Peer Review in the Department of Energy-Office of Science and Technology: Interim Report

Committee on the Department of Energy-Office of Science and Technology's Peer Review Program, National Research Council

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Committee on the Department of Energy-Office of Science and Technology's Peer Review Program
Board on Radioactive Waste Management
Commission on Geosciences, Environment, and Resources
National Research Council

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Preface

In March 1996, the National Research Council's Committee on Environmental Management Technologies (CEMT) recommended that the Department of Energy (DOE)-Office of Science and Technology (OST) develop and apply a standardized, rigorous, and independent external peer review process to all of its technology development programs (NRC, 1996). A subsequent report by the General Accounting Office (GAO, 1996) echoed these findings. As a result, in September 1996 OST instituted a new program to perform peer reviews of technologies (or groups of technologies) at various stages of development. Shortly thereafter, OST requested that the National Research Council form a committee to evaluate the effectiveness of its new program and to make specific recommendations to improve it, if appropriate. In particular, the committee was asked to review the following:

- internal procedures used by OST to identify the need for timely peer review of projects and programs;
- structures, protocols, and procedures for obtaining peer reviews of OST projects and programs, including who decides what will be peer reviewed, what criteria for peer review are used, and when in the R&D process peer review is requested; and
- feedback of peer review results into program management and development decisions.

The committee was directed to compare OST's practices to generally accepted norms for scientific and technical peer review, including practices for selection of peer reviewers and screening for bias and conflict of interest.

This is the first of two reports to be prepared by this committee on OST's new peer review program. OST requested this interim report to provide a preliminary assessment of the program. In particular, OST asked the committee to consider whether it is moving in the right direction toward the implementation of a credible, effective, and defensible peer review program. In its final report, the committee will provide a more detailed assessment of OST's peer review program after its first complete annual cycle. The final report will develop a general framework for evaluating the level of development (or "maturity level") of a peer review program, focusing on specific components of the peer review process.

Another NRC Committee, the Committee on Prioritization and Decision Making in the Department of Energy-Office of Science and Technology, is currently conducting a parallel review of the decision-making process in OST's technology-development program. One aspect of its work will be to examine the role and importance of peer reviews in OST's decision-making process. Our committee therefore has focused its work on OST's peer review program itself (including the peer review results used as an *input* to decision making), but has not addressed OST's decision-making process explicitly.

In conducting this study, the committee has been briefed on the newly instituted peer review program by OST staff at three committee meetings. The committee wishes to thank Gerald Boyd, acting Deputy Assistant Secretary for Science and Technology, in particular, for meeting with the committee at two of its meetings. In addition, Jef Walker, Anibal Taboas, Texas Chee, and Miles Dionisio were very helpful in providing requested materials, in briefing the committee on various aspects of the new peer review program, for sharing various "lessons learned" about the peer review program, and for coordinating briefings by other relevant DOE staff. They also helped facilitate committee members' observations of a number of the peer reviews. The committee also would like to thank the staff of the Institute for Regulatory Science (RSI) and representatives from the American Society of Mechanical Engineers (ASME)—most notably, Alan Moghissi and Ernest Daman—for arranging for the committee to observe selected peer reviews, for providing the committee with draft peer review reports, and for sharing their thoughts on the OST's peer review program.

In addition to briefings by DOE, RSI, and ASME, the committee also heard from representatives from other organizations that utilize and/or conduct peer reviews. The committee wishes to thank all of the invited speakers who made presentations to the committee on peer review practices in their organizations, specifically, Dorothy Patton and Jack Puzak from the Environmental Protection Agency (EPA), David Morrison from the U.S. Nuclear Regulatory Commission, Don Barnes from EPA's Science Advisory Board, Robert Marianelli from the Department of Energy-Office of Basic Energy Sciences, Donald R. Beem from the American Institute of Biological Sciences, and Carl Guastaferro from Information Dynamics, Inc. The latter two organizations have conducted reviews for federal agencies for many years. Although the mission of each of these federal organizations is distinct from that of OST, these presentations illustrated that many of the fundamental characteristics of successful peer review programs are applicable to a diverse range of objectives, from reviewing proposals to reviewing ongoing technology projects.

This report could not have been completed without the able assistance of National Research Council staff. Robin Allen provided meeting and committee support during the early stages of this study; Erika Williams assumed these responsibilities after the first committee meeting and also helped compile committee members' written contributions into coherent drafts. Susan Mockler prepared meeting minutes, conducted research, and edited several drafts of the report. This report also benefited significantly from the writing skills and insight of study director Gregory Symmes.

One of the challenges of this study has been that OST's peer review program has been somewhat of a "moving target" during the study period, as OST has made a number of changes in the program during the past eight months. Although this has made the committee's work more difficult at times, it reflects a positive commitment within OST to modify the peer review program as potential improvements are recognized. The committee offers this interim report to further advance this improvement process and looks forward to providing a more formal assessment in its final report.

C. HERB WARD, CHAIR

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Executive Summary

The Office of Science and Technology (OST) of the U.S. Department of Energy's (DOE's) Office of Environmental Management (EM) promotes the development of new and improved technologies to lower cleanup costs and risks and to improve cleanup capabilities throughout the nation's nuclear weapons complex. The annual budget for technology development activities within OST in fiscal year 1997 is approximately $300 million, which supports nearly 300 research and development projects at universities, national laboratories, and private-sector companies. These projects are chosen for new and continued funding through a complex technology-selection process, which uses the results from various types of reviews (see Appendix C), including programmatic reviews, technical assessment reviews, and peer reviews.[1]

Several recent National Research Council (NRC) reports evaluated DOE-OST's technology-selection process and recommended that OST develop and apply an independent, external review process to all of its technology-development programs (NRC, 1995b,c, 1996). These findings were echoed in a subsequent General Accounting Office (GAO) report, which concluded that "although the lead sites used significantly different systems to select projects, none of them used disinterested reviewers to determine the technical merit of the proposed work" (GAO, 1996, p. 7). In response to these NRC and GAO reports, the OST recently has instituted a peer review program that uses the American Society of Mechanical Engineers (ASME), with administrative and technical support provided by the Institute for Regulatory Science (RSI), to conduct peer reviews of technologies (or groups of technologies) at various stages of development.

OST asked the NRC to convene an expert committee to evaluate the effectiveness of its new peer review program and to make specific recommendations to improve the program, if appropriate. This is the first of two reports to be prepared by this committee on OST's new peer review program. OST requested this interim report to provide a preliminary assessment of OST's new peer review program. In the final report, the committee will provide a more detailed assessment of OST's peer review program after its first complete annual cycle.

The committee finds that OST has made progress in its implementation of the peer review program, especially in an environment that has, heretofore, not fully recognized the value of independent assessment of technologies. This new program apparently marks the first time that OST has applied peer review (i.e., technical review by independent, external experts)[2] to evaluate the technical merit of technology projects as part of its technology-selection process. The program has developed a process for selecting reviewers, developing technology-specific review criteria, and executing peer reviews. And although only a small percentage of OST's technology projects have been reviewed to date, the OST's peer review program appears to have the potential to be fair and credible. To fully achieve the objectives of this program, however, OST must continue to address a number of key issues that hinder the program's successful implementation.

[1] These peer reviews are termed "technical peer reviews" by OST.

[2] A more complete definition of "peer review" is provided on page 9 of this report.

USE OF THE TERM "PEER REVIEW"

One such problem has been the OST's use of the term "peer review" to refer to technical reviews conducted by EM technical staff or other reviewers not independent of the project under review. Such use of the term "peer review" has caused confusion and misunderstanding within both OST and external review groups (e.g., NRC, GAO), which have continued to criticize OST for a lack of a credible peer review program. **To avoid misunderstanding, OST should restrict the term "peer review" to only those technical reviews conducted by independent, external experts. OST should adopt alternative terms such as "technical review" for its internal reviews of scientific merit and pertinency**.

PLANNING OF REVIEWS

The committee has noted a lack of timeliness in a number of the reviews conducted under the new system. For example, some peer reviews have been conducted after OST apparently had already committed to fund the project's next stage of development, or even after a project nearly had been completed. In both such instances the main benefits of peer review were foregone because of the untimely review. The committee also has observed instances where peer reviews of specific projects were canceled shortly before the scheduled peer reviews. **To address these issues, the committee recommends that OST develop a targeted plan for the peer review program. In developing this plan, OST will need to consider factors such as how many of its technology projects can be peer reviewed, realistic schedules for the reviews, and the peer review program budget. To be effective, this plan also must assure that peer reviews are conducted early enough in the budget cycle to allow peer review results to be used as an input to meaningful funding decisions**.

SELECTION OF PROJECTS FOR REVIEW

Because it is a new program, OST's peer review program has been able to review only a small percentage of the technologies currently under development within OST. As a result, OST currently funds a large number of technologies that never have been peer reviewed, and many of these projects are in the later stages of development. **To address these issues, the committee recommends that OST develop a rigorous process for selecting projects to be peer reviewed. To be fair and credible, this process should employ well-defined project selection criteria, and OST peer review program staff should be directly involved in making decisions regarding which projects will be reviewed**. Due to the large number of projects in the later stages of development, the committee encourages OST to focus much of the short-term peer review efforts on high-budget, late-stage projects that never have been peer reviewed, but that still face upcoming decisions with major programmatic and/or funding implications. In the long term, however, the committee encourages OST to focus on proposals for new projects entering OST's development process to help ensure that only projects with sufficient technical merit are supported by OST.

SELECTION OF REVIEW CRITERIA AND OBJECTIVES

OST's peer review program has a list of nine general review criteria that includes broad issues such as cost effectiveness, reduced risk, regulatory acceptability, and public acceptance that address many nontechnical considerations which may not be appropriate for peer reviews. **The committee recommends that OST revise these general nontechnical criteria to focus on technical aspects of these issues, or remove them from the list of review criteria**. In practice, the nine general review criteria are often modified to technology-specific review criteria intended to focus the review on issues of particular interest to OST. The committee encourages OST to continue its practice of developing a minimum number of technology-specific review criteria because it allows OST peer review program staff to focus the reviews on particularly important issues, provided these technology-specific criteria address technical issues and do not obscure or preempt the principal goal of determining technical merit. **The committee recommends that OST develop a well-defined general set of technical criteria for peer reviews, to be augmented by technology-specific criteria as needed for particular reviews**.

Another important factor in successful peer review programs is that the objectives of the reviews and the review criteria are defined clearly and are understood by all those involved in the peer review. OST policy requires OST program managers to include a statement of desired "scope" and "purpose" when they request a peer review. The committee encourages OST to use these statements to communicate the objectives of the review clearly to all involved in the peer review (i.e., peer reviewers, principal investigators [PIs], and observers).

SELECTION OF REVIEWERS

The selection of peer reviewers is a critically important step in the peer review process. The committee finds that the criteria used to select reviewers are adequate to ensure the technical credibility of the peer review panel. **To ensure the independence of the peer reviewers, however, the committee recommends that OST also include a criterion that explicitly excludes EM staff and contractors with real or potential conflicts of interests, including all OST staff and contractors, from consideration as reviewers. OST also should consider modifying the criteria to emphasize expertise relevant to the review**.

In reviewer selection, it is also necessary that all relevant areas of expertise required to address the review criteria be represented on the peer review panel. This is particularly important for the very diverse and complex technologies being developed for environmental cleanup of the DOE complex. **The size of the review panel should depend on a number of factors, including the complexity and number of projects being reviewed, the stage of development of the project, and the specific review criteria for the review. One approach that could be used to help identify reviewers with relevant expertise would be to develop and use a large data base of potential reviewers**.

PEER REVIEW RESULTS

For a peer review program to be effective, the results should be used as important factors in making decisions regarding future support for the project and/or as input to improve the technical merit of the project. In order to achieve this objective, peer review results should be summarized in clearly written reports that provide the rationale for their conclusions and recommendations. OST has made progress in improving the technical quality of peer review reports by requiring more complete explanations of the reasoning for the panel's conclusions and recommendations, by adding a section that summarizes the review criteria, and by including short biographical sketches of the peer reviewers. **The reports could be improved further, however, by also including a statement of the objectives of the review and a list of references used in the analysis**.

OST also should strive to implement its written procedures for feedback of peer review results into program management and development decisions more fully. **In particular, the committee encourages OST to enforce its 30-day deadline for written responses to all peer review reports, and to require more detailed written responses from PIs and program managers that fully describe how the recommendations of the peer review panel were seriously considered**. OST also should begin to develop and collect data for a set of activity and performance metrics that can measure the overall effectiveness of the peer review program.

IMPLEMENTATION OF PEER REVIEW PROGRAM

To summarize, OST successfully has begun the process of implementing its new peer review program, but considerable effort is needed before peer review becomes an effective part of the standard operating procedures within the organization. OST increasingly has acknowledged that effective peer review can improve the credibility of its programs. The committee hopes that OST staff will recognize that such advice is valuable at many stages in the technology-development process. The committee does not suggest that the OST program staff is not qualified—and in fact believes quite the opposite. Technical reviews by the program staff are extremely valuable, but these programmatic reviews are not substitutes for peer review. Peer review of the program is a form of independent validation and a "reality check" on technical development. The peer review program will be meaningful only if OST acknowledges the benefits of effective peer review and makes peer review a vital part of the decision and management process throughout the organization. Although attaining these benefits will require a sustained effort from management, the entire organization will be rewarded through enhancement of the technology-development program.

Introduction

The U.S. Department of Energy's (DOE's) Office of Environmental Management (EM) was established in 1989 to address the health, safety, and environmental challenges associated with cleanup of the nation's nuclear weapons complex. Within EM, the Office of Science and Technology (OST) was created to promote the development of new and improved technologies to lower cleanup costs and risks (to workers, the public, and the environment) and to improve cleanup capabilities. OST supports the entire range of technology development activities—beginning with basic research through the new EM Science Program (NRC, 1997) and extending through development, demonstration, and (with the assistance of industrial partners) deployment into the cleanup program.

In fiscal year 1997 the annual budget for EM is about $6 billion, of which about $300 million is devoted to technology-development activities within OST. The importance of technology development to EM's mission has been recognized in *Accelerating Cleanup: Focus on 2006* (DOE, 1997a), a draft planning document for cleanup of the weapons complex. This document discusses the importance of technology development to reduce the "mortgage" at the complex—the long-term costs of maintaining contaminated buildings, equipment, and sites until they can be remediated.

OST sponsors close to 300 research and development (R&D) projects at universities, national laboratories, and private-sector companies on topics ranging from remote detection of contaminants in the subsurface using geophysical techniques to development of melters for waste vitrification. OST uses various types of reviews (e.g., programmatic reviews, technical assessment reviews, and peer reviews)[1] in its technology-selection process (see Appendix C for a description of the different types of reviews used within OST). These reviews are used to assess the merit of individual projects as well as the merit of entire technology development thrusts within the office.

Several recent NRC reports evaluated DOE-OST's technology-selection process and recommended that OST should develop and apply an independent, external review process to all of its technology-development programs. The report *Improving the Environment* recommended that "technology selection should incorporate a knowledgeable independent review group that has no vested interests in the outcome and that includes people from outside the Department who work in the commercial use of technologies" (NRC, 1995c, p. 104). The NRC's Committee on Environmental Management Technologies (CEMT) also evaluated this technology-selection process in its 1994 and 1995 annual reports (NRC, 1995b, 1996). In particular, these reports recommended that OST should develop and apply a standardized, rigorous, and independent external peer review process to all of its technology-development programs. These findings were echoed in a subsequent General Accounting Office (GAO) report, which concluded that "although the lead sites used significantly different systems to select projects, none of them used disinterested reviewers to determine the technical merit of the proposed work" (GAO, 1996, p. 7).

[1] These peer reviews are termed "technical peer reviews" by OST.

In response to these NRC and GAO reports, the OST recently has instituted a peer review program that uses the American Society of Mechanical Engineers (ASME), with administrative and technical support provided by the Institute for Regulatory Science (RSI), to conduct peer reviews of technologies (or groups of technologies) at various stages of development. According to the OST, the objective of this new program is to serve as a "management tool for assuring that the technology is of high quality and effective, that critical needs have not been overlooked, and that the technology has the best chance possible for implementation."[2]

OST asked the NRC to convene an expert committee to evaluate the effectiveness of its new peer review program and to make specific recommendations to improve the program, if appropriate. In particular, the committee was asked to review the following:

- internal procedures used by OST to identify the need for timely peer review of projects and programs;
- structures, protocols, and procedures for obtaining peer reviews of OST projects and programs, including who decides what will be peer reviewed, what criteria for peer review are used, and when in the R&D process peer review is requested; and
- feedback of peer review results into program management and development decisions.

In performing this assessment, the committee was asked to compare OST's practices to generally accepted norms for scientific and technical peer review, including practices for selection of peer reviewers and screening for bias and conflict of interest.

The responsibility for establishing and executing an effective peer review program lies entirely with EM and specifically with OST. OST has chosen to establish a relationship with two independent organizations, the ASME and RSI, to carry out some aspects of its peer review program. When the committee first began this review and in subsequent meetings, officials from ASME and RSI expressed their concerns about the scope of the study and, in particular, whether the committee would be evaluating the performance of either of these organizations. In undertaking this review, the committee has focused its attention exclusively on the design and effectiveness of the peer review program; the committee has not addressed the performance of ASME or RSI, nor has it evaluated or endorsed the organizational arrangements among ASME, RSI, and OST. The committee's findings and recommendations are directed at OST which, as noted above, has ultimate responsibility for the peer review program.

Another NRC Committee, the Committee on Prioritization and Decision Making in the Department of Energy-Office of Science and Technology, is currently conducting a parallel review of the decision-making process in OST's technology-development program. One aspect of its work will be to examine the role and importance of peer reviews in OST's decision-making process. Our committee therefore has focused its work on OST's peer review program itself (including the peer review results used as an *input* to decision making), but has not addressed OST's decision-making process explicitly.

This study is being carried out over a 15-month period (from January 1997 through March 1998), during which time the committee will produce both an interim (this report) and a final report. The committee has been briefed on the newly instituted peer review program by DOE staff at three committee meetings, and members and staff of the committee observed peer

[2] Presentation to committee by Anibal Taboas, DOE, February 24, 1997, Washington, D.C.

reviews conducted on the In Sire Redox Manipulation project in Richland, Washington, the Decontamination and Decommissioning (D&D) Large Scale Demonstration projects and three D&D Technology Development projects in Morgantown, West Virginia, the MAG*SEP technique[3] in Atlanta, Georgia, the Small In-Tank Processing Modules and Small Modular In-Can Vitrification projects in Columbia Maryland, and several High Temperature Melter and Characterization projects in Idaho Falls, Idaho. The committee also has reviewed all peer review reports that have been produced under the new program from its initiation in October 1996 through June 1997. In addition, during its meetings, the committee was briefed on current peer review practices at the Environmental Protection Agency (EPA), EPA's Science Advisory Board, the U.S. Nuclear Regulatory Commission (USNRC), the DOE-Office of Basic Energy Sciences (BES), Information Dynamics, Inc. (which conducts reviews for NASA's Office of Life and Microgravity Sciences and Applications), and the American Institute of Biological Sciences (AIBS).

This is the first of two reports to be prepared by this committee on OST's new peer review program. OST requested this interim report to provide a preliminary assessment of its new peer review program. In particular, OST asked the committee to consider whether it is moving in the fight direction toward the implementation of a credible, effective, and defensible peer review program. In this report, the committee describes the essential components of a credible peer review program and provides a preliminary assessment of OST's new peer review program and the status of its implementation. Recognizing that this is a new program in its early stages of implementation, the committee has focused on broad issues and has tried to offer constructive recommendations to assist OST in successfully implementing this program. In the final report, the committee will provide a more detailed assessment of OST's peer review program after its first complete annual cycle. This final assessment will develop a general framework for evaluating the level of development (or "maturity level") of a peer review program, focusing on specific components of the peer review process, and will include more detailed recommendations on how to improve OST's peer review program (including issues raised in this report), if appropriate.

[3] The MAG*SEP technique is a means of recovering selected radionuclides and heavy metals from water and other liquids through sorption onto specially coated particles.

Definition of Peer Review

Although one can argue legitimately that "peer review"[4] is the name given to any judgment of technical[5] merit by other experts working in or close to the field in question, the scientific and engineering communities generally use the term "peer review" in a narrower sense. In this report, we adopt these communities' sense of peer review, as articulated in the definition developed by the USNRC:

> A peer review is a documented, critical review performed by peers [defined in the USNRC report as "a person having technical expertise in the subject matter to be reviewed (or a subset of the subject matter to be reviewed) to a degree at least equivalent to that needed for the original work"] who are independent of the work being reviewed. The peer's independence from the work being reviewed means that the peer, a) was not involved as a participant, supervisor, technical reviewer, or advisor in the work being reviewed, and b) to the extent practical, has sufficient freedom from funding considerations to assure the work is impartially reviewed.
>
> A peer review is an in-depth critique of assumptions, calculations, extrapolations, alternate interpretations, methodology, and acceptance criteria employed, and of conclusions drawn in the original work. Peer reviews confirm the *adequacy* of the work. In contrast to peer review, the term "technical review" . . . refers to a review to verify compliance to predetermined requirements; industry standards; or common scientific, engineering, and industry practice. (USNRC, 1988, p. 2)

In this definition, the term peer review has the following characteristics:

- expert (including national/international perspectives on the issue),
- independent,
- external, and
- technical.

Most importantly, peer reviews must be carded out by independent reviewers who are experts in the technical issues relevant to the projects under review. Such reviewers must be highly qualified[6] and independent in order to evaluate credibly the scientific and engineering merit of

[4] The choice of the term "peer review" versus "merit review" is somewhat subjective. Because "merit review" is often used to describe evaluations that include programmatic/nontechnical aspects of projects (Royal Society, 1995), the committee has chosen to use the term "peer review" in this report.

[5] in this report, the committee uses the term "technical" to mean "relating to special and/or practical knowledge of an engineering or scientific nature."

[6] Determined by reputation and standing in the field (for example, publications and status in professional societies) and relevance to the project being reviewed.

the project with respect to current technologies, both domestic and international. In the report *Allocating Federal Funds for Science and Technology* (NRC, 1995a, p. 69), peers are defined as "established working scientists or engineers from diverse research institutions who are deeply knowledgeable about the field of study and who provide disinterested technical judgments as to the competence of the researchers, the scientific significance of the proposed work, the soundness of the research plan, and the likelihood of success." Note that such reviewers need not be expert in or familiar with the agency program or relevant contextual factors. Those are the proper province of agency management.

The USNRC's definition of "peer review" provides some guidance on the issue of potential conflict of interest by explicitly excluding potential reviewers who have been involved with the specific project being reviewed or who have financial interests in the outcome of the reviews. As Chubin and Hackett (1990) have pointed out, however, it is often difficult to identify true "experts" on a subject or technology who do not have some biases that could be perceived as a potential conflict of interest (e.g., competing interests, personal relationships). The committee will provide more specific recommendations on the issue of conflict of interest in its final report.

In the past, OST has used the term "peer review" generally to refer to internal reviews of OST projects by qualified EM technical staff who were not involved directly in the specific project under review. This use of terminology has caused confusion and misunderstanding within both OST and external review groups (e.g., GAO, NRC) who have continued to criticize OST for a lack of a credible peer review program. Although internal reviews of this type are necessary and should continue, they should not be confused with peer review because the term "internal peer review" is not consistent with the usual meaning of peer review (Bozeman, 1993). The committee believes that at least part of the criticism leveled at the OST project review process has resulted from inconsistent and inaccurate descriptions of the processes involved (e.g., internal peer review, technical peer review). **To avoid misunderstanding, OST should restrict the term "peer review" to only those technical reviews conducted by independent, external experts. OST should adopt alternative terms, such as "technical review," for its internal reviews of scientific merit and pertinency**. Careful attention to nomenclature will eliminate much of the confusion about the nature of OST's review process and could increase appreciation and respect for OST's new peer review program.

Benefits of Peer Review

The OST technology-development program involves the expenditure of hundreds of millions of increasingly scarce federal discretionary dollars each year. It is particularly important that decisions about investment of those funds are based on sound criteria (both technical and nontechnical), and that the decision-making process is respected by all parties in the technology development program. Rigorous peer review can be an important tool for OST in meeting these objectives, as well as improving those projects that are funded.

Effective peer review is first and foremost a valuable way to increase the technical quality of projects in a program. The 1995 CEMT report recommended development and implementation of such a peer review program for the OST technology-development program for just this reason (NRC, 1995b). When peer review results are used to improve the quality of a decision process (e.g., selection of proposals, prioritization of projects for funding), it also enhances the *credibility* of the decisions. Use of peer review therefore provides observers some confidence that decisions are consistent with the best available scientific and technical information.

When the results of peer reviews are used as important input into funding decisions early in the technology-development process, they also can dramatically increase the productive efficiency of a program. Projects that lack technical merit or have a low likelihood of success can be discontinued early in the research and development cycle (before large investments of funds are made) and the savings can be reallocated to other projects that show greater promise of success. In addition, a greater number of alternative projects can be supported in the early stages of the development cycle. In studies of corporate product development programs, Cooper (1993) has shown that such early decisions can result in a greater than 50 percent overall increase in productive efficiency.

Although "internal reviews" play a valuable role (e.g., in matching projects to program needs), for a number of reasons, peer review, if conducted effectively, can enhance both program quality and the credibility of decision making. These include the following:

- Independent experts who are newly exposed to a project often can recognize technical strengths, weaknesses, and ways to improve the project that may have been overlooked by those close to the project (Bozeman, 1993).
- Drawing from a large pool of independent, external experts can provide more breadth and depth of expertise to the analysis than that available within the internal reviewer pool, resulting in a more effective and meaningful review (NRC, 1995a). For example, such experts may be more effective than internal reviewers in evaluating a project in the context of other comparable or alternative technologies available in the private sector, other government agencies, or other countries.
- Independent experts often can be more open, frank, and challenging to the status quo in their comments than internal reviewers, who may feel constrained by organizational concerns.
- External review can enhance the credibility of the review process by avoiding both the reality and the appearance of conflict of interest (Kostoff, 1997a).

- Peer reviews conducted publicly (i.e., using known reviewers following an established process) that provide immediate feedback in the reviewers' own words can enhance credibility by increasing confidence in the process (Royal Society, 1995; NRC, 1997).

Of course, peer reviews in and of themselves cannot assure the success of a project or program. Effective peer review can increase the probability of project and program success, however. The realization of these benefits requires that the process of peer review be effective and credible and that peer review results are used as an important input in making decisions regarding future support for the reviewed project (Chubin and Hackett, 1990).

The following section of this report includes an initial assessment of OST's new peer review program and offers some general recommendations on how OST could improve both the effectiveness of its program and the usefulness of peer review products (i.e., reports) in helping to make programmatic decisions.

Peer Review Process

The peer review process can be broken down into five general steps (Figure 1):

1. selection of projects to be reviewed;
2. definition of the objectives of the peer review and selection of specific review criteria;
3. selection of peer review panel;
4. planning and conducting the peer review; and
5. use of peer review results in decision making.

In order for a peer review process to be credible and effective as a whole, each of these steps must be performed following well-defined procedures that are understood and accepted by everyone involved with the peer review program.

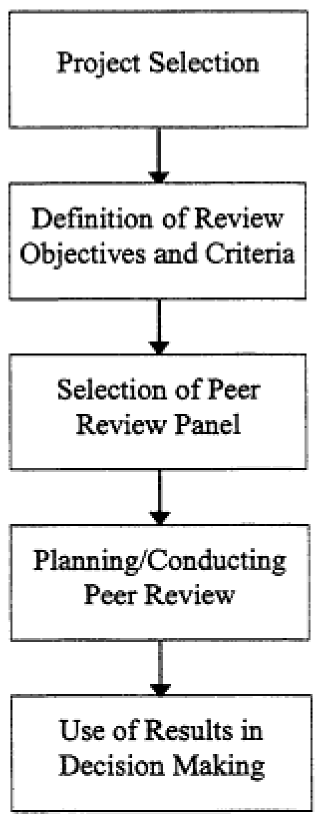

Figure 1
Flow-chart showing major steps of a peer review process.

BOX 1 AN OVERVIEW OF OST'S PEER REVIEW PROGRAM

The peer review program is managed within OST by the Peer Review Coordinator. The peer reviews are conducted by the American Society of Mechanical Engineers (ASME) with administrative and technical support provided by the Institute for Regulatory Science (RSI). Funding for the review program is provided directly to RSI through a $1.2 million annual grant from OST.

OST focus area (FA) and crosscutting area (CC) program managers[7] initiate the peer review process by making written requests for peer reviews to the Peer Review Coordinator. The FA/CC program managers are responsible for developing a prioritized list of technologies to be reviewed, providing documentation to reviewers, preparing responses to review panels' Consensus Reports, and for covering the cost of FA/CC program personnel and material needed for the peer reviews. The FA/CC program managers are the main decision makers regarding the funding of technology projects within OST.

Each project's **principal investigators** (PIs) are responsible for providing relevant project information for the peer reviewers, including written background documentation and oral presentations to the review panels, if needed.

The **Peer Review Coordinator** is the principal federal official responsible for managing the day-to-day activities of the program. Specific responsibilities of the coordinator include receiving, processing, and scheduling peer review requests from FA/CC program managers; coordinating peer review activities among FA/CC program managers, the ASME Peer Review Committee (see below), and the review panels; ensuring that reviews are executed in a timely manner, ensuring that FA/CC program responses to review recommendations are included in Final Reports; and managing the budget and records for OST.

The **ASME Peer Review Committee** is a standing body of the ASME whose sole purpose is to oversee the OST's peer review program and enforce relevant ASME policies, including compliance with professional and ethical requirements. The Peer Review Committee is responsible for appointing members nominated by the Executive Panel (see below) to individual peer review panels and assessing Interim Reports for conformity to ASME standards before being issued as ASME-sanctioned public documents. The **Executive Panel of the Peer Review Committee** (EP) consists of three to five ASME members who have served in leadership positions within ASME, and is responsible for overseeing the day-to-day operation of the peer review program.

Peer review panels consist of three or more technical experts chosen for their knowledge of the specific technology to be reviewed. Although ASME requires the peer review panel chair to be a member of ASME, other panel members need not be ASME members. The peer review panel conducts the review, prepares a Consensus Report detailing its recommendations and observations, and transmits the written report directly to the sponsoring FA/CC program manager.

[7] Focus areas were created by EM to assist in management and coordination of its technology development activities. The four focus areas, which are based on EM's major problem areas, are mixed waste characterization, treatment, and disposal; radioactive tank waste; subsurface contamination (formerly two focus areas: contaminant plume containment and landfill stabilization); and decontamination and decommissioning. In addition, EM created several crosscutting areas to coordinate activities that apply to multiple focus areas: robotics; efficient separations; characterization, sensors, and monitors; industry and university programs; and technology integration.

The **Institute For Regulatory Science** provides administrative and technical support for peer review activities. RSI's responsibilities include meeting planning, the compilation and distribution of background materials for members of review panels, facilitating peer reviews, and providing an executive secretary to assist in the preparation of Consensus Reports of peer review panels.

The size and scope of each review panel depends on the specific technology(ies) being reviewed and the areas of expertise required to address the review criteria. OST classifies specific peer reviews as Level I, II, or III, as defined below.

I. Multi-technology review of a complex nature involving site visits (five or more reviewers),
II. In-depth review of a technology involving site visits (three or more reviewers); and
III. Review of a document requiring no site visit (i.e., mail review).

The following sections provide a general analysis of OST's peer review program based on the committee's review of OST documents, presentations by DOE staff, observations of recent peer reviews, and the committee's assessment of peer review reports. The committee recognizes that OST's peer review program is in its early stages of implementation and therefore offers these comments and recommendations for OST's consideration as it continues to develop and improve its program. For the reader's reference, boxes 1 through 9 introduce relevant aspects of OST's current peer review program and the OST organization, and are based on OST's descriptions of the program. A complete description of OST's peer review program can be found in Appendix A, from which the text of most of the boxes is extracted. An overview of OST's peer review program is presented in Box 1.

SELECTION OF PROJECTS FOR PEER REVIEW

An effective project selection process ensures that projects are prioritized on the basis of criteria such as program relevance, cost effectiveness, and chance of implementation (Cole, 1991; McCullough, 1989). Box 2 presents OST's process for selecting technologies to be peer reviewed.

Seventeen technologies were peer reviewed by the OST program between October 1996 and May 1997, and thirty additional projects are scheduled to be peer reviewed through September 1997. Table 1 summarizes at what stage in OST's technology-development process these peer reviews took place, and it also shows the total number of active projects within OST. Because of the relatively low rate of peer reviews conducted under this program relative to the large number of active projects, OST currently funds a large number of technologies that never have been peer reviewed. Many of these projects are in the later stages of development.

BOX 2 OST'S PROCESS FOR SELECTING TECHNOLOGIES TO BE PEER REVIEWED

OST policy requires that a peer review be conducted on each technology/system before it passes through Gate 4 of OST's Technology Investment Decision Model (TIDM) process (see Box 3 and Appendix B for descriptions of the TIDM). Specifically, OST policy states that a technology peer review will be conducted on each technology/system. However, FA/CC Program Managers will give priority attention to those technologies that are preparing to pass through Gate 4 of the OST Technology Decision Process Procedure (Version 7.0) [DOE, 1997c]. Specifically, this procedure states that technical peer review reports are one of the documents required to pass through Gate 4. In addition, peer reviews may be appropriate at other phases of the technology maturation stages. (DOE, 1997b, p. 3)

The actual decisions to conduct peer reviews of specific technologies are made by FA/CC program managers in response to five main "drivers": (1) funding, (2) changes in status (e.g., when a project approaches a gate in the TIDM process), (3) regulatory issues, (4) stakeholder concerns, and (5) any technical or other issues that arise concerning a given technology. Currently, there is no OST-wide process for selection of technologies to be reviewed, although the need for such a system has been recognized by OST staff.[8]

TABLE 1 Status of Peer Reviewed Technologies in the Stage-Gate Model Gate (See Box 3)

	1	2	3	4	5	6	Unassigned
Peer Reviews Completed[a]	0	5	0	3	2	6	0
Peer Reviews Scheduled[a]	0	1	0	4	6	2	0
Active Projects[b]	0	2	34	86	111	27	33

[a] As of April 1997.
[b] As of May 1997.

[8] Presentation to committee by Miles Dionisio, April 14, 1997, Washington, D.C.

BOX 3 THE TECHNOLOGY INVESTMENT DECISION MODEL (TIDM)

The TIDM is the procedure developed by OST to provide a common basis on which to assess and manage the performance, expectations, and transition of technologies through the development process. It is a user-oriented decision-making process for managing technology development and for linking technology-development activities with cleanup operations.

The TIDM identifies six R&D stages from basic research through implementation of a technology (see Figure 2). The model incorporates decision points (or "gates") within the R&D process where projects are evaluated for funding of the next stage of development. These TIDM gates represent milestones at which peer review might assess a technology's soundness. For each stage, specific criteria, requirements, and deliverables provide a common basis for technology assessment. The "stage-gate" process is meant to guarantee early evaluation of projects against technical and nontechnical criteria to ensure that the technologies will provide superior performance and also will meet the acceptance requirements of the intended customers. The TIDM also addresses the technology transfer and commercialization factors that must be considered to get the technological innovations into the marketplace.

The FA/CC technology leadership is responsible for evaluating all documentation in accordance with the criteria for each gate. If the FA/CC program determines that the technology warrants passing through a gate, the technology maturation process will continue. If the program determines that the technology does not warrant further consideration, then funding is discontinued.

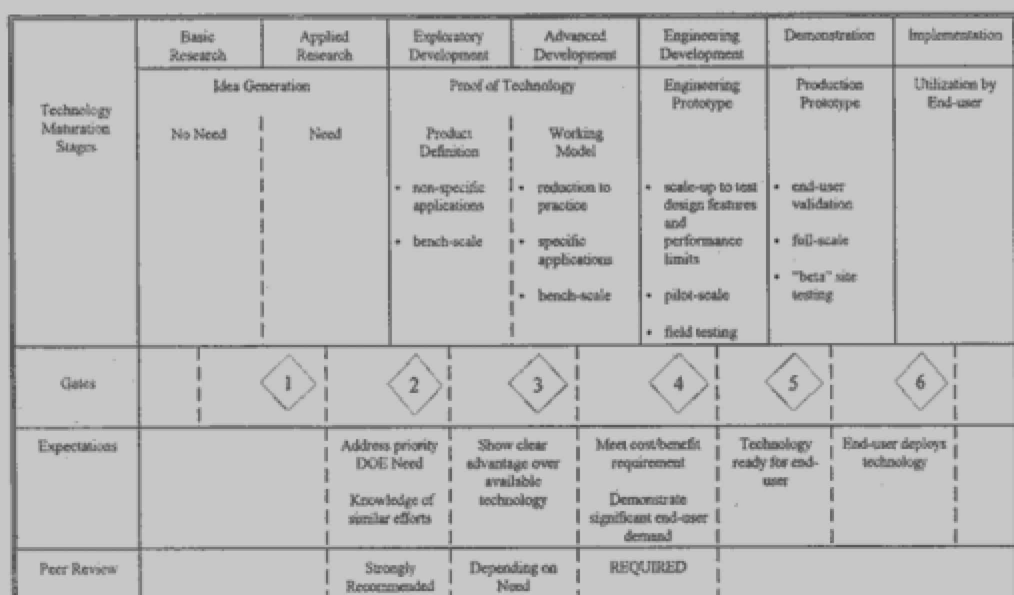

Figure 2
Diagram of OST's Technology Investment Decision Model (DOE, 1997b).

OST's decision to require peer reviews prior to Gate 4 is based upon the large increase in funding that typically occurs when a project moves from bench scale to field scale. This is a rational basis for prioritization, and Gate 4 is an appropriate time to schedule a review for projects that have not yet reached field scale. Such a mandate, however, does not constitute a sufficient and systematic approach for selecting and prioritizing the projects to be reviewed.

OST's policy to review all technology projects prior to Gate 4 also does not address the large number of technology projects that have already moved past Gate 4 (138 of 293 active projects) and have never been the subject of peer review. The committee believes that these projects should be peer reviewed before being considered for additional funding. The committee is encouraged that a significant number of the peer reviews conducted to date have reviewed technologies that are past Gate 4 (Table 1). Peer review of technologies beyond Gate 4 is particularly important for those technologies nominated for the Technology Deployment Initiative (TDI, see Box 4). This initiative is designed to aid in rapid deployment of demonstrated technologies that are ready for full-scale application. The probability that this initiative will lead to successful deployment of technologies can be maximized by assuring the technical merit of these technologies through the use of peer review results in the TDI selection process.

BOX 4 EM'S TECHNOLOGY DEPLOYMENT INITIATIVE (TDI)

EM has requested a total of $30 million in fiscal year 1998 for the TDI, an effort that will provide funding for projects proposing immediate application of proven technologies. The TDI is intended to expedite application of remediation technologies at multiple DOE sites to help reduce the EM mortgage and achieve the goals of the *Focus on 2006* program. TDI projects are selected by DOE managers through a competitive procurement process. Selection criteria include technical, business, and stakeholder/regulatory criteria. Field offices have primary management authority for TDI projects, with OST serving in an oversight capacity. Projects are funded as actual site cleanups, at a level of up to $5 million a year for four years. In order to encourage participation in the TDI, EM has committed to reinvesting cost savings obtained through TDI projects back into the site's programs, so that achieving cost savings would not result in decreased funding for the site.

In addition, the committee strongly encourages OST to focus a part of its peer review efforts earlier in the technology-development process. As previously discussed in the section entitled Benefits of Peer Review, peer review of technologies during the early stages of development maximizes the return on R&D expenditures. In a effective peer review/decision-making process, there will be fewer and fewer projects at later stages of development because many projects would be terminated at early gates alter relatively small funding investments. This is the opposite of the current situation within OST, where there are relatively few projects in the early stages but many projects in the later stages of development (Table 1).[9]

[9] Not including projects supported by the EM Science Program, which funds basic environmental research relevant to EM's cleanup mission. Over time, successful results from this program could feed into the early stages of OST's technology development program. All projects in the EM Science Program are peer reviewed before receiving any funding.

To address these issues, the committee recommends that OST develop a rigorous process for selecting projects to be peer reviewed. To be fair and credible, this process should employ well-defined project selection criteria, and OST peer review program staff should be directly involved in making decisions regarding which projects will be reviewed . Due to the large number of projects in the later stages of development, the committee encourages OST to focus much of the short-term peer review efforts on high-budget, late-stage projects that have never been peer reviewed, but that still face upcoming decisions with major programmatic and/or funding implications. In the long-term, however OST's objective should be to subject all new technologies to a peer review when they enter the program (i.e., at the proposal stage), followed by additional peer reviews at other critical points in the technology-development process (such as at Gate 4).

DEFINITION OF PEER REVIEW OBJECTIVES AND SELECTION OF REVIEW CRITERIA

The objectives of the peer review (i.e., what OST is attempting to achieve with the review) must be spelled out clearly so that they are understood by all involved in the process (Chubin, 1994; Chubin and Hackett, 1990). In addition, the specific review criteria (i.e., specific questions/issues that reviewers are asked to address in a particular review) should be defined prior to the selection of the peer review panel to ensure that the panel has the appropriate expertise required to address these issues. Because peer reviews are by definition technical in nature, both the objectives of the review and review criteria should focus on technical considerations. OST's procedure for defining peer review objectives and review criteria is described in Box 5.

BOX 5 OST'S PROCEDURE FOR DEFINING PEER REVIEW OBJECTIVES AND REVIEW CRITERIA

Peer Review Objectives. FA/CC program managers are required to include a statement of the desired scope and purpose of the review when requesting a peer review.

Peer Review Criteria. The following general criteria for peer reviews have been established for OST's peer review program in the ASME Manual for Peer Review (ASME, 1997): (1) relevancy, (2) scientific and technical validity, (3) state of the art, (4) filling an existing void, (5) non-duplicative/superior to alternatives, (6) cost effectiveness, (7) reduced risk, (8) regulatory acceptability, and (9) public acceptance. OST has provided no guidance on the relative weighting of these general criteria.

Although these nine criteria form the core of the criteria to be used during the peer review, the actual criteria used during each review are determined by the ASME Peer Review Committee in consultation with the FA/CC program manager. For each review, the FA/CC program manager develops a preliminary list of specific review criteria, which are then used by the ASME Peer Review Committee to develop the formal review criteria for the review panel. These criteria are used by project staff and other presenters to organize written materials and oral presentations for the peer review. In addition, even though these review criteria form the basis of the review panel's evaluation, the review panel does have the authority to pursue other issues that arise during the review.

Peer Review Objectives

The written statements of "scope" and "purpose" that OST focus area/crosscutting area program managers are required to submit to the Peer Review Coordinator when requesting a peer review can serve as a statement of the objective of the peer review. Such statements should be made available to all participants of the peer review (i.e., PIs, the ASME Peer Review Committee, all reviewers, and observers) prior to the review so that they clearly understand the context of the review. Although this has not yet been accomplished, the committee has been informed that these statements will be incorporated in all future peer review reports.[10]

Peer Review Criteria

OST's general list of review criteria includes broad issues such as cost effectiveness, reduced risk, regulatory acceptability, and public acceptance, which include many nontechnical considerations. Although program managers must consider these criteria when making decisions regarding technologies, such broad, mostly nontechnical issues may sidetrack reviewers into issues beyond their expertise or difficult to resolve within the time constraints of a two- to three-day review. Thus, these criteria are generally inappropriate for peer review. For example, if technologies are peer reviewed very early in their development, both regulatory and public acceptability may be indeterminate. **The committee therefore recommends that OST revise these general nontechnical criteria to focus on technical aspects of these issues, or to remove them from the list of review criteria**.

The committee encourages OST to continue its practice of developing a small number of technology-specific review criteria, provided these criteria are technical in nature and do not obscure or preempt the principal goal of determining technical merit. Specific review criteria allow individual peer review panels to focus their review efforts on issues that are especially relevant to a particular technology or a specific stage of technology development, or that are of particular interest to OST. **The committee recommends that OST develop a well-defined general set of technical criteria for peer reviews, to be augmented by technology-specific criteria as needed for particular reviews**.

SELECTION OF PEER REVIEWERS

The selection of peer reviewers is a critically important step in the peer review process. The process for selecting reviewers must consider the fundamental characteristics of peer review described earlier in this report (see the section entitled Definition of Peer Review) and the specific objectives and criteria for peer review, and should be conducted by a group independent of the group being reviewed (Cozzens, 1987; Koning, 1990).

Peer reviewers should be selected in accordance with formally established criteria. The minimum criteria for individual reviewers should include the following:

- relevant, demonstrated experience in the subject to be reviewed (Bozeman, 1993; Porter and Rossini, 1985);

[10] Statement by Alan Moghissi on changes in ASME policies during Radioactive Isolation Consortium peer review, July 8, 1997, Columbia, Maryland.

- peer recognition;
- knowledge of the state of the art of an aspect of the subject matter under review, including national and international perspectives on the issue; and
- absence of real or perceived conflict of interest (e.g., not selected from DOE or the DOE contractor community) and bias such that the panel as a whole is balanced (Abrams, 1991; Cole, 1991; Moxham and Anderson, 1992).

In assessing an individual's qualifications for participation in a peer review panel, all relevant career experience, published papers, patents, and participation in professional societies should be considered. It is also important to consider the individual's experience with peer review itself (Royal Society, 1995). The peer review panel should be balanced by including individuals with an appropriate range of knowledge and experience to provide credible and effective peer review of the technology being judged (Porter and Rossini, 1985). The chair should be internationally respected in the field under review and should be an experienced peer reviewer. Additionally, some representation of persons qualified in competing or alternative technologies is desirable.

BOX 6 OST'S REVIEWER SELECTION CRITERIA

Reviewers are selected and approved by the ASME Peer Review Committee based on three generally recognized criteria: (1) education and relevant experience, (2) peer recognition, and (3) contributions to the profession. A minimum of a B.S. degree in an engineering or scientific field and sufficient experience in the technical area being reviewed are required for participation in an OST-related review. Peer recognition is assessed by measures such as activity in a professional society. Contributions to the profession include publications in peer reviewed journals, patents, and meeting presentations.

Individuals with any real or perceived conflicts of interest with respect to the subject of the review may not serve on the Review Panel. According to ASME, "an individual who has a personal stake in the outcome of the review may not act as a reviewer" (ASME, 1997, p. 8). Every panel member must sign a statement indicating a lack of personal or financial interest in the outcome of the review.

OST's reviewer selection criteria are described in Box 6. The committee finds that the criteria used to select reviewers in the OST peer review program are adequate to ensure the technical credibility of the peer review panel. **In order to ensure the independence of the peer reviewers, however, the committee recommends that OST also include a criterion that explicitly excludes EM staff and contractors with real or potential conflicts of interest**, including all **OST staff and contractors, from consideration as peer reviewers. OST should also consider modifying the criteria to emphasize expertise relevant to the review**. For example, its first criterion (education and relevant experience) could specifically include knowledge of the state of the art of an aspect of the subject matter under review—including national and international perspectives on the issue.

Another important factor in selecting a peer review panel is that all relevant areas of expertise required to address the review criteria should be represented on the peer review panel. This is particularly important for the very diverse and complex technologies that are being developed by OST for environmental cleanup of the DOE complex, which may require large review panels. **Thus, the size of the review panel should depend on a number of factors, including the complexity and number of projects being reviewed and the specific review criteria established for the peer review**. As discussed in the section entitled Peer Review Criteria, the panel encourages OST to revise its general review criteria to focus on technical issues. If OST continues to include nontechnical review criteria such as public acceptance and regulatory acceptability, however, expertise in these areas also must be included on peer review panels. Many organizations that conduct peer reviews of such complex projects rely on large data bases of potential reviewers from which to select peer reviewers).[11] The committee notes that one reviewer served on six of the first ten review panels convened under the new peer review program. This suggests that a large data base was not used in reviewer selection at that time. **One approach that could be used to help identify reviewers with relevant expertise would be to develop and use a large data base of potential reviewers**.

PLANNING AND CONDUCTING THE PEER REVIEW

In order for the peer review to be fair and credible, the peer review panel should receive written documentation on the significance of the project, a focused charge that addresses technical review criteria, clear presentations by the project team, and adequate time to assess the project comprehensively so that it is able to write a report that effectively summarizes and supports its conclusions and recommendations.

BOX 7 OST'S DOCUMENTATION REQUIREMENTS

OST requires that the PIs provide written materials relevant to the nine general criteria for peer review (see Box 4). Depending on the specific stage of development of the project, the OST Revised Guidance (DOE, 1997b) describes the documentation generally required for a peer review. At Gate 4 of the Technology Development Process Procedure, for example, PIs are required to provide the following:

- literature references,
- progress report (topical),
- needs document,
- test plan,
- quality assurance plan,
- proof of design,
- life-cycle cost analysis,
- risk analysis,
- regulatory issues and review, and
- public acceptance issues and plans.

[11] Presentations to committee by Donald Beem on peer reviews conducted by AIBS on behalf of federal agencies, February 25, 1997, Washington, D.C., and by Carl Guastaferro, Information Dynamics, Inc., on peer review conducted for NASA's Office of Life and Microgravity Sciences and Applications, April 15, 1997, Washington, D.C.

The documentation requirements for OST's peer review program are presented in Box 7. As was the case with OST's general review criteria, some of these required documents address nontechnical issues and therefore should not be part of the materials reviewed by panelists during the peer reviews. **The committee encourages OST to refine its list of required materials to include only technical documents relevant to the review criteria established for the peer review**.

During some of the technology presentations at OST peer reviews, members of this committee have observed several problematic situations that impeded a thorough review, such as the withholding of confidential technical information from peer reviewers, which prevented panelists from judging the technical merit of a project, and lack of facilitation by the chair. These problems presumably will be resolved as the program matures. Although complete respect for confidentiality is central to the successful operation of peer review (Royal Society, 1995), confidentiality of proprietary information during review can be dealt with through panel selection and by requiring panel members to sign confidentiality agreements. Further, agreement to disclose information critical to a meaningful peer review under appropriate confidentiality agreements could be a condition of the initial project award.[12]

Openness is also an important characteristic of credible peer review process:

> One of the pre-requisites for confidence in the integrity of peer review (and, indeed, of other decision-making processes) is that its workings should be transparent. There are several levels to this. At the minimum, the membership of peer review and other decision-making panels should always be in the public domain. (Royal Society, 1995, p. 4-84)

The committee encourages OST to promote openness at the peer reviews in order to fully inform the public and others attending the reviews of the nature of the review. An approach used by the EPA Science Advisory Board is to make lists of the reviewers and their affiliations available and to have each reviewer publicly state his or her pertinent experience and any factors that could affect bias at the beginning of the peer review. The chair of the peer review panel also should clearly explain the objectives of the review and the specific review criteria that will be addressed by the panel.

USEFULNESS OF PEER REVIEW RESULTS

The peer review program will be effective only if the results are used as an important factor in making decisions regarding future support for the reviewed project and/or as input to improve the technical merit of the project (Bozeman, 1993; Cozzens, 1987). Peer review reports that clearly provide the rationale for their conclusions and recommendations are an essential first step in achieving these objectives. In addition, procedures should be established for incorporating peer review results into the programmatic decision-making process and for requiring project personnel to follow through on technical recommendations of the peer review

[12] The confidentiality of proprietary technical material was well handled during a recent peer review of the Radioactive Isolation Consortium's SMILE and SIPS technologies, conducted on July 8-9, 1997, in Columbia, Maryland.

panel. In a well-established peer review program, specific metrics also should be in place to evaluate the ability of the peer review program to achieve its objectives.

Peer Review Reports

BOX 8 OST'S PEER REVIEW REPORTING PROCEDURES

Each member of the review panel prepares a report containing the outcomes of the review. The review panel chair combines these individual reports into a Consensus Report, which typically contains four parts: (1) a brief description of the review subject, (2) the consensus of the panel on shortcomings and meritorious aspects of the project, (3) recommendations of the panel, and (4) an appendix containing the comments by each reviewer for which no consensus could be reached, or which were considered by the chair to be beneficial, but of secondary importance, to the investigators and managers.

OST's procedures for peer review reporting are presented in Box 8. Some of the early peer review reports that were reviewed by this committee did not document the reasoning for conclusions or provide adequate support for recommendations. More recent peer review reports have more clearly explained the rationale for the peer review panel's conclusions and recommendations, however. Two other improvements in recent peer review reports have been the addition of a section that summarizes the review criteria and the inclusion of short biographical sketches of the peer reviewers. **The committee believes that the peer review reports could be improved further, however, by also including a statement of the objective of the review and a list of references used in the analysis**. These additions could help improve the overall quality of the reports by helping the reviewers focus more clearly on their charge and also could make the reports more useful to program management by documenting the context of the review more clearly.

Feedback Procedures

BOX 9 OST'S REVIEW FEEDBACK PROCEDURES

One to two days after the completion of the peer review, RSI submits the peer review panel's Consensus Report to the FA or CC program manager who requested the review. The program manager is asked to prepare within 30 days a written response that describes how the Principal Investigator and/or the FA/CC program manager intend to respond to the findings and recommendations of the Consensus Report. This formal response is then combined with the substantive sections of the Consensus Report as an ASME Interim Report, which is used by DOE headquarters' staff to evaluate the management of the technology program. The Interim Report is then reviewed and approved by the ASME Peer Review Committee and released as an ASME Final Report.

OST's Technology Decision Process requires that peer review reports be used in all funding decisions made at Gate 4 or at any subsequent gate in the technology-development process. In these gate reviews, these reports constitute one input to be considered in determining whether to continue funding for a project (other inputs to the gate reviews include an estimated project budget, a life-cycle cost study, proof of design documents, and commercialization plan).

Box 9 summarizes OST's procedures that govern the feedback of peer review results into program management and development decisions. The committee has reviewed OST's written procedures on feedback and finds that they are reasonable, although the committee has observed that the implementation of many of these procedures has been uneven. The most significant problem concerns the timeliness of the reviews. In order to have any effect on programmatic decision making, peer reviews must be scheduled to occur before project decisions are made. Such planning has not occurred in a number of the peer reviews completed to date, and in these instances, the main benefits of peer review have been lost. For example, the decision to fund the next stage of development of the In Situ Redox Manipulation project apparently had been made prior to the peer review. In another peer review (of the Large-Scale Demonstration project at Fernald Plant I), the facility had already been decommissioned when the peer review was conducted. Although retrospective reviews can be useful in guiding other projects, clearly, if OST's new peer review program is to be effective, the peer reviews must occur prior to key decision points in the technology-development decision process. The committee also has observed instances where peer reviews of specific projects were canceled shortly before the scheduled peer reviews.

To address these issues, the committee recommends that OST develop a targeted plan for the peer review program. Such a plan should consider factors such as how many of OST's technology projects can be peer reviewed, realistic schedules for the reviews, and the peer review program budget. To be effective, this plan also must assure that peer reviews are conducted early enough in the budget cycle to allow peer review results to be used as an input into meaningful funding decisions. In developing such a plan, OST should consider expanding its practice of consolidating reviews of related projects into a single review or several overlapping reviews in order to increase the number of projects that can be reviewed in the peer review program. Another value of reviewing multiple projects during a single peer review is that it acts to normalize the peer review results (Kostoff, 1997b).

The timeliness and quality of the formal written responses from the FA/CC program managers also have been uneven. A number of formal responses from the program managers have not been transmitted to ASME within 30 days of the peer review, as required by OST policy. In addition, many of the written responses from OST program managers have not adequately documented how OST intends to follow through with the conclusions and recommendations of the peer review reports. For example, although the review panel for the Cost of *In Situ* Air Stripping of VOC Contamination in Soils Project made 10 specific recommendations for improving the project, OST's entire formal response was "The Program Manager agreed with the recommendations of the Review Panel, and the report is being revised" (ASME, 1996a, p. 5). For the peer review of Proposals for Salt Stabilization, OST's entire response was: "The DOE agreed with most recommendations of the Review Panel. However, while the project in priority 4 was not funded, three projects prioritized lower were funded." (ASME, 1996b, unpublished, p. 8). Such brief written responses do not provide sufficient explanation or documentation to be useful to OST decision makers charged with making funding decisions. **The committee therefore encourages OST to enforce the 30-day requirement for written responses, and to require more detailed responses that fully describe how the recommendations of the peer review reports were implemented or considered**.

A peer review report that finds that a project is technically sound, based on good science, and capable of practical realization should be a necessary but not sufficient condition for passing certain TIDM gates. A project could fail to pass the gate for programmatic reasons even if it were technically sound, but a report stating that a project is *not* technically sound should be a sufficient reason to reject a project at any gate. The project need not necessarily be terminated (e.g., it might need more development before moving to the next stage, or the review might be "appealed" and reconsidered, especially if the panel was divided in its conclusions), but it should not pass a gate in the face of an adverse review.

Metrics to Evaluate Program Success

Metrics assist in the measurement of effectiveness and can be used to evaluate the success of a program in realizing its objectives. Two types of metrics can be considered: activity metrics and performance metrics.[13] Activity metrics indicate whether the program is proceeding efficiently. Performance metrics indicate whether the program is achieving the desired results.

Although OST currently has no activity or performance metrics for its peer review program, properly chosen and clearly defined metrics could be a powerful management tool to help OST improve the efficiency and performance of this program. Activity metrics that could be chosen include (1) the percentage of projects reviewed at each gate, (2) the percentage of reviewed projects that were not funded in the next gate review decision, (3) the percentage of adequate DOE written responses to peer reviews that were received within the required 30 days, and (4) the degree of follow up on recommendations of the peer review panels. Performance metrics for the peer review program could be selected to measure the "success" of the program in meeting its objectives. For example, the percentage of resources going to "successful" projects could be an appropriate performance metric. These activity and performance metrics are provided as examples—ultimately OST management will need to establish its own set of metrics based on the success criteria they set for the technology-development program. The committee encourages OST to begin developing and collecting data for a set of activity and performance metrics for the peer review program. Metrics to evaluate the success of the peer review program will be discussed more fully in the committee's final report.

[13] The terms "activity metrics" and "performance metrics" are referred to as "formative evaluation" and "summary evaluation," respectively, in the field of program evaluation.

Implementation of the Peer Review Program

The committee is encouraged that OST continues to actualize its new goal of implementing peer review of its activities. OST presentations to this NRC committee at its April 1997 meeting showed progress since the February 1997 meeting, and some aspects of the peer review program (e.g., quality of peer review reports) have improved since the program's inception. OST now has a documented peer review process that is being applied on a small scale to evaluate the technical merit of individual projects.

Despite this progress, however, OST must address a number of issues, discussed in the previous sections, that are hindering the effectiveness of its new peer review program (e.g., selection of projects, definition of peer review objectives and criteria, criteria for reviewer selection, and improvement of peer review results). The committee also has perceived a lack of acceptance of peer review as a standard operating procedure within parts of the OST organization. In the following section, the committee discusses this issue and the leadership necessary to implement this peer review program successfully.

OST'S "CORPORATE" CULTURE

One feature characteristic of organizations that effectively use peer review as an input into management of their research and development portfolios is a peer review process that is ingrained in their organizational cultures; in other words, for these organizations, peer review is "standard operating procedure." Even after deciding on a peer review process that seems adequate on paper, OST still should change its organizational culture so that it embraces peer review as an essential part of its decision-making process. The peer review culture is not yet ingrained within the EM program (NRC, 1995b,c, 1996; GAO, 1996). This may derive from a time when DOE laboratories were working in fields such as weapons development, where the national expertise was predominantly within the DOE organization. Today, technology programs like those of OST are not peculiar to DOE but are common in other organizations, and a broad range of expertise is available outside of the DOE "family." OST is just beginning to turn to the outside world for technical advice, however. Indeed, during the committee's review, it became clear that some OST staff and contractors continue to view peer review as an externally imposed *requirement* to be complied with, rather than as an *opportunity* to benefit from independent expert advice. The committee is encouraged, however, that the EM Science Program (see Appendix C), which funds basic environmental research of relevance to EM, has embraced peer review for assessing the scientific merit of proposals. The committee hopes OST staff will recognize that such advice is valuable at many stages in the technology-development process.

An advantage of independent advice throughout the process, as mentioned in the section entitled Benefits of Peer Review, is that external experts do not have the same set of constraints on their thinking and are therefore more likely to recommend termination of projects that have little probability of future utility, because they have no "identity" with the project. Likewise, external reviewers are able to recommend adding additional resources to a promising project without being subject to the charge of programmatic favoritism.

The committee does not suggest that the OST program staff is not qualified—and in fact, believes quite the opposite. Technical review by the program staff is extremely valuable and essential, and program staff review is a major component of proper management of the public trust in these high-impact programs. These programmatic reviews are not substitutes for peer review, however. Peer review of the programs is a form of independent validation and a "reality check" on technical development.

ROLE OF LEADERSHIP

Kostoff (1997a,b) recently argued that one of the most important factors for high-quality peer review programs is the commitment of the organization's senior management to high-quality reviews:

> The primary requirements of excellent peer review are the dedication of an organization's senior management to the highest quality objective review and the motivation of the review manager to conduct a technically credible review. (Kostoff, 1997a, p. 652)

Implementing the necessary changes in OST to improve the technology-review process will be difficult. OST leaders will have to commit much attention and energy to integrating peer review into the organization's standard operating procedures. Such a change would lead to an improvement in the planning and execution of the peer review program and, more importantly, its effectiveness (i.e., the use of peer review results in better management decisions and in program improvement).

Organizational "culture" can be defined as the norm of what members value. Therefore, to affect a lasting change in an organization's culture, the normative values of its members must change. This change must start at the top, but to be successful it also must pervade all levels of the organization. Members of the organization will come to value peer review when they see benefits to their programs (e.g., through case histories), when management provides logical and consistent messages on the value of peer review, and/or when members are given incentives to use it (Kostoff, 1997b). Support for peer review must be consistent across programs for a sustained period of time to have an impact on the corporate culture.

Based on its observations to date, the committee has not seen this level of commitment to peer review in OST. Lack of consistent policy support for peer review is illustrated by two examples: (1) although OST policy requires a peer review before a technology passes through Gate 4 of the TIDM, decisions to conduct such reviews are reserved to the program managers, and (2) a new description of the OST Technical Peer Review Program (DOE, 1997b) describes the actual peer review process as it is currently being implemented, rather than presenting a clear description of how to implement an effective peer review program. As a result, this document implicitly endorses the status quo of an "immature" peer review process.

Only when obtaining outside advice through a fair and credible process and incorporating such advice into the routine decision-making process become standard procedure will the goal for peer review be achieved. As a means to that goal, OST needs to recognize the benefits of an effective peer review program and become champions of this paradigm. Peer review should be the expected way of doing business. When this is achieved, OST's work will be soundly credible not because it has been given a quick remedial polish but because it is fundamentally good technical work—because it meets high standards of quality.

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Appendixes

Appendix A

Description of OST's Peer Review Program[1]

The Office of Science and Technology's (OST's) peer review program was established in 1996 to address the concerns of external review groups such as the General Accounting Office and the National Research Council's Committee on Environmental Management Technologies (CEMT), who have criticized OST for its lack of a standardized, independent, external peer review system. This new, office-wide program was designed to provide credible peer reviews of OST's technologies at the appropriate stages in the technology development process.

Peer reviews are used by OST to provide an independent evaluation of the technical merits of a technology. These evaluations are intended to assist decision makers in making "go/no-go" decisions regarding further support for technology projects as they proceed through OST's Technology Decision Process (see Appendix C). In part, because the Technology Decision Process evaluates projects against both technical and nontechnical criteria, OST's peer review program does not directly make decisions regarding the funding of OST technologies. Rather, peer review results are used as one input into the decisions made at critical decision points (or "gates;" Figure C.1) between each stage of the research and development process.

Roles and Responsibilities

The main decision makers regarding the funding of technology projects within OST are the individual Focus Area/Crosscutting (FA/CC) program managers. As such, FA/CC program managers are the main "customer" of the OST peer review program. The peer review program is managed within OST by the Peer Review Coordinator, who represents the Deputy Assistant Secretary for Science and Technology. The peer reviews are conducted by the American Society of Mechanical Engineers (ASME) with administrative and technical support provided by the Institute for Regulatory Science (RSI). Funding for the review program is provided directly to RSI through a $1.2 million annual grant from the OST. This section describes the primary roles and responsibilities of the various entities involved in the OST peer review program.

FA/CC Program Managers

The FA/CC program managers initiate the peer review process by making written requests for peer reviews to the OST Peer Review Coordinator. The FA/CC program managers are responsible for developing a prioritized list of technologies to be reviewed, providing documentation to reviewers, preparing responses to review panels' Consensus Reports, and for covering the cost of FA/CC program personnel and material needed for the peer reviews.[2] The

[1] The material in this appendix is based on OST's description of its program, not on the committee's evaluation.

[2] At present, the direct cost of the peer review itself is covered by the grant to RSI rather than by the budget of the FA/CC program manager requesting the review; however the cost for preparing and presenting to the review panel is covered by the FA/CC program.

FA/CC program managers are responsible for incorporating the results of technical peer reviews into the decision-making process.

Principal Investigators

Each project's principal investigators (PIs) are responsible for providing relevant project information for the peer reviewers. Depending on the specific stage of development of project, the OST Revised Guidance (DOE, 1997b) describes the documentation generally required for a peer review. Such information includes written background documentation relevant to the nine general criteria for peer review (see below) and oral presentations to the review panels, if needed. At Gate 4 of the Technology Development Process Procedure, for example, PIs are required to provide the following:

- literature references,
- progress report (topical),
- needs document,
- test plan,
- quality assurance plan,
- proof of design,
- life cycle cost analysis,
- risk analysis,
- regulatory issues and review, and
- public acceptance issues and plans.

Peer Review Coordinator

The Peer Review Coordinator is the principal federal official responsible for managing the day-to-day activities of the program. Specific responsibilities include receiving, processing, and scheduling peer review requests from FA/CC program managers; coordinating peer review activities among FA/CC program managers, the ASME Peer Review Committee (see below), and the review panels; ensuring reviews are executed in a timely manner; ensuring FA/CC program responses to review recommendations are included in Final Reports; and managing the budget and records for OST.

ASME Peer Review Committee and Its Executive Panel

The Peer Review Committee (PRC) is a standing body of the ASME whose sole purpose is to oversee the OST's peer review program and enforce relevant ASME policies, including compliance with professional and ethical requirements. The PRC consists of 13 to 15 members chosen for their competencies and diversity of views. Membership in ASME is not required for appointment to the PRC. The PRC is responsible for appointing members nominated by the Executive Panel (see below) to individual peer review panels and assessing Interim Reports for conformity to ASME standards before being issued as ASME-sanctioned public documents.[3]

[3] As part of its assessment, the PRC may add comments to the Interim Reports before issuing them in final form.

The PRC also reviews and approves the Annual Report and presents it, along with a comprehensive evaluation of the technical quality of the OST program, to the Deputy Assistant Secretary for OST at an annual meeting.

The Executive Panel of the Peer Review Committee (EP) consists of three to five ASME members who have served in leadership positions within ASME (e.g., president, vice-president, or division chair). The EP is responsible for overseeing the day-to-day operation of the peer review program and acts on behalf of the PRC between its semi-annual meetings. The EP meets approximately four times per year.

Peer Review Panels

Peer review panels consist of three or more technical experts chosen for their knowledge of the specific technology to be reviewed. Although ASME requires the peer review panel chair to be a member of ASME, other panel members need not be ASME members. The complexity of the technology(ies) being reviewed and the type of review dictate the number of experts on a panel. The peer review panel conducts the review, prepares a Consensus Report detailing its recommendations and observations, and transmits the written report directly to the sponsoring FA/CC program manager. Peer review panels are terminated upon completion of their specific review task.

American Society of Mechanical Engineers

The ASME participates in the OST peer review program by ensuring peer reviews follow ASME procedures. The ASME establishes and sanctions the Peer Review Committee and its Executive Panel through formal approval by the Center for Research and Technology Development of ASME's Council of Engineering. The ASME also serves as a resource for identifying potential peer review panel members.

Institute for Regulatory Science

RSI provides administrative and technical support for peer review activities. RSI's responsibilities include meeting planning, compiling and distributing background materials for members of review panels, facilitating peer reviews, and providing an executive secretary to assist in the preparation of Consensus Reports of peer review panels.

Selection of Technologies to Be Reviewed

OST policy requires that a peer review be conducted on each technology/system before it passes through Gate 4 of OST's Technology Investment Decision Model (TIDM) process (see Appendix B for a description of the TIDM). Specifically, OST policy states that

> It is OST policy that a technology peer review will be conducted on each technology/system. However, FA/CC Program Managers will give priority attention to those technologies that are preparing to pass through Gate 4 of the OST Technology Decision Process Procedure (Version 7.0) [DOE, 1997c]. Specifically, this procedure states that technical peer review reports are one of the

documents required to pass through Gate 4. In addition, peer reviews may be appropriate at other phases of the technology maturation stages. (DOE, 1997b, p. 3)

The actual decisions to conduct peer reviews of specific technologies are made by FA/CC program managers in response to five main "drivers:" (1) funding (i.e., to justify proposed increases in spending or to justify previous spending on a given technology), (2) changes in status (i.e., when a project approaches a gate in the TIDM process), (3) regulatory issues (i.e., in order to ensure that a technology meets regulatory requirements, (4) stakeholder concerns (i.e., in order to reassure the public or other stakeholders of the technical credibility of a technology, and (5) any technical or other issues that arise concerning a given technology.

Types of Reviews

The size and scope of each review panel depends on the specific technology(ies) being reviewed and the areas of expertise required to address the review criteria. In general, there are three levels of technical reviews:

I. multi-technology review of a complex nature involving site visits (five or more reviewers);
II. in-depth review of a technology involving site visits (three or more reviewers); and
III. review of a document requiting no site visit (i.e., a mail review).

Selection of Reviewers

Reviewers are selected and approved by the Peer Review Committee based on three generally recognized criteria: (1) education and relevant experience, (2) peer recognition, and (3) contributions to the profession. A minimum of a B.S. in an engineering or scientific field and sufficient experience in the technical area being reviewed are required for participation in an OST-related review. Peer recognition is assessed by measures such as activity in a professional society. Contributions to the profession include publications in peer reviewed journals, patents, and meeting presentations.

Conflict of Interest

Individuals with any real or perceived conflicts of interest with respect to the subject of the review may not serve on as a member of a review panel. According to ASME, "an individual who has a personal stake in the outcome of the review may not act as a reviewer" (ASME, 1997, p. 8). Potential conflicts of interest among members of the review panels, the ASME Peer Review Committee, and RSI staff are handled by requiring everyone who participates in the review program to sign a statement indicating a lack of personal or financial interest in the outcome of the review. The ASME conflict of interest policy further requests that reviewers and members of the ASME Peer Review Committee and its Executive Panel recuse themselves from deliberations on any matter in which there may be an appearance of a conflict of interest.

Peer Review Criteria

The following general criteria for peer reviews have been established for OST's peer review program in the ASME Manual for Peer Review (ASME, 1997):

1) **Relevancy**: All projects supported by the OST must meet the needs of various parts of the Office of Environmental Management, including EM-30, EM 40, EM 60, and EM 70.[4] At a minimum, a DOE-wide need must be clearly and unambiguously identifiable.
2) **Scientific and technical validity**: Every technology supported by the DOE must be consistent with established scientific and engineering principles and standards. Furthermore, the likelihood of its success must be reasonable.
3) **State-of-the-art**: A prerequisite for desirability of a technology is that its design and engineering tools are state-of-the-art.
4) **Filling an existing void**: A technology is considered desirable if it fills unmet needs.
5) **Non-duplicative/superior to alternatives**: A technology can also be desirable if it does not duplicate an existing technology; or if there is duplication of an existing technology, it is superior to it as demonstrated by one or more criteria described under 6-9 below.
6) **Cost effectiveness**: The life cycle cost of a technology is an important criterion for its desirability.
7) **Reduced risk**: Reduction of risk to workers or the general public is an important parameter in decisions to implement a technology.
8) **Regulatory acceptability**: It is unlikely that a technology will be implemented unless it meets applicable regulatory requirements. The regulatory acceptability must be evaluated carefully before a technology starts the permitting process.
9) **Public acceptance**: Public acceptance of a technology does not necessarily follow peer acceptance of other parameters identified in this guidance. Furthermore, it is not always predictable. However, there are cases in which acceptance or lack of acceptance are clearly demonstrable.

OST has provided no guidance on the relative weighting of these general criteria. Although these nine criteria form the core of the criteria to be used during the peer review, the actual criteria used during each review are determined by the ASME Peer Review Committee in consultation with the FA/CC program manager. For each review, the FA/CC program manager develops a preliminary list of specific review criteria, which are then used by the ASME Peer Review Committee to develop the formal review criteria for the review panel. These criteria are used by project staff and other presenters to organize written materials and oral presentations for the peer review. In addition, even though these review criteria form the basis of the review panel's evaluation, the review panel does have the authority to pursue other issues that arise during the review.

[4] EM-30 is the Office of Waste Management, EM-40 the Office of Environmental Restoration, EM-60 the Office of Facility Transition and Nuclear Materials Stabilization, and EM-70 the Office of Site Operations. OST is EM-50.

Review Reports

Each member of the review panel prepares a report containing the outcomes of the review. The review panel chair combines these individual reports into a Consensus Report, which typically contains four parts: (1) a brief description of the subject that was reviewed, (2) the consensus of the panel on shortcomings and meritorious aspects of the project, (3) recommendations of the panel, and (4) an appendix containing the comments by each reviewer for which no consensus could be reached, or which were considered by the panel to be beneficial to the investigators and managers but were not important enough to be included in the main body of the Consensus Report.

The Consensus Report is provided to DOE investigators and managers who are requested to respond to the conclusions and recommendations within 30 days. A summary of the responses containing the salient features of the response are combined with the substantive sections of the Consensus Reports as the Interim Report. After DOE's response, the ASME PRC reviews the Interim Report, during which it may add to it substantive, explanatory, clarifying, and supplementary comments and recommendations. The Interim Report as reviewed and approved by the PRC is issued as a Final Report.

Copies of the Consensus Report, the responses from the investigators and managers, and the Interim Reports are made available to members of the PRC for review and comments during the entire review process. At the end of the year (or after a specific period), an Annual Report is prepared by the PRC. The report contains Final Reports of all projects, recommendations of the PRC, and other information that, in the judgment of the PRC, would be beneficial to OST. This report will be printed and widely distributed.

Feedback of Peer Review Results into Program Management and Development Decisions

One to two days after the completion of the peer review, RSI submits the peer review panel's Consensus Report to the FA/CC program manager who requested the review. The program manager is asked to prepare, within 30 days, a written response that describes how the PI and/or the FA/CC manager intend to respond to the findings and recommendations of the Consensus Report. This formal response is then combined with the substantive sections of the Consensus Report as an ASME Interim Report, which is used by DOE headquarters' staff to evaluate the management of the technology program. The Interim Report is then reviewed and approved by the ASME Peer Review Committee and released as an ASME Final Report.

OST's Technology Decision Process requires that peer review reports be used in all funding decisions made at Gate 4 or any subsequent gate in the technology development process. In these gate reviews, these reports constitute one input to be considered in determining whether to continue funding for a project.

Appendix B

Description of OST's Technology Investment Decision Model[1]

The Technology Investment Decision Model (TIDM) is the procedure developed by DOE's Office of Science & Technology (OST) to provide a common basis on which to assess and manage the performance, expectations, and transition of technologies through the development process. It is a user-oriented decision-making process for managing technology development and for linking technology-development activities with cleanup operations. The TIDM identifies six R&D stages leading to technology implementation. The model incorporates decision points (or "gates") within the research and development (R&D) process where projects are evaluated for funding of the next stage of development. Thus, these TIDM gates represent milestones at which peer review might assess a technology's soundness.

The TIDM represents a range of stages (and gates), from basic research through implementation of a technology (see Figure C.1). For each stage, specific criteria, requirements, and deliverables are described which provide a common basis for technology assessment. The "stage-gate" process is meant to guarantee early evaluation of projects against technical and nontechnical criteria to ensure that end products will provide superior performance and also meet the acceptance requirements of the intended customers. The TIDM also addresses the technology transfer and commercialization factors that must be considered to get the technological innovations to the marketplace.

The six stages (and gates) and a description of each, including goals, objectives, and measures of effectiveness follow. Programmatic driver criteria to enter each stage include technology end-user need; technical merit; cost; safety, health, environmental protection, and risk; stakeholder, regulatory, and tribal issues; and commercial viability. The focus area/crosscutting program (FA/CC) technology leadership is responsible for evaluating all documentation in accordance with the criteria for each gate. If the FA/CC program determines that the technology warrants passing through the gate, the technology maturation process will continue. If the evaluation indicates that the technology does not warrant further consideration, then further support from the FA/CC technology leadership will not be forthcoming.

The following was adapted from DOE's *Technology Decision Process Procedure—Working Copy (Revision* 7), April 25, 1997 (DOE, 1997c); and "Maximizing R&D Investments in the Department of Energy's Environmental Cleanup Program," by Paladino and Longsworth (1995).

[1] The material in this appendix is based on OST's descriptions of its procedures, not on the committee's evaluation.

	Basic Research	Applied Research	Exploratory Development	Advanced Development	Engineering Development	Demonstration	Implementation
Technology Maturation Stages	Idea Generation No Need	Need	Proof of Technology Product Definition • non-specific applications • bench-scale	Working Model • reduction to practice • specific applications • bench-scale	Engineering Prototype • scale-up to test design features and performance limits • pilot-scale • field testing	Production Prototype • end-user validation • full-scale • "beta" site testing	Utilization by End-user
Gates		1	2	3	4	5	6
Expectations			Address priority DOE Need Knowledge of similar efforts	Show clear advantage over available technology	Meet cost/benefit requirement Demonstrate significant end-user demand	Technology ready for end-user	End-user deploys technology
Peer Review			Strongly Recommended	Depending on Need	REQUIRED		

Figure B.1
Diagram of OST's Technology Investment Decision Model (DOE, 1997b).

Stage 1: Basic Research

In Stage 1, fundamental scientific research for building and documenting core knowledge not tied to a specific defined need is evaluated, with the goal of generating new ideas. Objectives at this stage include identifying a new environmental technology or use of good science. Activities at this stage consist of basic laboratory experimentation, development of theory and analytical models, and proof of principle. Effectiveness of a project at Stage 1 is measured by whether it satisfies a subset of the programmatic driver criteria: specifically, technology and user need; technical merit; cost; and safety, health, environmental protection, and risk.

Gate 1: Entrance into Applied Research Stage

At this gate, projects addressing national interests and environmental performance needs enter the applied research stage. The technology developer/principal investigator (TD/PI) must address the programmatic driver criteria listed above.

Stage 2: Applied Research

In the applied research stage, directed scientific/engineering research is conducted that has a link to remediation needs and results in a product concept. The goal is to conduct systems studies to address DOE priority needs. Research conducted includes proof of principle and lab-scale experimentation, with the objectives of defining data requirements, preparing experimental designs, determining material requirements, and determining business attributes. Project effectiveness at this stage is measured in terms of whether the project satisfies experimental design plan acceptance criteria and all of the programmatic driver criteria.

Gate 2: Entrance into Exploratory Development Stage

Gate 2 is a major decision point in the stage-gate model. At this gate, the TD/PI must show that the technology addresses a clearly defined DOE priority cleanup or waste management need and that it satisfies experimental design criteria. The TD/PI must also demonstrate knowledge of similar technology R&D activities taking place in other federal agencies, universities, industry, or international organizations to help information sharing, encourage cooperative relationships, and eliminate redundant research efforts. In addition, at Gate 2, the TD/PI initiates a comparison of the technology with the baseline and addresses the gate programmatic driver criteria.

Stage 3: Exploratory Development

The goal of the exploratory development stage is to conduct a systems study to address focus area priority needs. Technical feasibility of the project in terms of potential applications is evaluated (i.e., whether the technology be developed sufficiently to solve the problem), with the objective of verifying that the concept can be linked to specific needs. Project activities at this stage includes laboratory-scale prototyping, analysis of user needs, estimates of life-cycle costs, and identification of functional performance requirements and operational concepts. The effectiveness of the project is measured by whether (1) it continues to satisfy experimental design plan acceptance criteria, (2) experimental performance meets program expectations, and (3) programmatic driver criteria are met.

Gate 3: Entrance into Advanced Development Stage

At this gate, the technology must be shown to be linked with clearly defined DOE/private sector priority performance needs. Also, the TD/PI continues the baseline comparison and addresses gate programmatic driver criteria.

Stage 4: Advanced Development

The goal of Stage 4 is to show a specific DOE application of the product. A proof of design is required, and development includes full-scale laboratory testing, preliminary field testing, technical specification development, and infrastructure development plans. The objectives at this stage are assessment and validation of the technology's specifications and application by a review group. Effectiveness at this stage is measured by whether the application specifications satisfy the external review group's assessment, and whether programmatic driver criteria are met.

Gate 4: Entrance into Engineering Development Stage

Gate 4 is a major decision point, at which a review group completes an evaluation of information supplied by the focus area, TD/PI, and others to assess whether the technology is the right technology, at the right place, at the right time. The deliverables produced by the TD/PI address gate programmatic driver criteria and include a cost-benefit analysis showing the anticipated benefits of cost savings and risk avoidance, and strategies for DOE deployment, commercialization, cost sharing, regulatory compliance, and licensing. DOE's approval of expenditure at this gate depends upon the commitment of an end user to implement the technology.

Stage 5: Engineering Development

At this stage, knowledge gained from research and development is used to develop systematically a detailed approach for full-scale design. The goal is the classification of the technology as likely to exceed DOE baseline or to meet select government performance requirements or a problem set. Objectives at this stage include scaling up and refining detailed designs for prototypes and pilots, and clarifying the DOE deployment strategy and schedules to meet performance needs. This stage of development yields drawings, schematics, and computer codes; construction and demonstration units; prototypes and pilot-scale systems; system evaluation; reliability testing; infrastructure plans; and procurement specifications. Effectiveness is measured by results of completed and documented preliminary tests, successful test plans, and satisfied programmatic driver criteria.

Gate 5: Entrance into Demonstration Stage

At Gate 5, the DOE deployment schedule is established. In addition, the TD/PI must address gate programmatic driver criteria, complete and document preliminary test results, and demonstrate that test plan requirements have been satisfied.

Stage 6: Demonstration

In Stage 6, the product or technology is subjected to a "real world" demonstration, either at a DOE site or at another location, using actual waste streams and/or anticipated operating conditions with the goal of verifying design assumptions made up to this point. Objectives include conducting full-scale testing, system testing, and market conditioning to determine system suitability. Effectiveness is measured through programmatic driver criteria and by the acceptance of the technology by the end-user.

Gate 6: Entrance into Implementation Stage

To pass through Gate 6, results of the technology/system test must be fully documented. The technology partner must be fully invested (i.e., the procurement path is defined), and gate programmatic driver criteria must be engaged fully. In addition, implementation and commercialization viability must be defined clearly according to accepted business standards.

Stage 7: Implementation

At Stage 7, the product or technology has been proven to be viable, cost-effective, and applicable to required needs. The technology is available for transfer to the private sector, or already commercially available for use and is put into service by DOE and/or the end user. An end user signs a contract or approves the operational use of the technology.

The TIDM incorporates several essential principles that DOE believes should be maintained:

1. Developers need to understand and address the needs and dynamics of the marketplace early in the innovation process.
2. Decision criteria must encompass both technical and nontechnical factors.
3. Formal decision points should provide the mechanism for determining investments in selected projects.
4. Decisions should reflect an EM R&D investment strategy.

Appendix C

Description of OST's Review Program[1]

The DOE-Office of Science and Technology (OST) has developed an extensive review program with the goal of improving the design, management, and implementation of its programs and technical projects (see Figure C.1). OST seeks to integrate the results of its many reviews to aid managers in decision making. Results may feed into many decisions and activities, such as improving programs and management, formulating budgets, setting priorities, determining technology maturity and availability, and accelerating or decelerating programs. Reviews take place throughout the various levels of the EM organization and can be assigned to three different categories, described below:

- *Programmatic reviews* are designed to assess the appropriateness and effectiveness of the structure, goals, management, and budget of a particular organization or program. This type of review may be conducted internally (by OST staff) or externally (by standing bodies and groups with EM or OST oversight responsibilities). Reviewers must possess a high level of familiarity with the mission and activities of the organization or program being evaluated.
- *Technical assessment reviews* are designed to evaluate one or more projects with respect to organizational needs, objectives, responsibilities, or budget, and are used to provide the program or project manager with technical advice and direction. Evaluation criteria include effectiveness in contributing to meeting needs, cost effectiveness, and public and regulatory acceptability. Technical assessment reviews are conducted internally. Reviewers include technology developers and users, who possess program and project knowledge expertise, and knowledgeable stakeholders, for example, regulators.
- *Technical peer reviews*, also called merit reviews, are used to evaluate a project on its scientific or engineering basis, the competence of the researchers, the soundness of the research plan, and the likelihood of success. Reviewers may consider budgetary aspects of a project only from the standpoint of whether the proposed budget is adequate to complete the work. Technical peer reviews are conducted externally and independently, such that the investigators whose work is being reviewed play no part in the selection or organization of the review panel. From the technical peer review, OST seeks to gain independent, unbiased, technical input or justification for funding project development. This type of review fits most closely the generally accepted definition of "peer review."

These three types of reviews are performed across the organizational levels of the OST, which comprise department, program, and project levels. Reviews conducted at each of these levels are discussed below.

[1] The material in this appendix is based on OST's description of its program (DOE, 1996), not on the committee's evaluation.

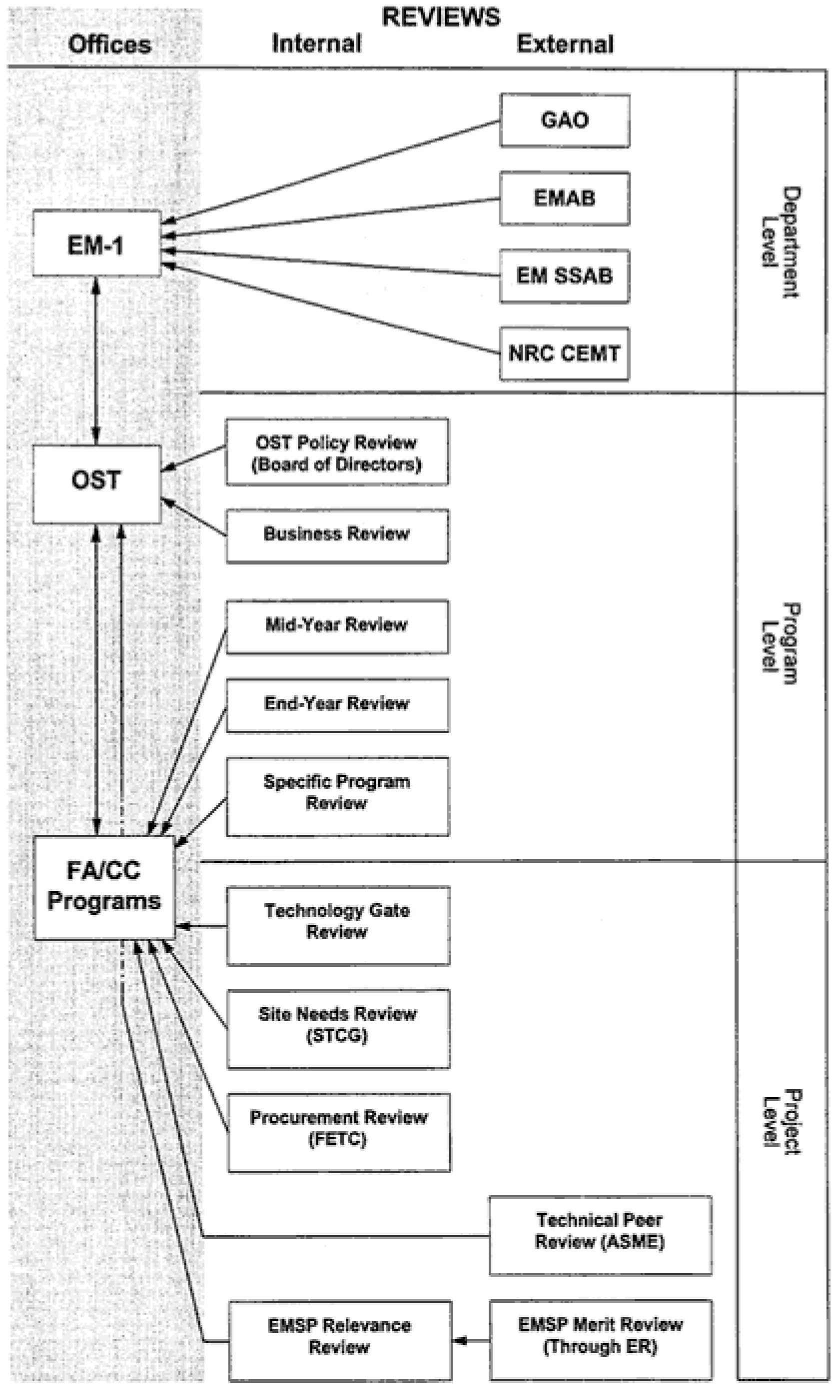

Figure C.1
Diagram of OST's review program showing the different types of reviews, the offices to which reviews are submitted, and the level of the organization at which reviews occur. ASME = American Society of Mechanical Engineers; CEMT = Committee on Environmental Management Technologies; EM-1 = Office of the Assistant Secretary for Environmental Management; EM = Office of Environmental Management; EMAB = Environmental Management Advisory Board; ER = Office of Energy Research; FA/CC = Focus area/crosscutting area; FETC = Federal Energy Technology Center; NRC = National Research Council; OST = Office of Science and Technology; SSAB = Site-Specific Advisory Board; STCG = Site Technology Coordinating Group. Modified from DOE (1996).

Department-Level Reviews

Department-level reviews assess the effectiveness of EM's technology-development program, and all are classified as programmatic reviews. These reviews are submitted to the Assistant Secretary for EM. OST considers department-level reviews to be external in that they are initiated and conducted independently of OST and the focus areas. The following groups conduct department-level reviews:

- U.S. General Accounting Office (Gao). The GAO provides congressionally mandated programmatic oversight to the Department of Energy, and the observations and conclusions from GAO reports are made available to and used by OST.
- National Research Council (NRC)'S Committee On Environmental Management Technologies (CEMT). Until it was discontinued in September 1997, the CEMT[2] reviewed the broad issues of technology development, implementation, and evaluation within EM. It also evaluated specific technologies that EM considers most important toward reaching its goals. The CEMT submitted two annual reports to the Assistant Secretary for EM (NRC 1995b, 1996). The responsibilities of the CEMT have been assumed by six committees, including the present committee.
- Environmental Management Advisory Board (EMAB). The EMAB provides advice and recommendations to the Assistant Secretary for EM on a broad range of issues relevant to EM. The EMAB is supported by EM and is chartered under the Federal Advisory Committee Act (FACA) and is composed of representatives from tribal, state, and local governments; other federal agencies; environmental and citizen groups; labor organizations; science organizations; and academia. Of the five subcommittees under the EMAB, the Technology Development and Transfer Committee is most directly related to OST.
- Environmental Management Site Specific Advisory Board (EM SSAB). The EM SSAB provides a means for community members to contribute to site-specific policy and technical decisions (e.g., future land use, integrated risk management, resource allocation, and EM priority setting). The board is supported by EM, chartered under FACA and includes all board members from each local EM board throughout the DOE complex. The local boards have unique mission statements, operating procedures, and meeting schedules. Local board members are appointed by the Assistant Secretary for EM and include community members, members from local and tribal governments, and ex officio representatives from DOE, EPA, and state governments.

Program-Level Reviews

OST uses program-level reviews to chart progress being made and to assess the suitability of OST and focus area objectives, policies, and plans. These reviews are initiated and conducted within OST and the focus areas, and use both internal and external experts. Program-level reviews include the following:

- OST Board Of Directors Reviews. The OST Board of Directors provides guidance and management for EM's science and technology programs, reviews entire program areas, and weighs high-level policy issues. The board consists of the Deputy Assistant Secretary for OST

[2] Formerly the parent body of this committee.

and the field office managers at the Savannah River, Idaho, and Hanford operations offices, and at the Federal (formerly Morgantown) Energy Technology Center (FETC). The OST Board of Directors reviews are classified as programmatic reviews.

- OST Business Reviews. OST business reviews are conducted on a monthly basis and evaluate business management, program design, and execution of technology development activities, as presented by FA/CC program managers. The Deputy Assistant Secretary for OST performs these programmatic reviews.
- Focus Area Mid-Year Reviews. These reviews, conducted for each focus area, assess program management, direction, technical emphasis, and overall soundness of the respective focus area's technology-development program. Both internal and external experts participate as reviewers, which include representatives of private industry, EM user groups, the scientific and academic communities, other federal agencies, and, in some instances, members of the Community Leaders Network (OST's primary stakeholder organization). Mid-year reviews are held in the second or third quarter of the fiscal year, and are classified as programmatic reviews.
- OST Year-End Review. This internal review is an evaluation of individual projects in the context of overall program direction and available resources and is intended to guide EM-50 headquarters staff as they finalize programs for the budget year. In assessing projects, the staff review associated technical peer review reports and consider progress made. The OST year-end review is classified as a technical assessment review.
- Focus Area And Crosscutting Program Reviews. These programmatic reviews assist managers in balancing the respective program's portfolio of technologies to fit the needs of users and stakeholders. Program reviews are conducted by the FA/CC program managers and are attended by technology users, stakeholders, and external industry and academic experts. The results of program reviews feed into EM's strategic planning.

Project-Level Reviews

Project-level reviews may be internal or external, and are used to assess proposed or ongoing projects for scientific merit, potential for meeting a site need, potential for risk reduction and safety improvements, cost-effectiveness, regulatory and public acceptability, and commercial viability. Project-level reviews include the following:

- American Society of Mechanical Engineers (*ASME*) Peer Reviews. The ASME operates under a grant from DOE to conduct technical peer reviews of proposed or ongoing focus area projects. Reviewers are subject matter experts independent of DOE. Review panels are convened to review specific technologies or groups of technologies and are disbanded after issuing their reports. The ASME peer review process is described in further detail in Appendix A.
- Site Technology Coordinating Group (STCG) Reviews. STCG reviews are internal evaluations used to identify and prioritize site technology requirements. STCGs are located at each DOE Operations Office, and are, in general, headed by the Technical Program Officer and composed of site technology users, technology developers, site contractors, and stakeholders. The groups review focus area plans in order to ensure that technology-development decisions address site cleanup needs. STCGs also serve as liaisons to regulators and stakeholders (including local SSABs), and ensure that these perspectives are incorporated into site technology decisions. The work of the STCGs can be categorized as technical assessment reviews.

- Procurement Reviews. Procurement reviews are evaluations of proposals received in response to a solicitation for environmental restoration research and development projects. These solicitations are used when DOE is able to define, but unable to solve, a specific problem. Procurement reviews are conducted by FETC and are considered technical assessment reviews.
- Environmental Management Science Program (EMSP) Reviews. The EMSP is an EM-sponsored research program designed to bridge the gap between fundamental research and needs-driven technology development for environmental restoration. Two types of reviews are conducted as part of the proposal evaluation process for the EMSP. The Office of Energy Research (ER) conducts a peer review to evaluate the merit of proposals received and forwards selected proposals to a panel of EM managers. The EM managers then conduct a technical assessment review to evaluate the proposals' relevance to EM remediation needs.

Appendix D

Biographical Sketches

C. Herb Ward (chair) is the Foyt family chair of engineering at Rice University, where he directs the Energy and Environmental Systems Institute. Dr. Ward also directs the Department of Defense Advanced Applied Technology Demonstration Facility, and for the past 15 years, he has directed the activities of the National Center for Ground-Water Research. In addition, Dr. Ward serves as co-director of the U.S. Environmental Protection Agency (EPA)-sponsored Hazardous Substances Research Center/South & Southwest. His research interests include the microbial ecology of hazardous waste sites, biodegradation by natural microbial populations, microbial processes for aquifer restoration, and microbial transport and fate. Dr. Ward is also an expert on the technical issues surrounding cleanup of the nation's nuclear weapons complex. He has served on several National Research Council (NRC) committees, including the Committee on Environmental Management Technologies (CEMT). Dr. Ward received his Ph.D. in plant pathology, genetics, and physiology from Cornell University and an M.P.H. in environmental health from the University of Texas.

Barry Bozeman is the director of the School of Public Policy at the Georgia Institute of Technology, where he specializes in science and technology policy, focusing on research and development impact evaluation, technology transfer, and commercialization. Dr. Bozeman is an expert on the use of peer review to evaluate the impacts of research and development. His work on peer review has included a state-of-the-art review paper titled "Peer Review and Evaluation of R&D Impacts" (in *Evaluating R&D Impacts: Methods and Practice*, Bozeman and Melkers, 1993), as well as studies on peer review for the National Science Foundation and the U.S. Air Force. He has served on the NRC's Committee to Address Continued Review of the Tax System's Modernization of the Internal Revenue Service. Dr. Bozeman received his Ph.D. in Political Science/Public Administration from the Ohio State University.

Radford Byerly, Jr. recently retired as vice-president for public policy of the University Corporation for Atmospheric Research after a distinguished career in academia and government, specializing in science management and policy. Among his many positions, Dr. Byerly has worked at the National Institute of Standards and Technology (NIST; then the National Bureau of Standards) in the environmental measurement and fire research programs; has served as chief of staff of the U.S. House of Representatives Committee on Science and Technology; and was director of the University of Colorado's Center for Space and Geosciences Policy. He currently serves as a member of NASA's Space Science Advisory Committee and serves on National Science Foundation site visit committees and review panels. Dr. Byerly is a member of the NRC's Board on Assessment of NIST. He received his Ph.D. in physics from Rice University.

Linda Capuano is the vice-president of technology and new business development at AlliedSignal Aerospace. In this capacity, Dr. Capuano is responsible for restructuring the company's review process for selecting research and development programs. Prior to joining

AlliedSignal, she worked as vice-president of business development at Conductus, and she held a number of engineering and management positions at IBM. Dr. Capuano also served on the U.S. Department of Energy (DOE) Task Force on Alternative Futures for the DOE National Laboratories ("Galvin Task Force"), which explored the relevance of national laboratory research, including the role of peer review in research at the DOE's national laboratories. Dr. Capuano received her Ph.D. in materials science from Stanford University.

Richard Conway is a recently retired senior corporate fellow at Union Carbide Corporation. His areas of expertise include contaminated site remediation, hazardous waste management, and environmental risk analysis of chemical products. Mr. Conway was elected to the National Academy of Engineering in 1986 for his contributions to environmental engineering and for the development of improved treatment processes for industrial wastes. He has received many awards and honors, including the Hering Medal, Gascoigne Medal, Dudley Medal, Rudolfs Medal, and honors from the American Society of Civil Engineers, the Water Environment Federation, and the American Society for Testing and Materials. Mr. Conway has been involved in numerous NRC activities, including the Board on Environmental Studies and Toxicology, the Water Science and Technology Board, and the Committee on Peer Review of Department of Defense Environmental Scholarships and Grants, and the Commission on Engineering and Technical Systems. He earned his M.S. in environmental engineering at the Massachusetts Institute of Technology.

Thomas Cotton is vice-president of JK Research Associates, Inc., where he is a principal in activities related to radioactive waste management policy and strategic planning. Before joining JK Research Associates, he dealt with energy policy and radioactive waste management issues as an analyst and project director during 11 years with the U.S. Congress's Office of Technology Assessment. His expertise is in public policy analysis, nuclear waste management, and strategic planning. Dr. Cotton has served the NRC as a member of the CEMT and the Committee on the Remediation of Buried and Tank Wastes. He received a Ph.D. in engineering-economic systems from Stanford University.

Frank Crimi recently retired as vice-president for Lockheed Martin's Advanced Environmental Systems Company. He joined Lockheed in 1992 after completing 34 years in engineering and management positions with the General Electric Company. Mr. Crimi has over 30 years in design, operations, and maintenance of DOE naval nuclear power plants with special emphasis in decontamination and decommissioning of nuclear facilities. He was the General Electric project manager for the Shippingport Atomic Power Station decommissioning and recently chaired the Long Island Power Authority's Independent Review Panel during the decommissioning of the Shoreham Nuclear Power Station. Mr. Crimi was a member of Public Service of Colorado's Management Oversight Committee for the Fort Saint Vrain Nuclear Generating Station decommissioning. He currently is on advisory boards for the decommissioning of the Trojan and Connecticut Yankee Nuclear Power Plants. Mr. Crimi completed a B.S. in mechanical engineering at Ohio University in Athens and did graduate studies in mechanical engineering at Union College, Schenectady, New York.

John Fountain is a professor of geochemistry at the State University of New York at Buffalo. His research focuses on various aspects of contaminant hydrology, including aquifer remediation and the characterization of fractured rock aquifers. Dr. Fountain is a member of the NRC's Committee on Technologies for Cleanup of Subsurface Contaminants in the DOE Weapons Complex. He received his Ph.D. in geology from the University of California, Santa Barbara.

David T. Kingsbury is the vice-president and chief information officer at Chiron Corporation. He recently resigned as director of the Division of Biomedical Information Sciences and chief information officer of the Johns Hopkins University. His research interests include computational biology and databases, molecular diagnostic techniques in medical microbiology, and the biochemistry and mechanisms of pathogenesis of the slow (unconventional) viruses. Dr. Kingsbury is an expert on the administration of peer reviews, having served for four years as assistant director for Biological, Behavioral, and Social Sciences at the National Science Foundation. He also serves as editor-in-chief of the *Journal of Computational Biology* and is North American editor of the *Journal of Chemical Technology and Biotechnology*. Dr. Kingsbury received his Ph.D. in biology at the University of California, San Diego.

Gareth Thomas is a professor in the Graduate School of the Department of Materials Science and Mineral Engineering at the University of California, Berkeley. He is a renowned expert in the theory and application of electron diffraction and high-resolution microscopy to problems in materials science and engineering. Dr. Thomas is a member of both the National Academy of Sciences and the National Academy of Engineering. In addition to holding a variety of positions at Berkeley, he also has held positions at the Lawrence Berkeley Laboratory, where he founded the National Center for Electron Microscopy. Dr. Thomas has been involved in peer reviews for a variety of scientific societies and scholarly journals, and he currently is serving as editor-in-chief for the journal *Acta/Scripta Materialia*. He has served on the NRC Committee on Materials Research Opportunities and Needs in Materials Science and Engineering. Dr. Thomas received his Ph.D. and Sc.D. from Cambridge University.

Appendix E

Acronyms

AIBS	American Institute of Biological Sciences
ASME	American Society of Mechanical Engineers
BES	Office of Basic Energy Sciences (DOE)
CC	Crosscutting area
CEMT	Committee on Environmental Management Technologies (NRC)
D&D	Decontamination and decommissioning
DOE	U.S. Department of Energy
EM	Office of Environmental Management (DOE)
EMAB	Environmental Management Advisory Board (DOE)
EMSP	Environmental Management Science Program (DOE)
EP	Executive Panel of ASME Peer Review Committee
EPA	U.S. Environmental Protection Agency
ER	Office of Energy Research (DOE)
FA	Focus area
FACA	Federal Advisory Committee Act
FETC	Federal Energy Technology Center
GAO	U.S. General Accounting Office
NIST	National Institute of Standards and Technology
NRC	National Research Council
OST	Office of Science and Technology (DOE)
PI	Principal Investigator
PRC	Peer Review Committee (ASME)
R&D	Research and development
RSI	Institute for Regulatory Science
SSAB	Site-Specific Advisory Board (DOE)
STCG	Site Technology Coordinating Group (DOE)
TD	Technology Developer
TDI	Technology Deployment Initiative
TIDM	Technology Investment Decision Model
USNRC	U.S. Nuclear Regulatory Commission