Council Report "An End State Methodology for Identifying Technology Needs for Environmental Management, With an Example From the Hanford Site Tanks." May 10, 1999.

DOE. 1999d. Work Package Ranking System for OST's FY 2001 Corporate Review Budget (Draft). Prepared by National Prioritization Team for

Office of Environmental Management's Office of Science and Technology. March 10, 1999.

GAO (U.S. General Accounting Office). 1994. Department of Energy: Management Changes Needed to Expand Use of Innovative Technologies. GAO/RCED-94-205. August.

GAO. 1996. Energy Management: Technology Development Program Taking Action to Address Problems. GAO/RCED-96-184. July.

GAO. 1998. Nuclear Waste: Further Actions Needed to Increase the Use of Innovative Cleanup Technologies. GAO/RCED-98-249. September.

NRC (National Research Council). 1994. Alternatives for Ground Water Cleanup. Washington, D.C.: National Academy Press.

NRC. 1995. Committee on Environmental Management Technologies: Report for the Period Ending December 31, 1994. Washington, D.C.: National Academy Press.

NRC. 1996a. Environmental Management Technology-Development Program at the Department of Energy: 1995 Review. Washington, D.C.: National Academy Press.

NRC. 1996b. The Hanford Tanks: Environmental Impacts and Policy Choices. Washington, D.C.: National Academy Press.

NRC. 1996c. Understanding Risk: Informing Decisions in a Democratic Society. Washington, D.C.: National Academy Press.

NRC. 1997a. Building an Effective Environmental Management Science Program: Final Assessment. Washington, D.C.: National Academy Press.

NRC. 1997b. Innovations in Ground Water and Soil Cleanup: From Concept to Commercialization. Washington, D.C.: National Academy Press.

NRC. 1998a. A Review of Decontamination and Decommissioning Technology Development Programs at the Department of Energy. Washington, D.C.: National Academy Press.

NRC. 1998b. Peer Review in Environmental Technology Development Programs: The Department of Energy's Office of Science and Technology. Washington, D.C.: National Academy Press.

NRC. 1999a. The State of Development of Waste Forms for Mixed Wastes: U.S. Department of Energy's Office of Environmental Management. Washington, D.C.: National Academy Press.

NRC. 1999b. An End State Methodology for Identifying Technology Needs for Environmental Management, With an Example From the Hanford Site Tanks. Washington, D.C.: National Academy Press.

NRC. 1999c. Ground Water and Soil Cleanup: Improving Management of Persistent Contaminants. Washington, D.C.: National Academy Press.

NRC. 1999d. Decision Making Related to the U.S. Department of Energy's Environmental Management Office of Science and Technology. Washington, D.C.: National Academy Press.

Appendixes

Appendix A

List of Recommendations from A Review of Decontamination and Decommissioning Technology Development Programs at the Department of Energy

COMMITTEE ON TECHNOLOGIES FOR DECONTAMINATION AND DECOMMISSIONING

PETER B. MYERS, *Chair,* Consultant, Washington, D.C.
PATRICIA ANN BAISDEN, Lawrence Livermore National Laboratory, California
SOL BURSTEIN, Wisconsin Electric Power Company (retired), Milwaukee
JOSEPH S. BYRD, University of South Carolina (retired), Lexington
BRUCE CLEMENS, James Madison University, Harrisonburg, Virginia
FRANK CRIMI, Lockheed Environmental Systems (retired), Saratoga, California
MILTON LEVENSON, Bechtel International (retired), Menlo Park, California
RAY O. SANDBERG, Bechtel Corporation (retired), Moraga, California
ALFRED SCHNEIDER, Georgia Institute of Technology (retired), Dunwoody, Georgia
LINDA WENNERBERG, Environmental Business Systems, Dorchester, Massachusetts

RECOMMENDATIONS

The DDFA should improve its strategic planning. A comprehensive strategic plan, with specific objectives and goals, is essential for decision making in successful management of the DDFA. A high priority should be assigned to updating the 1995 draft Strategic Plan to reflect DOE's current priorities, scope, schedule, and budget. The plan should be widely disseminated to senior managers to provide a common basis for development and use of associated management and implementation plans. The Strategic Plan should be updated and reissued periodically as DOE policies, procedures, and objectives evolve.

Top management in the Office of Science and Technology (OST) should evaluate and prioritize the technology needs of the operating sites, and needs must be prioritized and communicated from each site up to OST. After verification and evaluation of actual, as opposed to perceived, technology gaps that cannot be satisfied by existing technology, OST must prioritize the remaining candidate projects for implementation within the constraints of the available budget. This is a “top-down” management function and cannot be delegated. This is absolutely essential to ensure that technology project selection will yield an advantageous return in cost, schedule, and personnel safety.

OST and the DDFA should link all actions and funding to the prioritized needs. All actions (selection of technologies to be demonstrated, implementation of demonstrations, establishment of rankings for budgetary purposes) and funding by the OST must be supported by “top-down” prioritized actual needs of D&D cleanup projects in progress or scheduled for implementation.

The DDFA should define a reasonable target end state for each D&D technology. To establish performance goals, DDFA should take the initiative to define and propose end states that would be reasonable for specific DOE D&D activities. These steps are necessary to provide a justification for DDFA to develop new technologies (where baseline technologies cannot reach a specified end state) or to benchmark new technologies that are claimed to be “faster, cheaper, and better” than the baseline. All proposed demonstration projects should be reviewed by DDFA to ensure that the definition of the desired end state for each demonstration project is clear, complete, and consistent with the latest changes in DOE strategic plans and negotiated site planning and operations.

The DDFA should improve its approach to introducing and gaining acceptance of demonstrated technologies. The Large Scale Demonstration Program (LSDP) was designed to introduce and gain acceptance by site managers of innovative technology into D&D activities within the DOE complex. Each site already has established methods for performing D&D activities and sites appear reluctant to take on the perceived risk of adopting alternative methods.

OST and DDFA should develop and apply a uniform and consistent approach to comparative technology assessments across all projects. The comparative assessments should be based on a standard methodology that prevails across the various programs, sites, and projects. The committee recommends that DDFA refine its cost estimating methodologies for baseline and alternative technologies so that cost comparisons are meaningful and can be fully documented. Methodologies for incorporating non-economic criteria (safety, human factors, waste generation, degree of maturity, and technological risk) should also be standardized.

The DDFA should be more aware of technologies developed in the private, academic, and foreign sectors. The DDFA should develop a well-defined and effective procedure to identify and disseminate information on technologies commercially available in the United States and abroad that can be brought to bear on D&D problems within the DOE complex. To achieve this the DDFA should increase its interactions not only with the national laboratories but also with private industry and international organizations, develop more regional diversity in its contacts with universities, and make its technology needs and programs more visible and comprehensible to private industry.

The DDFA should communicate its program results in a more effective and timely manner. Failure to provide adequate communication of the results of the demonstrations, tests, or assessments to prospective end users in a timely manner and in sufficient detail greatly reduces the prospects for acceptance and deployment of new technologies.

The DDFA should establish a better connection between university and industry programs and prioritized long-term studies. As part of its long-term strategy, DDFA should become more familiar with programs sponsored by or in progress at universities, industrial organizations, and other government organizations that may be applicable to D&D activities.

Appendix B

List of Recommendations from Peer Review in Environmental Technology Development Programs: The Department of Energy's Office of Science and Technology

COMMITTEE ON THE DEPARTMENT OF ENERGY-OFFICE OF SCIENCE AND TECHNOLOGY'S PEER REVIEW PROGRAM

C. HERB WARD, *Chair,* Rice University, Houston, Texas
BARRY BOZEMAN, Georgia Institute of Technology, Atlanta
RADFORD BYERLY, JR., University Corporation for Atmospheric Research (retired), Boulder, Colorado
LINDA A. CAPUANO, AlliedSignal Aerospace, San Jose, California
RICHARD A. CONWAY, Union Carbide Corporation (retired), South Charleston, West Virginia
THOMAS A. COTTON, JK Research Associates, Vienna, Virginia
FRANK P. CRIMI, Lockheed Martin Advanced Environmental Systems Company (retired), Saratoga, California
JOHN C. FOUNTAIN, State University of New York, Buffalo
DAVID T. KINGSBURY, Chiron Corporation, Emeryville, California
GARETH THOMAS, University of California, Berkeley

RECOMMENDATIONS

Linkage of Peer Reviews to Management Decisions

As part of the documentation provided to peer review program management during the process of selecting projects for review, OST program managers should be required to clearly identify the upcoming decision or milestone for which the results of the peer review will be used.

Selection of Projects for Review

To aid in the selection of projects to review, OST should adopt two additional criteria to choose from those projects that satisfy one of the three existing selection criteria: (1) technologies that are being considered for deployment, and (2) technologies for which a request for further funding has been received or is anticipated.

Although the two additional selection criteria would assist OST in identifying those projects for which peer review is of highest priority, application of these criteria would still leave a large number of projects that are not peer reviewed. To address this issue, the committee recommends that OST should expand its practice of evaluating a number of related technologies in a single peer review, whenever possible.

Selection of Reviewers

OST should establish a more systematic approach to accessing reviewer information from other databases (e.g., chemical engineers, geologists, physicists, materials scientists, biologists) or from other professional societies, as needed, to ensure the appropriate range of expertise for all review panels. The reviewer selection process should in general avoid DOE staff as peer reviewers and should ensure that the DOE-affiliated persons are never more than a small fraction of a panel's membership.

Documentation for Peer Reviews

A detailed proposal or statement of work should be required for all peer reviews. It should describe the specific activities that will be carried out if the project is funded.

Addressing the Backlog of Peer Reviews

OST should consider adopting a triage approach that would allow far greater numbers of technologies to be peer reviewed. This approach would involve a formal prescreening of projects by peer reviewers based exclusively on the written documentation on the project — in effect, a “mail review” of projects, followed by a formal meeting of the panel to discuss and rank them. The approach would help OST to fulfill its policy that “all projects are to be peer reviewed" in the short term (as of May 1, 1998, OST had reviewed only 43 of 226 projects that were receiving funding from the program).

Evaluation and Improvement Mechanisms

OST management should develop an effective evaluation and improvement process for the peer review program that includes regular benchmarking against other peer review programs and the collection of activity and performance metrics.

OST's Organizational Structure and Leadership

OST leadership should develop an explicit strategy to accomplish a change in its organizational culture by distributing (1) educational materials that summarize the basic principles and benefits of peer review as a tool for decision making, (2) case histories illustrating how peer review input served to improve specific projects, and (3) summaries of key performance metrics that demonstrate how peer reviews are used to meet the overall objectives of OST's program.

Potential Applications of Peer Reviews in OST

OST should carefully evaluate the objectives and roles of all its existing reviews and then determine the most effective use of peer reviews (of various types) in meeting its overall objectives.

Appendix C
List of Recommendations from An End State Methodology for Identifying Technology Needs for Environmental Management, with an Example from the Hanford Site Tanks

COMMITTEE ON TECHNOLOGIES FOR CLEANUP OF HIGH-LEVEL WASTE IN TANKS IN THE DOE WEAPONS COMPLEX

B. JOHN GARRICK, *Chair,* PLG Inc. (retired), Newport Beach, California
VICKI M. BIER, University of Wisconsin, Madison
ALLEN G. CROFF, Oak Ridge National Laboratory, Tennessee
MARSHALL E. DRUMMOND*, Eastern Washington University, Cheney
JOHN H. ROECKER, Consultant, Colbert, Washington
CLAUDE G. SOMBRET, Commissariat à l'Energie Atomique (retired), Villeneuve Les Avignon, France
MARTIN J. STEINDLER, Argonne National Laboratory (retired), Downers Grove, Illinois
RAYMOND G. WYMER, Oak Ridge National Laboratory (retired), Tennessee

RECOMMENDATIONS

An end state based approach to establishing an appropriate technology development program in support of DOE's environmental management program should be adopted. In particular, this approach should encompass reference end states for each waste stream, plus plausible alternative end states for each waste stream to accommodate uncertainty and potential future programmatic changes.

Sufficient technology development resources should be invested in scenarios involving alternative end states to provide reasonable assurance that a solution will be available in case unforeseen but all too frequent technical surprises or externally imposed changes make it impossible to implement the preferred

* Resigned from committee May 15, 1998

baseline approach. DOE should consider alternative end states unless the remediation process is short term and a proven cost-effective technology exists.

Detailed documentation of the steps taken in implementing the end state based approach should be developed for use by the custodians of the waste, those engaged in technology development, and oversight groups. Circumstances where alternative end states are not considered should be well documented as part of the evidence base justifying the decision made. In addition, executive level documentation appropriate for decision makers, such as DOE senior management and the Congress, should be developed.

If initial conditions or end states cannot be specified adequately, a plan leading to the timely resolution of the open items should be prepared and executed. In the interim, enabling assumptions regarding the initial conditions and desired end states of the waste should be developed and clearly stated, preferably by problem owners, but by technology providers if necessary. End states and related technology requirements will frequently have to be identified in the face of major uncertainties about costs, benefits, public acceptability, and other relevant factors.

Cost-risk studies should be more widely used in remediation decision making that forms the basis for technology development in an end state based approach. In particular, such studies should be used both to determine what must be done to protect human health and the environment at reasonable costs and to identify activities that yield only minimal risk reduction and hence should be considered as candidates for possible elimination.

The end state based approach should be applied on a broad scale to comprehensively identify technology development needs. The need for such an assessment based on alternative end states is highlighted by the extensive uncertainty surrounding the entire tank closure program.

The DOE-EM Tank Waste Remediation Technology Development Program should make an end state based approach a functional part of the process for defining its work.

Alternative scenarios including defined end states should be formulated and evaluated, and technology development unique to these scenarios should be pursued on a basis that is prioritized with the help of performance assessment results and additional knowledge from relevant scientific research.

OST should adopt broadly the end state based method of identifying technology requirements to reduce sensitivity to future uncertainties such as changes in regulations, budgets, policies, and program participants. Technology development activities with long lead times should be designed to transcend the effects of these inevitable changes.

An end state based framework for making decisions about technology needs should be used to provide much needed visibility of the relationship of the various activities (including risk studies) to the final objectives.

Given DOE's lack of experience in privatization of such major functions as research, development, and cleanup operations, the committee recommends parallel pursuit of technology development for an alternative to the current privatization strategy for the Hanford Tank Waste Remediation System. It is not considered prudent to rely totally on privatization to develop the required technologies for systems with the history and complexity of high-level radioactive waste in tanks. The uncertainties are great, and the chances for failure are too high not to pursue alternatives.

Appendix D

List of Recommendations from The State of Development of Waste Forms for Mixed Wastes: U.S. Department of Energy's Office of Environmental Management

COMMITTEE ON MIXED WASTES

PAUL A. DEJONGHE, *Chair,* Study Centre for Nuclear Research (retired), Mol, Belgium
ANN N. CLARKE, ANC Associates, Inc., Brentwood, Tennessee
JURGEN H. EXNER, JHE Technology Systems, Inc., Alamo, California
KENT F. HANSEN, Massachusetts Institute of Technology, Cambridge
JOANN S. LIGHTY, University of Utah, Salt Lake City
RICHARD J. SAMELSON, Consultant, Pittsburgh, Pennsylvania
MARTIN J. STEINDLER, Argonne National Laboratory (retired), Argonne, Illinois
BRUCE M. THOMSON, University of New Mexico, Albuquerque

RECOMMENDATIONS

General

The Mixed Waste Focus Area (MWFA) should no longer emphasize the development of new classes of waste forms. The MWFA should emphasize the engineering design, integration, and scale-up of its proposed treatment processes and their demonstration and deployment, as needed, at the DOE sites.

The MWFA should continue its practice of defining, identifying, and responding to technology deficiencies.

The MWFA should broaden its use of a systems approach in selecting, developing, and deploying technologies. This approach would include characterization of the waste and definition of the required performance of a proposed treatment technology, based on EM's needs, regulatory requirements, and stakeholder expectations.

Waste Characterization

The MWFA should develop simplified methods to characterize the waste, with emphasis on nondestructive examination and nondestructive assay techniques. According to available inventory data, emphasis should be placed on developing better methods to determine heavy metals and solvent contamination in the waste.

The MWFA should continue to develop, demonstrate, and encourage deployment of techniques and procedures to ensure that all new waste streams are adequately characterized.

The MWFA should strive for a balance between the risks, benefits, and cost of detailed characterization and the risks, benefits, and cost to adapt or to develop more robust treatment technologies that can handle a wide variety of waste compositions. Both characterization and technology development efforts should be pursued.

Treatment Technologies

The MWFA should integrate treatment technologies being developed for its five treatment groups into a mixed waste treatment strategy. This strategy should consider the waste form as a part of an overall mixed waste management system that includes:

- compatibility of waste form with transportation and disposal options,
- trade-offs between risks to personnel associated with additional waste characterization and additional costs of a more robust treatment and stabilization system, and
- trade-offs between the increased number of disposal options for a very stable waste form and the lower costs but reduced disposal options for less stable waste forms.

The MWFA should demonstrate new treatment technologies on at least the pilot plant scale using real wastes or realistic surrogates before the technology is designated as ready for deployment.

The MWFA should continue to address technology deficiencies that it has identified through input from the Site Technology Coordinating Groups and update its Technical Baseline Report to reflect progress in addressing these deficiencies.

The MWFA should continue to provide research funding for developing robust processes, such as the plasma torch that can treat and stabilize waste of poorly defined or variable composition, recognizing the trade-off between better waste characterization and development of improved treatment technology.

Waste Form Characterization and Performance Assessment

OST should continue to support programs aimed at fundamental understanding of waste form durability and degradation processes. These programs should lead to a better representation of the waste form in performance assessment (PA) modeling.

OST should work to promote consensus among the U.S. Environmental Protection Agency (EPA), the U.S. Nuclear Regulatory Commission (USNRC), DOE, and the scientific community on waste form testing methods that will be generally acceptable for providing at least a qualitative evaluation of long-term waste form performance in disposal environments.

OST should support efforts to obtain data that will allow a more realistic inclusion of waste forms in PA models, including intrusion scenarios. Without such data the waste form will never receive proper credit in PA, with the resulting cost penalties for additional engineered barriers and possible restriction in site selection.

OST should play a more significant role in promoting (funding) cooperation among investigators who are characterizing waste forms and those who are developing PA models to help ensure that characterization data are useful for PA models, and that PA models properly incorporate this data.

The MWFA should continue basic research related to the understanding of the physical and chemical attributes of waste forms.

Regulatory Guidelines

Environmental Management (EM) should work with EPA and the USNRC to agree on clear guidelines that define acceptable waste forms for future disposal facilities. This should be done as soon as possible to reduce the risk of EM deploying technologies that are later judged to be inadequate due to unanticipated regulatory requirements.

Appendix E

List of Recommendations from Groundwater and Soil Cleanup: Improving Management of Persistent Contaminants

COMMITTEE ON TECHNOLOGIES FOR CLEANUP OF SUBSURFACE CONTAMINANTS IN THE DOE WEAPONS COMPLEX

C. HERB WARD, *Chair,* Rice University, Houston, Texas
HERBERT E. ALLEN, University of Delaware, Newark
RICHARD BELSEY, Physicians for Social Responsibility, Portland, Oregon
KIRK W. BROWN, Texas A&M University, College Station
RANDALL J. CHARBENEAU, University of Texas, Austin
RICHARD A. CONWAY, Union Carbide Corporation (retired), South Charleston, West Virginia
HELEN E. DAWSON, Colorado School of Mines, Golden
JOHN C. FOUNTAIN, State University of New York, Buffalo
RICHARD L. JOHNSON, Oregon Graduate Institute of Science and Technology, Portland
ROBERT D. NORRIS, Eckenfelder, Brown and Caldwell, Nashville, Tennessee
FREDERICK G. POHLAND, University of Pittsburgh, Pittsburgh, Pennsylvania
KARL K. TUREKIAN, Yale University, New Haven, Connecticut
JOHN C. WESTALL, Oregon State University, Corvallis

RECOMMENDATIONS

Setting Technology Development Priorities

In situ remediation technologies should receive a higher priority in the Subsurface Contaminants Focus Area (SCFA) because of their potential to reduce exposure risks and costs.

SCFA should fund tests designed to develop and determine performance limits for technologies capable of treating the types of contaminant mixtures that occur at DOE sites.

SCFA should focus a portion of the program's work on development of remedial alternatives (including containment systems) that prevent migration of contaminants at sites where contaminant source areas cannot be treated. Methods for monitoring long-term performance of these systems should be included in this work.

Improving Overall Program Direction

SCFA should continue its efforts to work more closely with technology end users in setting its overall program direction. Working with end users, SCFA should identify key technical gaps and prepare a national plan for developing technologies to fill these gaps. Although SCFA consulted with end users and developed a prioritized list of problem areas (known as work packages) for funding in fiscal year 1998, it was unable to use this list to guide its program because the entire SCFA budget went to supporting multiyear projects that began before SCFA was formed.

SCFA should strive to increase the involvement of technology end users in planning the technology demonstrations it funds. End users should be involved in planning every demonstration that SCFA funds, as in the Accelerated Site Technology Deployment Program.

SCFA should significantly increase use of peer review for (1) determining technology needs and (2) evaluating projects proposed for funding. Peer reviews should carry sufficient weight to affect program funding.

SCFA should improve the accuracy of its reporting of technology deployments. SCFA should use a consistent definition of deployment and should work with the Office of Environmental Restoration to verify the accuracy of its deployment report.

Overcoming Barriers to Deployment

SCFA should sponsor more field demonstrations, such as those funded under the Accelerated Site Technology Deployment Program, to obtain credible performance and cost data. SCFA should consider whether sponsorship could include partial reimbursement for failed demonstrations, if an alternate remediation system has to be constructed to replace the failed one.

SCFA should ensure that the project reports it provides contain enough technical information to evaluate potential technology performance and effectiveness relative to other technologies. The project descriptions contained in SCFA's periodic technology summary reports are not sufficiently detailed to serve this purpose. SCFA's project reports should follow the guidelines in the *Federal Remediation Technologies Roundtable's Guide to Documenting and Managing Cost and Performance Information for Remediation Projects.*

A key future role for the SCFA should be the development of design manuals for technologies that could be widely used across the weapons complex. Possible models include the Air Force Center for Environmental Excellence design manual for bioventing, the American Academy of Environmental Engineers WASTECH monograph series, and the Advanced Applied Technology Demonstration Facility surfactant-cosolvent manual.

Appropriately qualified SCFA staff members (with in-depth knowledge of remediation technologies) should be available to serve as consultants on innovative technologies for DOE's environmental restoration program. These staff members also should develop periodic advisories for project managers on new widely applicable technologies.

Addressing Budget Limitations

DOE managers should reassess the priority of subsurface cleanup relative to other problems and, if the risk is sufficiently high, should increase remediation technology development funding accordingly.

SCFA should pursue a variety of strategies to leverage its funding. Strategies include (1) improving collaborations with external technology developers to avoid duplication of their work, (2) developing closer ties with the Environmental Management Science Program, and (3) continuing involvement with working groups of the Remediation Technologies Development Forum.

Appendix F

List of Recommendations from Decision Making in the U.S. Department of Energy's Environmental Management Office of Science and Technology

COMMITTEE ON PRIORITIZATION AND DECISION MAKING IN THE DEPARTMENT OF ENERGY OFFICE OF SCIENCE AND TECHNOLOGY

RAYMOND G. WYMER, *Chair,* Oak Ridge National Laboratory (retired), Tennessee
ALLEN G. CROFF, Oak Ridge National Laboratory, Tennessee
MARY R. ENGLISH, University of Tennessee, Knoxville
THOMAS M. JOHNSON, LFR Levine-Fricke, Emeryville, California
DUNDAR F. KOCAOGLU, Portland State University, Portland, Oregon
MICHAEL MENKE, Value Creation Associates, Redwood City, California
GEORGE L. NEMHAUSER, Georgia Institute of Technology, Atlanta
LINDA WENNERBERG, Environmental Business Strategies, Cambridge, Massachusetts
EDWIN L. ZEBROSKI, Elgis Consulting, Inc., Sunnyvale, California

Consultants

THOMAS A. COTTON, JK Research Associates, Inc., Arlington, Virginia
ROBERT GIORDANO, Giordano and Associates, Saratoga Springs, New York
DETLOF VON WINTERFELDT, University of Southern California, Los Angeles, California

RECOMMENDATIONS

Importance of a Central RD&D Function

A centralized RD&D function within DOE-EM should be maintained because of its potential advantage in coordinating potentially duplicative technology development efforts needed at DOE-EM sites and because it is in a better position to address important broader issues (e.g., alternative technologies in the baseline functional flowsheets and alternative functional flowsheets) than more specifically directed RD&D.

Balancing Research with Development and Demonstration

The percentage of OST technologies that reach the deployment stage should not be the sole figure of merit used in judging the OST program, although it is an important one. A long-term view should be adopted wherein the direct use of OST technologies or the use of derived technologies is also considered in the evaluation of OST's portfolio of technology development projects.

Site Baseline Remediation Functional Flowsheets

The expertise of technology developers supported by OST could be of value to the site problem owners in formulating and maintaining technically sound and practicable cleanup functional flowsheets. Therefore, efforts should be made to have substantial involvement of appropriate OST and OST contractor personnel in reviews of functional flowsheets. Such participation would have the benefits of (1) ensuring that OST technology developers fully understand the site problem owners' technical needs and their bases and (2) increasing the sites' confidence in OST's dedication and ability to meet their needs.

Technical Alternatives to Baseline Remediation Functional Flowsheets

The development of alternative functional flowsheets is the responsibility of DOE-EM offices other than OST, but they should seek OST's input. It is highly desirable that the problem-owning EM offices should seek out and acknowledge the potential vulnerabilities—in cost, risk, and technological failure—of the baseline functional flowsheets and processes and, with OST's assistance, develop alternative flowsheets as appropriate. OST should encourage this course of action and seek to collaborate in it.

OST should attempt to provide input to alternative functional flowsheets and, in particular, should advocate their development when the baseline functional flowsheet involves high cost, high or poorly defined risk, and/or substantial probability of technical failure. OST should identify specific technology development opportunities aimed at supporting alternative functional flowsheets and processes designed to enhance the overall probability of remediation successes and to minimize program delays. In practice, this means that OST should be allowed to commit a portion of its resources to developing technologies to address needs derived from such alternative functional flowsheets, in addition to developing technologies to meet the needs derived from the baseline flowsheets.

Independent External Reviews

Peer reviews of technology development projects should be part of OST's decision-making process. These project peer reviews should occur as necessary and in a way that is not an overly burdensome commitment of OST resources. Therefore, the OST review system should be streamlined by reducing the number and types of reviews based on an analysis of the objectives being served by each. Reduction in the number of reviews could be accomplished in part by combining reviews where practicable.

An independent external review should be held on the basis of, and rationale for, decisions on funding targets within OST. One goal of this review should be to identify the technical areas of greatest need, where improvements over existing conventional approaches would have the greatest benefit to DOE-EM. This review and its outcome should take into consideration such factors as DOE-EM programmatic strategies, political pressures, stakeholder pressures, risk to human health and the environment, safety, cost-benefit, and timing. Such a review might be carried out by an already constituted authoritative body such as the Environmental Management Advisory Board (EMAB) or by a group created specifically to conduct the review.

Site remediation functional flowsheets should be subjected to independent external review before they are adopted, and periodically during development of the technologies that are to implement them. The EM offices developing these flowsheets should have them peer reviewed, that is, reviewed by technical experts who are independent of and external to the program. This expertise may be found in academia, private industry, and national laboratories. The purpose of such reviews is to identify possible vulnerabilities or uncertainties in the functional flowsheet assumptions and technology selections. The committee understands that the other EM offices already sponsor such peer reviews of functional flowsheets for the most part, but it would recommend the practice for all important functional flowsheets.

OST should work with other DOE-EM offices to the extent possible (e.g., by establishing a role for OST contractors) in the schedule of peer reviews of the site baseline functional flowsheets.

OST's Institutional Environment Affects Customer Interactions, Relevance to Site Needs, and Deployment

To the extent possible, OST should increase its efforts to identify site technology needs on a current basis and to anticipate future needs. Regularly scheduled meetings with site problem owners should be considered. More discussions of technical issues and their implications for technology development needs should be held with the working-level scientists and engineers.

OST should ensure that the decisions underlying the technologies it develops are well documented, traceable to customer needs, and supported by sound technical reviews. Records should be kept of the reasoning by which the deciding factors were evaluated, including whatever method(s) were used in their evaluation.

Although the technology development projects should be based primarily on specific needs at the sites, some should be of an exploratory nature to meet the need for backups and alternatives to the baseline functional flowsheets.

Top-Level Strategic Planning and Goals

OST managers, in conjunction with other top-level EM managers, should produce strategic goals and plans that define explicitly the technical problems the program will (and will not) address, and use these goals and plans effectively within OST program units to assist them in making technology development decisions.

Use of a Structured Decision-Making Process

For decisions involving the allocation of significant resources, OST should institute a decision-making structure wherein projects and/or proposals are evaluated against consistently defined criteria such as project cost, probability of technical success, probability of implementation on field applications, potential cost savings, and human health risk reduction.

Industrial RD&D Decision-Making Practices Applicable to OST

OST should adopt, where applicable and appropriate in the OST environment and to the extent practicable, basic principles of private-sector formal decision-making and follow-up practices. In particular, an attempt should be made to assess the following factors and adopt them consistently where applicable across the entire organization:

- Understand, focus on, and monitor changes in customer needs and requirements.
- Agree on clear and measurable goals.
- Use a formal (i.e., common, consistent, structured, and rational) technology development decision-making process and apply it uniformly.
- Think strategically (i.e., long-term and high impact).
- Measure and evaluate to guide resource allocation.
- Communicate across organizational boundaries (i.e., with technology users).
- Continually improve the research and development (R&D) management process.
- Hire the best people possible and maintain expertise.

Specific Methodologies

OST should examine the efficacy of the sets of criteria and scoring techniques currently used by OST program units (e.g., Site Technology Coordination Groups, Focus Areas, and Crosscutting Programs). This could be done by (1) using one or more contractors with suitable expertise to survey alternative decision-making analytical methods and (2) using the considered judgment of OST management to identify those analytical methods that are well suited to OST's various needs.

Project Selection and Evaluation Criteria

To the extent practicable, and with input from its various organizational elements, OST headquarters should establish general selection and prioritization criteria, and guidelines for applying these criteria, to include allowance for instances in which exceptions to the criteria may be appropriate.

Procurement of Externally Demonstrated Technologies

A better-coordinated, less duplicative, and less cumbersome system should be established for integration of technology procurement activities. Since decisions to develop technologies should be made only if warranted following a “make-or-buy” review, the ability to assess available technology is crucial. These assessments should be done through up-to-date surveys of commercially available technologies that are coordinated across OST organizational units.

Project Monitoring

OST should use the minimum number of stages needed to track projects. This will reduce the administrative load and will lead to better decisions by producing better-defined decision points and clearer lines of demarcation between them.

In selecting a new technology development project for funding, OST should base this decision on both technical merit and quantifiable estimations of the project's probable value to site cleanup activities. OST has developed this latter concept as part of the criteria of the stage-and-gate system, but OST program units do not uniformly adopt and use these criteria to guide their selection of new projects for funding.

OST should correct the additive scoring system to account better for threshold criteria. One way to do this would be to multiply scores in key categories rather than add them.

Cost Estimates

OST should do “cost avoidance” (or return on investment) calculations on its more expensive technologies in a more credible manner than was done in past efforts and should communicate the results to potential technology users in the most effective way possible. Initial estimates of costs and benefits should be developed at the inception of large RD&D projects, and periodic refinements of the estimates should be a part of the project as it progresses.

Exploratory Development

Additional funding should be sought (or some existing funding redirected) for exploratory development directed to technologies for alternative functional flowsheets.

Appendix G

Acronyms And Abbreviations

ANS	American Nuclear Society
BRWM	Board on Radioactive Waste Management
CEMT	Committee on Environmental Management Technologies
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
D&D	Decontamination and Decommissioning
DDFA	Decontamination and Decommissioning Focus Area
DOE	U.S. Department of Energy
EM	DOE Office of Environmental Management
EM-30	DOE Office of Waste Management
EM-40	DOE Office of Environmental Restoration
EM-50	DOE Office of Science and Technology
EM-60	DOE Office of Nuclear Material and Safety Stabilization
EPA	U.S. Environmental Protection Agency
FY	Fiscal Year
GAO	General Accounting Office
LSDP	Large Scale Demonstration Project
MWFA	Mixed Waste Focus Area
NRC	National Research Council
OST	DOE Office of Science and Technology
RCRA	Resource Conservation and Recovery Act
RD&D	Research, Development, and Demonstration
SCFA	Subsurface Contaminants Focus Area
TCLP	Toxicity Characteristic Leaching Procedure
TISA	Technology Integration Systems Application
USNRC	U.S. Nuclear Regulatory Commission

Appendix H

Organizational Structure of Relevant Parts of the Department of Energy's Office of Environmental Management as of August 1999