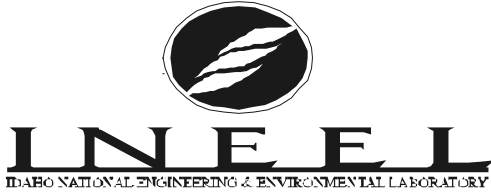


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Integrating the Integrators – A Roadmap to Success

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Integrating the Integrators-A Roadmap to Success

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ABSTRACT

The U.S. Department of Energy Environmental Management's (DOE-EM) investments in science and technology, as well as science and technology investments associated with other parts of the DOE are aimed at meeting the Departments cleanup goals. These investments, primarily focused on EM's cleanup mission, comprise the Environmental Quality Research and Development (R&D) portfolios.

Synchronizing EM's Cleanup Project Managers (operations facility and process owners throughout the DOE complex) operational needs with EM R&D including the extensive work of the six Focus Areas (major thrust areas within DOE-EM) has been a continuing challenge. This recent initiative to better integrate the R&D program is in response to evolving needs within the Department to apply proven system engineering methods to clarify requirements and define EM's process to effectively orchestrate their R&D Program. To optimize this partnership, DOE-EM's Integration Program is successfully unifying the operational needs with the R&D as described in this paper.

INTRODUCTION

Background

The U.S. Department of Energy Environmental Management (DOE-EM) mission is to clean up the environmental legacy from U.S. nuclear weapons production and other sources of pollutants such as DOE nuclear research. EM's goal is to clean up the majority of sites by the year 2006, allowing the focus of efforts thereafter to concentrate on the most complicated and difficult problems. The EM cleanup effort is expensive, technologically complex, closely regulated, and relatively unique in the world. Achieving the goal of accelerated cleanup within the current budget requires targeted investments to respond to hundreds of needs identified by cleanup project managers at the affected sites. EM's investments can provide more effective, less expensive, and safer environmental remedies, as well as technologies where no effective remedy currently exists. These investments can also provide the data or alternative approaches that reduce the risk that cleanup will be delayed or will exceed the available budget. Science and technology efforts within EM span the full spectrum from research to direct assistance for cleanup projects and lead to fully integrated, technically defensible solutions for cleanup and long-term environmental stewardship at DOE sites.

Investments in science and technology have already provided solutions to a number of EM cleanup problems once thought to be intractable. These earlier investments by EM have also provided better, safer, and cheaper alternatives to the baseline technologies originally considered at the start of the cleanup. However, to achieve the goals of *Accelerating Cleanup: Paths to Closure* more is needed.

EM takes advantage of research programs elsewhere within DOE, other Federal agencies, universities, industry, and the international community. Other offices within DOE execute research programs that address EM's cleanup project manager needs, including the Offices of Science, Civilian Radioactive Waste Management, and Materials

Disposition. EM participates in jointly funded and managed programs with these other DOE offices that provide benefit to both the EM cleanup project managers and partnering sponsors.

EM also engages other federal agencies performing research that support EM objectives. DOE jointly funds or manages programs with the Department of Defense and the Environmental Protection Agency. These agencies have science and technology efforts focused on cleanup, environmental compliance, resource conservation, and pollution prevention technologies, all of which are integral elements of the EM mission.

Collaboration with industry and academia, through efforts such as Cooperative Research and Development Agreements, Small Business Innovative Research grants, technology transfer initiatives, Research Opportunity Announcements, Program Research and Development Announcements, and DOE-sponsored university research, provide the Department with outside perspectives on how to accomplish EM's cleanup goals. DOE has also reached out to the international community, especially to the former Soviet Union, in order to share experience and resources in solving unique needs for cleanup of radioactively contaminated sites.

The EM cleanup mission includes the remediation of contaminated soil and groundwater, the deactivation and decommissioning of facilities, treatment, storage and disposal of waste, and the safe management of nuclear materials and spent nuclear fuel. Accordingly, EM's investments in science and technology focus on these areas and are both extensive and diverse. The rationale for the science and technology investment portfolio is to address:

- The problems that must be resolved to complete the EM program mission,
- The end states that represent program completion, and
- The pathways to the end states and the needs that must be met to traverse that path to completion.

EM's investments in science and technology are driven by the need to reduce high life-cycle costs, reduce environmental, safety and health risks, and to provide solutions to problems that cannot currently be solved. EM's cleanup efforts will continue well into the 21st century with annual costs continuing to exceed \$3 billion after 2010, and cleanup work scheduled past the year 2030.

While EM is aggressively moving forward to close 90% of its sites prior to 2006, EM's greatest challenge will be to complete cleanup at some of the largest and most technically complex sites. In fact, 77% of the estimated costs after 2006 are accounted for by the Savannah River Site, the Hanford Site, and the Idaho National Engineering and Environmental Laboratory. The \$147 billion life-cycle cost estimate includes the costs of completing all known EM work scope, but there will also be continuing site stewardship costs that are not included in this total.

Much of what needs to be done has never been done before, or even attempted. Not all of the work scope (i.e., complete set of required activities) has been completely determined, and often the cleanup of one site is dependent upon another for completion. A review of the critical paths to achieve site closures, prepared by the Field Offices, show medium to high risks as being the norm. That is, programmatic risks associated with technology, work scope, and intersite dependency must be substantially reduced for EM to achieve its aggressive schedule while maintaining or reducing cost. Technical issues, regulatory changes, and funding constraints all require that advances in science and technology be achieved and applied for EM to succeed with planned cleanup activities.

Science and Technology Working for Cleanup

Science and technology investments will provide the scientific foundation, technical assistance, new approaches, and new technologies that contribute, as an integral part of DOE-EM programs, to significant reductions in risk (both technological and safety and health), cost, and schedule for completion of the EM mission. The strongest advocates for investing in science and technology will be the DOE-EM cleanup project managers.

EM's investments in science and technology are:

Solution Driven — All science and technology investments must support implementation decisions, enable action where solutions are lacking, enable actions that significantly reduce cost and schedule while maintaining or enhancing health and safety, or fundamentally transform the nature of the problem.

Fully Integrated with Cleanup Project — All activities will be linked directly to cleanup goals that reflect stakeholder values and site compliance agreements, with financial accountability transitioning from the technology developers to the cleanup project manager as efforts mature toward technology deployment.

Invested in a Balanced Portfolio — Investments in science and technology include scientific research; technology development, demonstration and deployment; and technical assistance.

Improved Planning and Integration -"Integrating the Integrator"

Improving the integration of EM's investments in science and technology with site cleanup projects will enable and, in some cases enhance, execution and implementation. To accomplish this goal, the Focus Areas must work directly with the site programs and project staff to identify the correct cleanup needs and to develop technical responses that make sense. That is, the technical responses must adequately solve a specific problem, not a generic one, and be delivered in time to meet the cleanup project manager's schedule. Significant progress has been made in the last year. The Focus Areas are working hard to connect every work package to specific cleanup projects and prepare technical responses that provide solutions to specific cleanup project manager needs. Investments in basic research must also be related to cleanup problems, but at a foundational level. This research provides new or additional knowledge that is needed to address programmatic or technology challenges.

In Fiscal Year 1999, EM will take the next step in integrating its science and technology investments with the needs of the cleanup projects. Cleanup project managers will be asked to partner with the Focus Areas in developing specific work packages that support the execution of their project. This connection, as identified by the cleanup project manager, between the project needs and the work package represents a partnership between the project manager and the Focus Area. Modification of this partnership must be agreed to by both the cleanup project manager and the Focus Area. Starting in Fiscal 2000, EM will only fund new Focus Area work packages that have been planned in partnership with a cleanup project manager. For basic research investments, EM will continue to solicit proposals based on science and technology needs identified by the cleanup project managers and subject matter experts, and will fund basic research projects based on the scientific quality and relevancy of the proposed research. EM will facilitate the formation of partnerships between the researchers, the Focus Areas, and the cleanup project managers to ensure that the research is relevant and is integrated into technology development and deployment.

The partnership achieves a number of goals. It makes science and technology integral to compliance because the investments are driven by site cleanup. As such, it requires the cleanup project manager and the technology developer to work together to gain regulatory acceptance throughout the development process. The cleanup project managers will now be planning to use the output of the science and technology investments; this enables a well planned "hand-off," in terms of both dollars and scope, between the developer and the cleanup project manager. EM science and technology funding for technology deployment is leveraged with operations funding for a deployment project. A minimum cost-share of one-to-one (science and technology to operations funds) is required for deployment projects, however, the cost-share often ranges up to one-to-four or higher, especially when indirect operational costs for the project are considered. Of course, developed technologies must be handed off through a commercial vendor, and though there is no guarantee that the technology will be selected in a procurement, the partnership will at least ensure that the developed technology meets all requirements and presents genuine advantages. Finally, in this partnership approach the cleanup project managers and the Focus Areas are creating the right balance between near-term deployments and long-term/high return-on-investment activities.

Within the context of the above factors it is the purpose of this paper to describe the science and technology investment program development process aimed at creating solutions to cleanup needs.

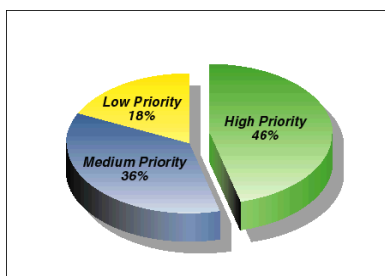
PROGRAM DEVELOPMENT PROCESS — CREATING SOLUTIONS TO CLEANUP NEEDS

Approach to Satisfy the Objectives for EM Science and Technology Investments

EM has designated four major objectives for its science and technology investments:

- 1.a - EM science and technology investments will meet the highest priority needs identified by cleanup project managers, including those on the critical path to site closure and those that represent major technology gaps in project completion.
- 1.b - EM science and technology investments will reduce the cost of EM's costliest cleanup projects.
- 1.c - EM science and technology investments will reduce technology risk. Technology risk is the programmatic risk (as opposed to risk to the environment or the safety and health of workers) that critical cleanup projects may not be completed on time and/or within budget due to a technology deficiency (denoted by Technology Risk >3, in the *Paths to Closure* data).
- 1.d - EM science and technology investments will accelerate and increase technology deployment by bridging the gap between development and use.

Additional information related to these objectives is given in Figure 1.



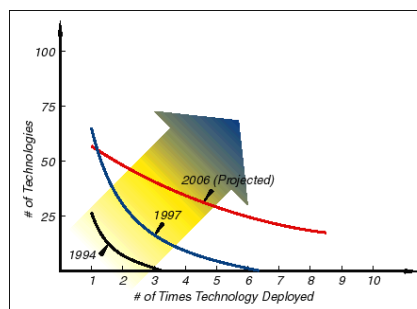
1a. Meet the sites' high priority needs

FY97-FY70	
	\$ Billions
High Level Waste	47
TRU/Mixed Low Level Waste	20
Deactivation and Decommissioning	11
Environmental Restoration	15
Plutonium and Nuclear Material	7
Spent Fuel	6

1b. Reduce the cost of major cost centers

Critical Path to Closure		
Field Office	# PBS Tech Risk > 3	# Pathways and/or Events Tech Risk > 3
AL	5	9
ID	5	11
OR	6	20
RL	5	11
SR	16	18
All Other	13	17
TOTAL	50	86

1c. Reduce technology risk



1d. Accelerate technology deployment

Figure 1. Meeting the four objectives of EM's science and technology investments.

EM has adopted systems engineering and technology roadmapping as key tools in its approach to business. The systems engineering approach provides the foundation for EM cleanup program and project decisions and implementation that are requirements driven, technically defensible, cost-effective, and satisfy stakeholders and regulators. Technology roadmapping provides a methodology to define and focus science and technology investments and activities to obtain the maximum benefit to the EM cleanup program.

As depicted in Figure 2, development and execution of EM's science and technology investments can be described in four steps: 1) identification of cleanup project manager needs through data collection and analysis; 2) technical

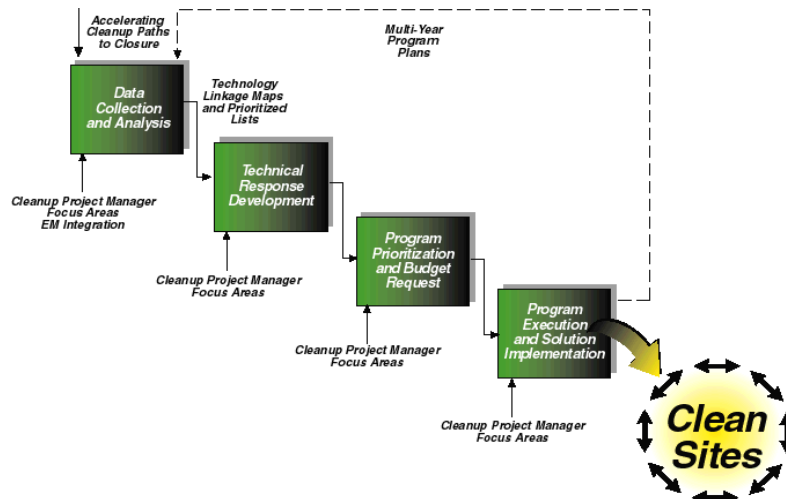


Figure 2. Development and execution of EM's science and technology investment program.

response development; 3) program prioritization and budget request; and, 4) program execution and solution implementation.

The involvement of EM cleanup project managers is essential at each step in the program development and execution process. EM cleanup project managers are the operations facility and process owners throughout the DOE complex. They are responsible for: remedial action, pollution prevention, deactivation and decommissioning, the safe management of waste, and the disposition of nuclear material and spent fuel. EM cleanup project manager participation, review, validation, and ultimate ownership ensures science and technology investments properly flow through the technology development process and result in the implementation of solutions to EM cleanup problems. Cleanup project manager involvement also serves to ensure stakeholder involvement is provided during the development, demonstration, and deployment of new technologies.

In addition to science and technology investments that directly address cleanup-project-related needs, EM also invests in basic research. Merit review, a critical component of managing research and development activities, is an integral part of the program development and execution process.

Oversight for user involvement is provided by User Steering Committees, one committee for each Focus Area. These User Steering Committees provide managerial review of the science and technology investments in their area of responsibility.

Data Collection and Analysis — Defining the Problems to be solved

Identification of cleanup project manager needs is the first step in the development of solutions to EM cleanup problems. Input from cleanup project managers is essential to accurately define and validate the needs to be addressed by EM's science and technology investments. EM relies heavily on their input as the primary source for the definition and communication of site-specific needs. The needs identified by cleanup project managers reflect stakeholder values as a result of stakeholder participation in establishing site-specific compliance agreements and identifying site needs.

Program needs are currently derived from site-specific needs developed by cleanup project managers and documented in cleanup project manager need statements, disposition map technology risk levels, critical pathway technology risk levels, and information in the Project Baseline Summaries (PBSs), which are the highest level project descriptions.

- Cleanup project manager need statements include information on the priority, the timing, (including potential deployment/implementation schedule) and the technical detail associated with a site problem.
- Disposition map technology risk levels illustrate the maturity of the planned technological solution (e.g., bench scale prototype to an existing operating facility). An example disposition map with programmatic risk level indicators is shown in Figure 3.

- Critical pathway analysis also provides an understanding of the maturity of the technological solution, but links the risk to key activities and events in the path to complete cleanup of the site.
- Project Baseline Summary information includes life-cycle cost, schedule, current technical approach, and environment, safety and health risk.

These data sets provide insight as to the size (cost and pervasiveness) and complexity of the technical issues facing EM. They also identify the cleanup project manager, when the solution is needed, and the impact of not addressing the need. Taken in aggregate, they provide the fundamental basis for the development of a technical response.

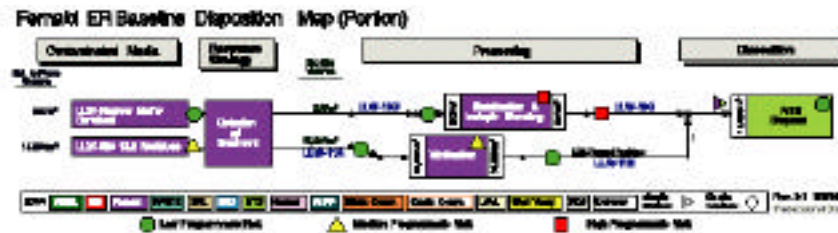


Figure 3. Disposition maps display the cradle to grave management strategy for the waste streams at each site.

Technical Response Development — New and Improved Solutions

The development of a satisfactory technical response is an iterative process that is based on the results from the data collection and analysis. The technical response is developed through continuous dialogue between the cleanup project managers and the science and technology developers. In this step the Focus Areas develop fully integrated, multi-year responses to the site needs.

The Focus Areas work closely with cleanup project managers to identify and document the specific science and technology requirements a solution must meet. The Focus Areas are the liaisons between the cleanup project managers and the scientists working on research projects. Information such as target waste streams, waste quantities to be processed, work-off schedule, system processing rate requirements, regulatory requirements and issues, commercialization potential, stakeholder issues, environmental risks, programmatic risks, technology availability and maturity, disposition of treatment residuals, and stewardship requirements are all considered.

Strategic planning and documentation are key to developing sound technical responses to cleanup project manager needs. The Focus Areas establish life-cycle planning for the solutions they are providing. The planning level of detail associated with these activities is commensurate with the particular program stages of science, development, demonstration, or implementation. Documentation of the technical response strategy and performance metrics provides a framework with which to develop test plans, commercialization strategies, and project review criteria.

The preparation of the technical response includes integration of the specific science and technology investment with the cleanup project manager’s project, an essential requirement for successful implementation. It is through this process of integration that joint planning is done to ensure budgets are adequate to support the development efforts, schedules line up with technology insertion points, and the cleanup programs have the financial resources and technical support to enable implementation and deployment of new solutions.

Finally, ongoing science and technology investments are evaluated at key decision points to determine if an effort should be continued or if an alternate strategy should be adopted. Cleanup project managers are involved in these project evaluations to ensure continued commitment to implementation of the solution. This iterative set of cleanup-project-manager approved, technical responses provide the basis for the complete investment portfolio.

Program Prioritization/Budget Request — Investment Strategy to Maximize Returns

The complexity and duration of the EM cleanup effort, combined with budget constraints and regulatory changes, requires EM to carefully prioritize and sequence cleanup projects. These same factors drive a continuous effort within EM to rank and prioritize science and technology investments. The prioritization efforts are used to assist in decision-making and are the basis for outyear budget requests.

The prioritization process is iterative and integrative, beginning at the site problem level and progressing to higher levels and greater breadth with each iterative step. While Focus Areas develop technical responses to each need, to ensure an optimum investment portfolio the responses must be integrated and prioritized. To ensure that a technical response meets a cleanup need, only those that are endorsed by a project manager will be considered for integration and prioritization in the portfolio. Prioritization is first done by the Focus Areas, and then thoroughly reviewed, changed as necessary, and approved by the Focus Area's User Steering Groups.

At this point the technical responses are compiled into work packages. These Focus-Area-developed work packages represent a set of related technical responses to site problems. A national prioritization process is then applied through a multi-attribute analysis using the data sets on a work package basis. In this manner, the work packages and technical responses are listed in priority order. The output of the prioritization system goes through a final review cycle. DOE's Field Office Managers and EM's Deputy Assistant Secretaries determine the final integrated priority list. This integrated priority list is the basis for the Congressional budget request for EM's investment portfolio.

EM's national level prioritization process for science and technology was first used in March 1998 to prioritize the Fiscal Year 2000 budget request. The process used data provided by the sites in support of the *Accelerated Cleanup: Paths to Closure*. As the process is used, improvements will be made. The prioritization methodology and criteria will be modified as necessary to establish a stronger and more effective national prioritization system.

Program Implementation and Execution — Making it Work

The final step in the program development process is to make the planned investments in science and technology and then to ensure that the results are deployed in cleanup projects.

Each fiscal year, Congress provides EM funding for cleanup projects and investments in science and technology. These funds are allocated according to the integrated priority list and a set of work packages are authorized. In general, a significant fraction of the investment portfolio will be applied to the continuation of existing work scope, as most research and development activities are multi-year efforts. However, when new work scope is to be initiated, the work is announced and competed. This competition ensures that the best talent is brought to bear on EM's key problems. The requests for proposals are conducted through either targeted or broad solicitations depending on the work scope. That is, new research efforts are broadly announced to the larger scientific audience, while near term deployment opportunities, requiring a more rapid response, may be biased toward the private sector.

The investment portfolio is managed through the Focus Areas. This approach means that for any given problem area, the complete set of activities ranging from science to deployment is managed as an integrated investment. This requires the Focus Areas to coordinate the research and development efforts of universities, national laboratories, industry, and site management contractors and also to be aware of other federal and state programs investing in related research and development.

The Focus Areas function as national programs, and therefore they preferentially support science and technology that addresses the needs of multiple EM sites. In general, national programs within DOE are difficult to manage because they require the cooperation of diverse sites that are progressing with cleanup under different schedules and regulatory requirements. In addition, no two waste streams, facilities, or site geology's are quite the same. The Focus Areas understand and take into account the differences between the sites, whether they are regulatory, political, or technical, to ensure the rapid and widespread implementation of solutions.

Implementation of solutions at the sites is the driving force behind EM's science and technology investments. To meet the goals set in *Accelerating Cleanup: Paths to Closure*, the investment portfolio must enable or accelerate the cleanup effort and reduce cost and risk. In FY 1998, there are literally hundreds of science and technology activities within EM that are focused on performing cleanup better, safer, faster, and cheaper.

While cleanup technologies are often developed at national laboratories, universities, and other academic institutions, EM procures many cleanup services and equipment from commercial providers through a competitive bidding process. The implications for EM's science and technology program are twofold. First, technology developers must successfully transfer their innovations to the commercial sector before they can be fully deployed. Second, even if technology providers, the EM science and technology program, and cleanup project managers work

closely together to develop a new technology, there is no guarantee that the technology will win in a competitive procurement. The technology must stand on its own merits, be cost effective, and offer significant and desired advantages over other approaches without introducing unacceptable technical risk.

Success in implementing and executing the program depends on a number of program elements, the more significant of which are:

- Review and evaluation of planning and results
- Multi-year program plans
- Project-level roadmaps
- Use of success indicators and metrics
- Improved communication

Review and Evaluation — Ensuring a Quality and Focused Program

Internal and external review by peers and sponsors is generally recognized in the science and technology community as important to sound decision making. Reviews by independent peers are widely used to evaluate research proposals and to assess the productivity and progress of ongoing work. In addition, reviews present an opportunity to enable EM cleanup project managers to ensure that the technologies being supported can be implemented. Two issues are foremost during EM reviews—scientific or technical merit and programmatic relevance (potential to meet cleanup project manager needs).

Scientific merit review is performed by independent peer reviewers from universities and DOE laboratories, selected by the Office of Science on the basis of their professional qualifications and expertise. These reviewers perform a rigorous, formal external peer review and evaluation of each proposal or progress report. The evaluation criteria include scientific and/or technical merit, appropriateness of the proposed method or approach, competency of applicant’s personnel and adequacy of proposed resources, reasonableness and appropriateness of the proposed budget, and other appropriate factors. The relevance review for research projects is performed by Environmental Management subject matter experts. The criteria for the relevance review include reduction in time required to achieve EM mission goals, decrease in risk (to public and workers, or the environment), major cost savings, new knowledge or a solution to an intractable problem.

Technical merit reviews of technology and technology maturity are conducted for EM by the American Society of Mechanical Engineers (ASME). ASME review panels provide independent, external evaluation of the technical merits of a technology. Merit review is done at various stages of development from basic research to late-stage demonstration and deployment. These reviews provide an important input to technology development managers for “go/no-go” decisions for project selection or continuation. They provide a common basis on which to assess and manage performance, expectations, and transition of science and technology projects. Merit reviews are required for all new projects, at least every three years for continuing projects, and for projects that are entering the Engineering Development Stage.

Programmatic Relevance Reviews (Midyear Reviews) are conducted by each Focus Area to evaluate research projects for programmatic relevance and technical, schedule, and cost performance. Of paramount interest is project maturity and progress toward meeting cleanup project manager requirements. Project maturation from research through deployment is tracked and facilitated. Programmatic relevance review panels include DOE program managers, subject matter experts, cleanup project managers, stakeholder representatives, and technology developers, as appropriate. Projects which do not progress or for which cleanup project managers endorsement wanes are considered for termination.

Ad hoc reviews are conducted for EM by the National Academy of Sciences-National Research Council (NAS/NRC). In addition to the NAS, the Environmental Management Advisory Board reviews programmatic aspects of EM investments in science and technology. These ad hoc reviews generally address broad program issues and help guide EM in addressing problems of greatest significance to DOE. For example, following reviews by its Board on Radioactive Waste Management (Committees on Environmental Management Technologies, Remediation of Buried and Tank Waste, and the Waste Isolation Pilot Plant) and Board on Engineering and Environmental Systems (Committee on Deactivation and Decommissioning (D&D) of Uranium Enrichment Facilities), NAS/ NRC

provided comments on the EM approach to addressing technology needs as well as peer review, priority setting and decision making.

All reviews culminate in written documentation and an action plan that delineates steps to correct deficiencies and take advantage of new opportunities. Information from reviews is considered by program managers and line management in selecting or continuing projects for funding, for developing new areas of investigation, and for evaluating programmatic progress. Such information is also used to document the progress and productivity of EM programs for DOE senior management, Congress and the public.

Success Indicators/Metrics — Performance Measured by Cleanup Project Managers

Performance measures and the appropriate associated metrics are critical to the evaluation and ultimate success of a program. Within EM, the performance measures associated with science and technology investments have evolved with the EM program; they will continue to evolve as the program changes. Performance measures for EM's investments in science and technology must address both the performance of individual investments and the success of the overall program.

Performance metrics are in accordance with the four major science and technology objectives outlined previously. Technology deployment to meet identified needs and technology based cost savings (as a component of enhanced performance goals) are part of EM's current corporate performance measures. The above two EM corporate measures will be enhanced to better measure the outcomes of EM's science and technology investments. To properly monitor performance of EM's science and technology programs, two additional measures will be added. Reduction in the cost of cleanup is described by the achievement of EM's enhanced performance goals. EM will review, on an annual basis, by cleanup project, progress towards enhanced performance goals and what portion of that progress is attributable to specific investments made by EM in science and technology.

Corporate performance measures for technology deployment will be retained as an output measure. However, EM will evaluate, by project, how many of these new technologies are provided as a result of EM's investments and, more importantly, what impact those technologies are having on cleanup projects.

Solutions to high priority needs are a measure of the responsiveness of the investments to the cleanup project manager community and the ability to effectively manage EM science and technology investments. EM will measure both the numbers of high priority needs that we are trying to address and our success in meeting those needs.

Reduction in technology risk will not only reduce cleanup costs, it will allow us to evaluate and track investments in areas where EM baselines have technology gaps or uncertainties. EM will evaluate on an annual basis how science and technology have served to lower technology risk levels. This evaluation will include both science and technology developed through EM's investments as well as externally developed science and technology brought to bear on EM's cleanup problems.

The performance measures will be evaluated and documented by the cleanup project managers and will help EM evaluate the impact of EM's investments in science and technology. The results of the evaluation will also be used to modify and improve the investment strategy to continually increase the effectiveness of the science and technology investment portfolio.

Multi-Year Program Plans

The technical strategy, scope, and performance measures are derived from the Focus Area Multi-Year Program Plans (MYPPs). The MYPPs describe EM's planned investment portfolio, science through deployment, for each problem area. Each MYPP is a result of extensive discussion and planning between the science and technology community and the cleanup project managers. The MYPPs are developed in conjunction with and endorsed by the cleanup project manager community and approved by senior EM management from the Field Offices and Headquarters.

These documents are EM's primary science and technology roadmaps; they contain the problem sets, the planned technical investments, the performance measures, and the projected outcomes associated with those investments. They are used for planning purposes by both the cleanup project manager community and the science and technology community and provide the basis for EM's science and technology budget requests.

Project-Level Roadmaps

EM is beginning to prepare project-level roadmaps, its lowest and most detailed level of science and technology roadmaps, for a number of specific, critical activities to remove major critical path barriers or other impacts at lower levels than those addressed in the MYPP roadmaps. These activities may be projects, technologies, or technical issues. A project-level roadmap is an analysis of the current status of that activity (“where we are”), the hoped-for end state (“where we want to go”), and the science and technology investments needed to successfully achieve that end state (“how to get there”). EM will use project-level roadmapping to identify critical needs for investments in science and technology and the timeline for meeting those needs. The roadmaps will include a set of logical, time-sequenced steps showing project activities and decision points along with the complete set of science and technology activities needed to address technology gaps and reduce the cost, schedule, and technical risk associated with cleanup. This roadmap will represent the cleanup project manager’s definition of the science and technology investments needed to ensure the success of the project and when the products of those investments are needed. The cleanup project manager will then use this document to drive federal science and technology investments.

The value added by project level roadmapping is that it reduces programmatic risk within the projects and, potentially, their cost and schedule; helps ensure a sound technical basis for each project; gives the clean up project manager more control over the science and technology program; and aligns the resources of the cleanup programs and the science and technology programs. The goal of EM science and technology roadmapping is to align and optimize the science and technology investment portfolio by identifying both gaps in the current program and activities that do not support the cleanup projects.

The EM R&D Program Plan represents the highest level of roadmapping strictly within EM. Subordinate to this Program Plan are two lower levels with successively more detail. The second level of EM Roadmapping is at the “Problem Area” level and will consist of a series of six Multi-Year Program Plans that address EM’s major Problem Areas, e.g., high-level waste, nuclear materials, etc. The lowest level and most detailed roadmaps are generated for a number of specific, critical science and technology projects. These roadmaps describe where science and technology efforts can make a significant contribution to cleanup project success. Figure 4 shows the relationship between these three levels of EM roadmaps.

Improved Communication of Scientific Results — Making an Impact Now and Later

Improving our fundamental understanding of the problems we face will provide a basis for both near- and long-term returns on science and technology investments. Near term impacts from science investments depend on the rapid and accurate communication of potential new scientific and technological applications to specific cleanup project managers.

Improved communication of scientific results is being addressed in several ways. First, EM is working to connect each of the research projects directly to cleanup projects. Often the results of scientific research improve our understanding of the problems we are addressing or the processes we are operating. This improved understanding enables us to make better decisions as we move forward with cleanup. This contribution to the cleanup objectives, though difficult to quantify, is significant.

Secondly, EM is working to disseminate research and research results using a variety of information exchange tools, including world wide web, workshops, and symposiums. Site specific workshops and topical workshops are facilitating information exchange on specific problem areas and scientific disciplines. These workshops are providing opportunities to identify and validate research needs, disseminate research results, review and discuss the

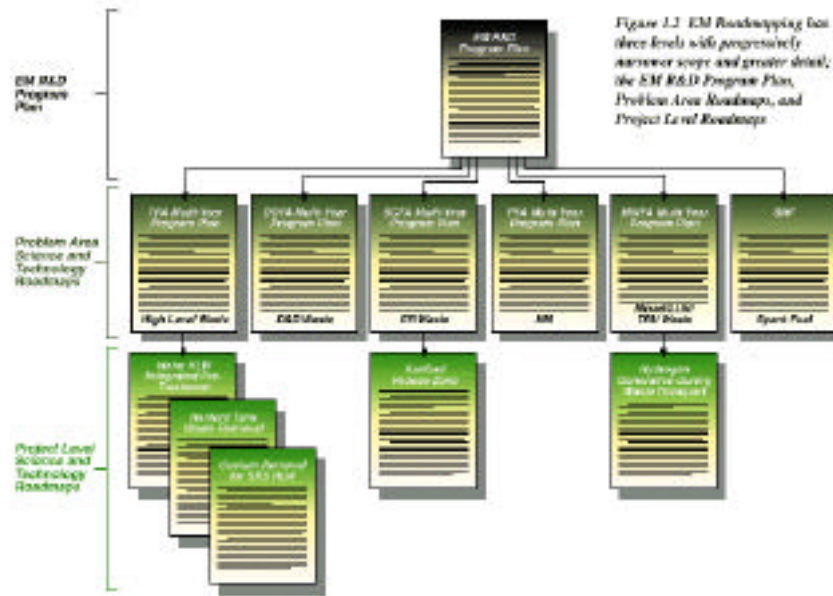


Figure 4. EM roadmapping has three levels with progressively narrower scope and greater detail.

current site specific cleanup plans, and communicate research activities that may address cleanup problems National workshops and symposiums are being used to provide opportunities to Disseminate information across sites and scientific disciplines.

Thirdly, the use of the focus area-centered approach contributes to the improved communication of science. The Focus Areas assist cleanup project managers in evaluating operational needs and identifying how investments in science, as well as in technology, help provide solutions. The Focus Areas are a liaison between the cleanup project managers and the hundreds of scientists working on research projects. This allows the scientists to better target their research and allows the cleanup project managers to receive and apply scientific results more quickly.

ACCOMPLISHMENTS AND EXPECTATIONS — THE PROGRAM IS WORKING

Yesterday — Solutions Already in the Field

EM's past investments have already made a significant impact on the cleanup effort. Solutions mentioned here and in the following section on today's achievements are based on earlier investments.

Mixed Waste Treatment and Disposal

The DOE has developed and commercialized several technologies for treatment of mixed waste. Polymer macroencapsulation is currently being used at Envirocare of Utah, Inc. for treatment of radioactively contaminated lead and certain types of mixed waste debris. The macroencapsulated waste is subsequently disposed in the Envirocare mixed waste disposal cell. Waste from over 20 sites has been treated in this manner. Three other DOE-developed technologies have been commercialized at Envirocare including: extrusion polymer microencapsulation, kinetic mixing polymer microencapsulation, and chemically bonded phosphate ceramics (CBPC). This suite of technologies provides a very robust, flexible system for treating various DOE mixed waste streams including soils, salts, ash, sludges, and other finely divided solids. The kinetic mixer and CBPC processes have already been used, on a small scale, to stabilize DOE mixed waste for disposal. All these technologies are expected to be online, at full scale, by early FY1999.

Working inside Tanks

Remotely operated machines must be used to perform work in extremely hazardous environments, such as inside radioactive waste tanks. Robots, however, must be designed or adapted, tested and shown to reliably perform the necessary tasks. Such machines have been adapted and deployed by EM to characterize and clean up tanks at Oak Ridge, and testing is underway at Hanford.

Non-Aqueous Phase Liquid (NAPLs) Remediation

When EM was formed in 1989, eminent ground water authorities pronounced the contamination of fine-grained soils with NAPLs as beyond state-of-the-art and recommended that certain aquifers be classified as “terminally ill.” Many sites within DOE and in private industry contain NAPLs, but the 1989 baseline technology for cleaning up such aquifers, pump-and-treat, was simply too slow and ineffective and, consequently, many decades of treatment would be required before sites could be cleaned up and closed. The situation for remediation has become much brighter—rapid and effective new technologies for NAPL remediation have been commercially applied and are being deployed at DOE sites to shorten closure pathways.

Implementation of Mature Solutions

Not all solutions require that new technologies be developed, and many technologies that are commercially available or are readily adaptable to DOE applications are now being deployed through large scale demonstrations. From FY96 to FY98, the DDFA has demonstrated 55 technologies at full-scale, and 24 of these have been deployed a total of 91 times. As a result of side-by-side comparisons with conventional baseline methods, technologies that have existed for several years, but not been used at DOE sites (e.g., the oxygasoline cutting torch), are being widely used both within DOE and beyond.

Today — Providing Solutions to EM’s Urgent Problems

Providing scientific and technical solutions to EM problems requires a combination of rapid response to unanticipated complications that affect critical pathways, development and adaptation of new technologies to solve intractable problems, side-by-side comparison of potential new technology applications with existing practices and, above all, sustained communication with cleanup project managers. Examples of specific ongoing problem solving actions include:

Enabling TRU Waste Transportation

Efficient waste management on a national scale requires the capability to transport hazardous materials safely, and the path to closure for many sites relies on transporting TRU wastes to the Waste Isolation Pilot Plant (WIPP). A significant number of waste containers do not qualify for shipping, however, because the wastes may generate flammable gases. Improved non-destructive methods for measuring the amount of flammable gases and methods to destroy the gases or prevent their generation are being developed with the aim of enabling shipment of more than 90% of the currently rejected containers.

Cesium Removal

The previously selected process to separate cesium from tank waste liquids at Savannah River, In-Tank Precipitation (ITP), was found to be impractical, and a new approach is needed. Today a systematic pursuit of an alternative is underway. Based on prior work, EM has proceeded from identification of over one hundred possible methods through a comprehensive evaluation to down-select four approaches for detailed assessment. The best method will be selected during the next year, and will result in delivery of an integrated and tested system.

Subsurface Barriers

The first logical step in contaminated site remediation is containment to prevent the cleanup task from growing larger. An array of barrier solutions that prevent contaminant migration is being made available for adaptation to solve site specific problems. Such solutions include reactive barriers that destroy or selectively immobilize the contaminants and inert barriers such as jet grout, soil freezing, in situ redox manipulation, thin-walled diaphragms, and viscous liquids. Monitoring and performance verification systems are included with these barriers.

Reactor Deactivation

Production reactors at Hanford and Savannah River constitute one of DOE’s greatest deactivation and decommissioning problems. The first production reactor to be addressed, C Reactor at Hanford, has been prepared for low-cost, environmentally safe storage for up to 75 years. Twenty improved and innovative solutions have been

demonstrated and evaluated during this project, including a laser tracking and data system, the STREAM data management and integration system, and anti-contamination clothing for workers with a personal heat- stress monitoring system to prevent overheating. Cost effective solutions will be promoted for deployment in the deactivation and decommissioning of the remaining twelve production reactors.

Tomorrow — Enabling New Critical Paths

The very nature of science and technology, dealing with what is not yet known, makes the prediction of specific future accomplishments imprecise. Nonetheless, it may be expected that EM's research and early-stage technology development activities will yield long-term dividends. By concentrating investments in areas that are high-cost, and are of relatively long duration with significant technology risks, EM increases the potential for return. High level waste management and facility deactivation and decommissioning, for example, both extend well beyond the 2006 accelerated cleanup target and thus present opportunities for high-yield investment. Additionally, research is concentrated in technology areas that are relatively poorly developed and especially where new knowledge is needed to solve problems.

Colloids

One poorly understood technology area is the role of colloids in contaminant transport. Colloids are particles that are so small as to defy simple physical separations such as filtration or settling but large enough to also disobey the rules of solution chemistry. Such particles complicate many EM actions from the processing of tank waste to remediation of ground water. Colloids sometimes transport adsorbed contaminants through natural and man-made barriers. In other situations, colloids form gels that clog pipes, filters, or ion exchange columns. Today, the lack of understanding of their behavior makes it impossible to confidently model the role of colloids in transporting contaminants, especially through fractured, porous media. Tomorrow, these complications will be accurately predicted and avoided. As a bonus, colloids may even be usefully applied to enhance some separations.

Advanced Separations

Processing high level waste is made difficult by the varied properties of the multiple constituents of the wastes and the different requirements for their disposal. The waste is heavily loaded with nonradioactive constituents (such as sodium and nitrate) that create large volumes for disposal when treated; high radiation constituents (such as Cs-137 and Sr-90) that require heavy shielding to protect personnel; and long-lived radioactive constituents (such as the actinides) that make it necessary to isolate the product for very long times.

Tomorrow, advanced separation techniques for these different constituents will enable treatment that is more cost-effective in specifically meeting the individual requirements of the different materials. Efficient and reliable computational and experimental methods will be used to design and test new extraction reagents to enable such separations.

Dilute Contaminant Cleanup

Contaminants in subsurface plumes are typically most concentrated near the source and are surrounded by much larger volumes of less contaminated soils or ground water. Initial remediation is appropriately focused on the concentrated zones where risks are greatest. But determining how much of the plume requires active remediation and what can be left to natural attenuation must be based on sound knowledge of the effectiveness of microbial degradation and chemical attenuation as barriers to further migration and for cleanup. Research now underway will enable better risk-based choices between natural attenuation and enhanced remediation to be fitted to site-specific conditions with high confidence.

Actinide Storage and Disposal

Complex actinide metal residues from weapons production, including plutonium, highly enriched uranium, and other nuclides, must be efficiently converted to forms that can be safely stored or disposed. Tomorrow, research that is now ongoing will enable such materials to be treated and their long-term safety assured.

Spent Nuclear Fuels

Spent nuclear fuels are by-products of the Atomic Age for which there is no experience in long term management. Research is underway to understand the radiolytic and corrosion processes that will operate on fuels stored in both wet and dry conditions and after disposition. Tomorrow, the results will provide a foundation for developing,

evaluating, selecting, and matching waste forms for safe disposition and for developing models of their long-term performance.

Finding and Removing Contaminants on Surfaces

Although lasers have become ubiquitous in medicine, commerce, and industry, the potential range of their application for EM solutions to characterization and treatment needs is in the future. Characterization using Laser Induced Fluorescence Imaging has already been demonstrated at full scale. Tomorrow, the surfaces of metals and concrete will be scanned quickly and safely using lasers, and the identified contaminants will be removed by laser ablation without generating large volumes of wastes. Other selective decontamination methods such as plasma etching or specifically designed extractants will also be available.