RESEARCH AND DEVELOPMENT IN SUPPORT OF THE FIVE-YEAR PLAN

Clyde W. Frank
Department of Energy Headquarters
Robert B. Craig
Hazardous Waste Remedial Actions Program*
Larry W. Clark
Department of Energy/Oak Ridge Operations
Louis I. Middleman
Management Systems Laboratories

ABSTRACT

To support its 30-year cleanup goal and significantly reduce overall program cost, the Department of Energy (DOE) has committed to increase its investment in, and coordinate its management of, applied Research, Development, Demonstration, Testing, and Evaluation (RDDT&E) to resolve existing technical issues and rapidly advance beyond currently available waste management and waste site cleanup technologies. DOE has established a national applied RDDT&E program that will include involvement of DOE Operations Offices, national laboratories, other Federal agencies, universities, and industry and that will seek the advice of external advisory and technical review groups. This paper describes a plan that clearly maps out a time-phased, needs-driven RDDT&E program to provide technologies over the next two decades for the safe, expeditious, and economical completion of DOE site environmental restoration and improved waste management operations.

INTRODUCTION

The Applied Research, Development, Demonstration, Testing, and Evaluation (RDDT&E) Plan expands and extends the Applied Research and Development section of the Department of Energy's (DOE's) August 1989 Environmental Restoration and Waste Management Five-Year Plan. Based on the salient RDDT&E needs entailed in solving the human health and safety and environmental compliance problems identified by the Operations Offices and prioritized in the Five-Year Plan, this Plan's primary purpose was to provide an initial map to guide the new Office of Technology Development (OTD) (under the new Office of Environmental Restoration and Waste Management) in fulfilling its mission: "to manage and direct programs and activities to establish and maintain an aggressive national program for applied research and development to resolve major technical issues and rapidly advance beyond current technologies for environmental restoration and waste management operations."

Although the OTD will not prioritize cleanup and compliance activities, it will contribute to setting those priorities. DOE's prioritization methodology will include, among other criteria, the relative power or weakness of current technology and the likelihood that new, more effective, and less costly technologies will be deployable in time to meet regulatory requirements. With such information in hand, OTD will be able to guide the Operations Offices toward permanent solutions faster and at lower cost or toward interim measures where permanent solutions must wait for basic research.

The RDDT&E Plan is the work of a large number of scientists, engineers, and managers who understand, as an integrated unit, both DOE's problems and present-day solutions to these problems. Section 1 of the Plan is an overview, setting forth the purpose, scope, planning premises, and a management process for continuing or implementing appropriate applied RDDT&E and for requesting, selecting, funding, and monitoring the development and deployment of new technologies. Section 2, Research and Development, is structured to reflect the RDDT&E needs in Environmental Restoration and Waste Management Operations as discussed in Section 5 of the Five-Year Plan. Section 3, Education, describes initiatives designed to create the human resource base needed to manage and execute DOE's Environment and Waste Management activities over the long term. Section 4, Future Innovative Technology to Solve DOE Problems, describes the unconstrained thought processes that must be brought to bear to meet DOE's major challenges. Section 5, RDDT&E Funding Plan, describes existing funding for RDDT&E and initiatives to be undertaken in FY 1990.

PLAN SCOPE

Within the Plan's scope are identification of technology initiatives needed to resolve problems at facilities currently under the cognizance of the Assistant Secretaries for Defense Programs and Nuclear Energy and the Director, Office of Energy Research. The objective of these initiatives is to make needed new or adapted technologies available before the end of FY 1995, as well as to begin initiatives required within that time period to make new technologies available beyond FY 1995. A significant new national education initiative, aimed at addressing the current and projected shortage of appropriately prepared and motivated scientists, engineers, and technicians, described briefly in the Five-Year Plan, appears in further detail. The Plan establishes mechanisms for calling on the expertise not only of DOE's national laboratories but of other Federal laboratories, universities, industry, and the international waste technology community. In May 1990, this Plan will

become part of the first revision of the Five-Year Plan and will be annually updated to reflect evolving needs and strategies.

Certain basic and fundamental observations can be made. First, in general, the DOE Defense Complex is primarily a very large metals production (and electronics fabrication) industry. Although the metals may be unusual, the processes and materials used to support their production often are not. The chlorinated hydrocarbon degreasers and the machine cutting fluids are, for example, essentially the same in DOE and private industry.

Second, if DOE is successful, current technologies will appear as antiquated in the 21st century as technologies of 50 years ago seem today. In 1940, scientists had to use photographic plates to spectrally characterize molecules. Current technology has advanced to allow chemical mapping of the human body. This same degree of advancement must be made relative to restoring the environment in the next 20 years. The effort will require the use of present resources and the development of new resources to address and solve the problems resulting from DOE's past disposal practices.

Third, to meet its commitments, DOE must develop the ability to process increasingly dilute solutions. The Department, like all other production entities that relied on shallow land burial, cribs, ponds, lagoons, and underground storage tanks and transfer lines for disposal, has created a system that has affected surface water and groundwater. The forces driving subsurface contamination include percolation, vapor transport, and transportation of contaminants by leaked and spilled solvents. The subsequent migration of organics, inorganics, and radioactive materials has resulted in wide dispersion of waste material at low concentrations. Thus, the environmental remediation challenge must focus on the source of the material and on restoring and preventing contamination of the waters under and around DOE facilities. Confining contamination, removing the source of contamination, and restoring water containing low concentrations of contaminants pose problems of enormous magnitude.

The challenge is to process high volumes of low-value (concentration) materials and to enhance natural degradation--the earth's own technology. Present technology has been developed to extract valuable materials from ores or process streams. The production of metals, pharmaceuticals, organics, and weapons is based on extraction of valuable components from high-value (concentration)/low-volume and high-value/high-volume production streams. This kind of process not only produces a usable material but also produces a side stream of low-value/high-volume waste. Generally, this waste has been disposed of into shallow land burial sites, has migrated, and has ultimately been intercepted by surface water or groundwater. The result has been lower and lower value/higher and higher volume streams. Technology does not exist to efficiently and effectively extract or remove these dilute contaminants from water.

Fourth, technologies must be developed to ensure that DOE does not have to revisit these contamination problems in 2020. By then, postclosure monitoring under the Resource Conservation and Recovery Act and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) must show that DOE will have achieved its 30-year goal. Technologies developed through the RDDT&E process must address anticipated environmental regulations of the future, not the present. Coupled with such technologies must be the development of technologies, processes, and materials that minimize the amount of waste generated requiring disposal. When disposal is necessary, all assurances must be developed to ensure minimum environmental impact.

The objective of this Plan is to increase the order of DOE's management of RDDT&E. The Five-Year Plan took the first step in this direction by consolidating the waste-related activities of three Program Secretarial Offices under a single focal point for Environmental Restoration and Waste Management (ER&WM). Now with the creation of a Technology Development function within ER&WM, DOE can begin to consolidate and focus the needed talent base, currently dispersed throughout the national laboratories, other Federal laboratories, industry, and academia.

The two merged funnels shown in Fig. 1 portray DOE's previous practice and future goals in terms of the order/disorder process.

One narrow end represents the production of a useful material. The by-products have migrated and dispersed, resulting in the development of a more disordered system as represented by the middle portion of the figure. The remaining half represents the future goal of environmental restoration RDDT&E for DOE: to develop methodologies for restoration and support technologies that process the low-value/high-volume contaminant streams, through efficient and cost-effective methods, to high-value/low-volume streams easily separated from the environment. Coupled with this thrust must be studies directed at minimizing waste generation from present production operations.

PLAN APPROACH

In management, decreasing disorder means decreasing the uncertainty of that which must be managed. Five words--Perplexity, Problem, Program, Project, and Process--describe management domains in order of decreasing uncertainty. For a Perplexity, one knows neither the start nor the end (as is the case with more than 75 percent of DOE's CERCLA sites). With a Problem, one knows the

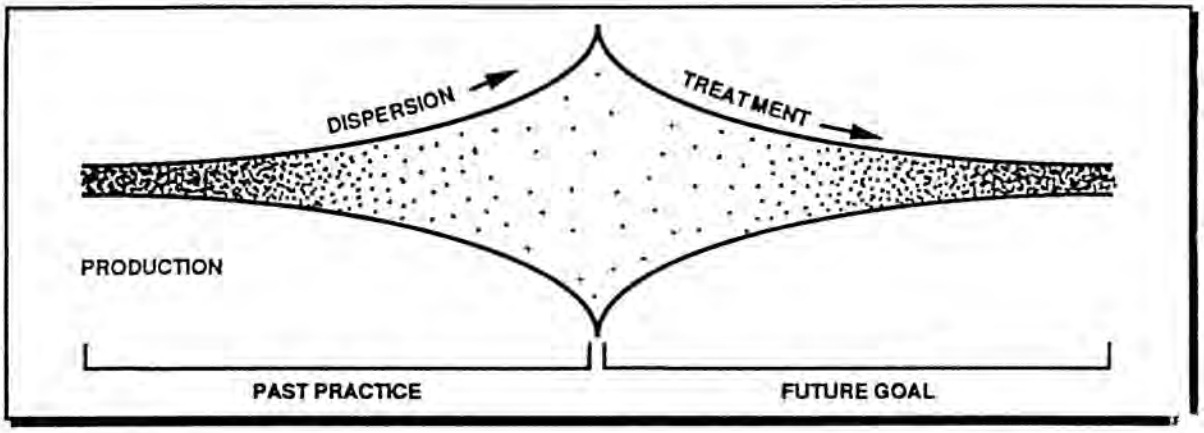

Fig. 1. The Department of Energy's pratice and goals per order/disorder

start but not the end. With a Program, one knows the start and has a qualitative fix on the end. A Project embodies detailed specifications for the end. A Process repeatedly achieves the same known end. Most of DOE's environmental restoration and waste management endeavors are currently in the Program, Problem, and Perplexity categories. A focused RDDT&E effort must rapidly move these endeavors into the Project and Process stages if DOE is to meet its 30-year cleanup and compliance goal.

Magnitude and Complexity of the Problem

For more than four decades, DOE operations have polluted large volumes of soils and groundwater with radioactive and hazardous substances, usually with both. Before figuring out how to remediate an inactive contaminated site, before being allowed by law to do any remediation whatsoever, DOE must characterize the sites, more than 3,700 of them at DOE installations across the country. Characterizing means answering at least the following questions: Where did the waste come from? What is it (almost certainly a mixture, probably including both hazardous chemical and radioactive constituents)? Where is it now? At what concentrations? Where is it going? How fast and in what direction(s)? What are its migration pathways into the biosphere? What quantitative risks does it pose to (what are its effects on) humans and the biosphere now and in the future? What remedial alternatives exist for a permanent solution? What are the alternatives for interim measures, if necessary? How can all interested parties determine and agree on what is wise to do at a given site?

Few of these questions can be answered using off-the-shelf methods. DOE must be able to call upon industry and the technical community to solve these problems and to implement solutions. To conduct site investigations and prepare and evaluate the analyses necessary to identify problem magnitude, potential solutions, and alternative costs, both DOE and the regulators need more scientists, engineers, and technicians with appropriate knowledge and skills. The education initiative that forms Section 3 of this Plan is an important step toward motivating and developing the human resource base needed to carry out a task of such enormity and length.

Need for a Focused RDDT&E Program

Technical resources exist in the DOE system and the private sector, but they are used to examine only selected problems. It is as though the people who need to be working together to solve the problems are virtuoso musicians, accustomed to playing solos, who arrive at a symphony rehearsal, each with different music, and therefore find that no one can say what the score is. Worse yet, there is no conductor. Who would fund the resulting performance? Who would attend? DOE is funding such a performance now, and the nation is watching and listening. Throughout the land are well-intentioned left hands not knowing what the well-intentioned right hands are doing. In some cases, one works at the earliest stage of a problem while another has already patented a solution.

The goal is permanent and cost-effective solutions to all problems. But where available technology, even available basic research, cannot yield or indicate permanent solutions, the applied RDDT&E program must discern what course of action can be effective in the interim. In simple terms, the program must decide three things: what must be done immediately, what must start now to be ready later, and what can be delayed without increasing the amount of ecological damage, health effects, or costs. Such decisions have in the past been made independent of a national plan.

The program will select and support two different kinds of RDDT&E activities in parallel: first, activities leading to specific solutions of (and interim measures for) particular problems and second, activities leading to solutions of generic problems. In the first category are such things as alternatives for remediating the pre-1970 buried transuranic waste at Idaho National Engineering Laboratory (INEL) and the single-shell high-level waste (HLW) tanks

and piping at Hanford; disposing of the calcined HLW at INEL; eliminating seepage basins and liquid discharges to the ground at Hanford, Fernald, and Savannah River Site (SRS); and treating hazardous and mixed waste in accordance with the Environmental Protection Agency's (EPA's) Land Disposal Restrictions.

The second, generic, category of activities will support eventual permanent solutions. Because more than three-fourths of DOE's inactive sites have not gone through the remedial investigation/feasibility study stage of CERCLA, characterization technologies must be a high RDDT&E priority. Today's site characterization technology is expensive and slow. Between $10,000 and $75,000 buys one state-of-the-art monitoring well to give a core sample at a depth of 100 ft. It takes another well to get a sample at 150 ft, a third at 200 ft, etc. Applied RDDT&E must develop multiple-depth single-well technology and better sampling analysis techniques. Today it costs about $150 to test one sample for chromium. Why not pennies?

But why traditional wells at all, or traditional off-line, one-at-a-time laboratory sample analysis? We need to stretch the present limits of scientific knowledge and engineering capability to open and explore new ways of thinking. For site characterization we want real-time monitoring. Why not drill "microwells" with lasers, insert fiber optic cables, and let attached monoclonal antibody sensors report status continuously?

Management Emphasis on Communication and Cooperation

In line with the policy to establish a new DOE culture based on openness and communication both within and outside the Department, the RDDT&E program will work to end the "not-invented-here" syndrome and ensure interdisciplinary and interlaboratory cooperation by emphasizing partnerships with universities and industry and technology coordination groups. Competition will focus on problems, not funding. There will, it is hoped, be resources to encourage and implement most if not all excellent endeavors.

The RDDT&E Plan identifies some key management activities and technology programs that must be nationally and internationally coordinated, in development and implementation, for both effectiveness (doing the right things) and efficiency (doing things right). These include needs such as (1) standardized methods and equipment for waste handling and waste site characterization, particularly for mixed waste; (2) a standardized approach and tools and instruments for evaluating the performance of technologies at disposal and remediation sites; (3) standardized software architecture and components for robotic and other automated systems needed to minimize human exposure to radioactive and other hazardous substances during characterization and remediation of inactive sites and during repair or modification of elements of active facilities and processes; and (4) a uniform system for collecting, storing, retrieving, and manipulating waste management data and information and for sharing and coordinating data and information within and outside the Department.

RDDT&E Integral to Achieving Environmental Goals

As stated in the Five-Year Plan, DOE is committed to a 30-year goal of achieving compliance and accomplishing the environmental restoration of its sites. RDDT&E is integral to the attainment of this goal, which requires conducting program activities designed, both in their processes and in their results, to decrease workers' and the public's exposure to radioactive and hazardous substances and to do the job faster and at a lower cost. RDDT&E will consider both the long-term benefits to human health and the environment and the health hazards to workers. The DOE Office of Environmental Restoration and Waste Management will work with the Assistant Secretary for Management and Administration to help involve private industry in seeking and implementing solutions by establishing a streamlined procurement process to cut lead time, first, between a good idea and the tested realization of that idea, and second, between technology availability and full-scale implementation.

Compliance and remediation cannot always wait for improved technologies; the provisions of some agreements require DOE to begin certain activities now, using the best means at hand. But when waiting can bring significant benefit, present conflict resolution methods may allow consensus changes in priority. Where feasible, given safety and regulatory concerns, RDDT&E must increase DOE's ability to realize enormous cost savings by remediating buried waste in place, without digging it up for processing and reburying the residue. When waste must be dug up, RDDT&E must make reburial unnecessary or, if that is not possible, must stabilize and significantly reduce the hazard of the volume to be reburied. Only by so doing can DOE fulfill its promise to the Congress and the nation to prevent passing a negative legacy on to future generations. To support this aim, RDDT&E must yield significant waste minimization through production process modification.

Regulatory/Public Policy Issues Addressed in Parallel with Technical Issues

To facilitate implementation of new technologies, DOE will require all RDDT&E activities to address as a parallel issue regulatory compliance and the need for public involvement in DOE's RDDT&E activities. In the past, development focused on science and engineering in a limited forum, excluding public policy concerns and the regulatory process required to gain permits for technology demonstration or full-scale implementation. DOE will involve the public early

and clearly define to the regulatory bodies the process of technology selection to ensure regulatory acceptability and to speed the issuance of permits. DOE will conduct its RDDT&E program in a consensus forum. Conferences, written material, and invitations to observe key demonstrations of new technologies will keep the public abreast of progress. The State and Tribal Government Working Group (STGWG) that reviewed and helped make significant improvements in the Five-Year Plan participated in the formulation of this RDDT&E Plan, and its participation again proved beneficial.

Waste Minimization and Recycle

Waste minimization, the reduction in the generation of radioactive, hazardous, and mixed waste before treatment, storage, or disposal, is a legal requirement, an ethical responsibility, and often a financial benefit. DOE will make waste minimization a key factor, not only in process and facility modification but also in the procurement of goods and services. The major new modernization goal of minimizing waste generation entails a significant RDDT&E component. The Office of Technology Development will manage the Office of Environmental Restoration and Waste Management's contribution to the design and demonstration of new processes to avoid the generation of waste containing hazardous constituents. Equipment used in waste processing will be designed for cleaning with nonhazardous substances and/or to yield a nonhazardous product.

Recycling is another major initiative. Contaminated metals from decontamination and decommissioning operations and decommissioned facilities may be used in noncritical structural or shielding applications for DOE HLW disposal and monitored retrievable storage facilities. Less likely, but possible, is the use of contaminated steel as canister material to contain the borosilicate glass that will come from the Defense Waste Processing Facility's HLW immobilization process at SRS and, later, from the Hanford Waste Vitrification Plant. Facilities will be designed to recycle the large volume of waste process water they generate, rather than use it "once through."

Mixed Waste Treatment and Land Disposal Restrictions

Complexwide strategies will address issues like the management of mixed (radioactive and chemically hazardous) wastes, regional treatment facilities, and intersite recycle and processing of recovered materials. DOE's strategy for managing mixed wastes is to minimize their generation, treat the hazardous constituents of those that must be generated in accordance with the EPA's Land Disposal Restrictions, and dispose of only those that have been treated to attain the least hazard possible in a manner appropriate for the radioactive constituents.

Developing Partnerships

Although DOE has set effective precedents for partnerships between universities and Federal organizations both domestically and abroad (e.g., SRS, Alfred University of New York, The University of Florida, and Catholic University; international cooperation with the Federal Republic of Germany, Japan, the United Kingdom, France, Austria, and France), fulfilling DOE's 30-year compliance and cleanup commitment will require coordination and cooperation unprecedented in its magnitude and diversity. This Plan describes a rational approach to the integration of existing technologies from other agencies, international technologies, university and industrial capabilities, regulatory and public policy processes, and basic research. This coordination and cooperation will be established through the development of various partnerships managed by the DOE Operations Offices, for example,

- laboratory/university consortia for education and research;
- laboratory/industry partnerships for development, testing, evaluation, and implementation of new technologies;
- Federal agency cooperation through joint EPA/DOE demonstrations (e.g., the Superfund innovative Technology Evaluation program), National Institute of Standards and Technology/DOE collaboration on needed standards, and joint funding of cooperative RDDT&E projects with the Department of Defense;
- inter-Operations Office R&D laboratories partnerships in the areas of minimization or, for example, between the Idaho and Richland Operations Offices on demonstrations, biotechnology, and education; and
- bilateral international agreements for technology exchange.

Prioritizing RDDT&E Activities

The needs for applied RDDT&E identified and emphasized in this Plan have been generally defined by the priorities established in the Five-Year Plan to deal with DOE's environmental restoration and waste management problems on a worst-first basis. The technology selection process has both absolute and relative elements. In absolute terms, DOE has begun and will continue to evaluate existing and emerging technologies according to a system of attributes such as effectiveness in solving or providing interim measures to confine or contain a problem, the magnitude

and/or level (international, national, DOE-wide, site-specific) of the problem, estimated time and dollars to implement, and others. In relative terms, DOE will filter sets of competing candidate technologies for both their regulatory-related and technical compatibility.

The initial Five-Year Plan priorities were set using a subjective analysis, pending the development of a methodology incorporating the consensus of the public, EPA, affected States, Indian Nations, and other regulatory and environmentalist concerns. The same holds for RDDT&E prioritization. Ultimately, RDDT&E activities must be prioritized according to a set of properly weighted attributes, including immediate and long-term risk reduction, with Five-Year Plan priorities as inputs.

PLAN DEVELOPMENT

A special Secretarial meeting of the National Laboratory Directors and DOE Operations Office Managers in early June 1989 set the stage for the RDDT&E planning process. The RDDT&E Task Force was established June 26. The idea was to take a dual-path approach to planning: first, bottom up, to discover where the department is in its journey from problems to solutions; second, top down, to decide where the Department needs to be and how to get there. Representatives from the laboratories and DOE were selected to participate on 18 technical teams to identify, in a preliminary way, the areas of potential technology advancements through applied R&D. The team subject areas were characterization/assessment, soils, mixed waste strategy, decontamination and decommissioning, prioritization, biotechnology, thermal/photochemical processes, chemical processes, international technologies, industrial integration, production, instrumentation, preparation/packaging, information systems, survey laboratories' future, robotics, university/laboratory consortia, and demonstration.

The team reports constituted an initial technology and strategy baseline for RDDT&E and confirmed the need for a centrally managed national program. It became clear that, though committed to advancing the state of the art in all technical areas, RDDT&E throughout the system tends toward solutions looking for problems. Therefore, technology development requires a focused Headquarters element, a focus not of wizardry but of wisdom and leadership to harness DOE's technical power base *and direct its activities* toward fulfilling DOE's commitments.

PLAN REVIEW

An effort of this magnitude, at the forefront of scientific knowledge, engineering capability, and public and regulatory scrutiny, requires for its success the review and consensus of many interested parties. DOE sought, as it did in the review process for its Five-Year Plan, to bring the energies and insights of all appropriate constituencies to bear on the formulation of this RDDT&E Plan. Predecisional Draft 1 (September 1989) went out to DOE internal Headquarters elements, the national laboratories and Operations Offices, the Hazardous Waste Remedial Actions Program, the Ad Hoc Waste Management Contractors Committee, and the Waste Management Review Group under the auspices of Virginia Polytechnic Institute and State University. Predecisional Draft 2 (October 1989) went also to the STGWG. This Draft Plan (November 1989) has in addition been distributed to the Congress, the Office of Management and Budget, the EPA, the Nuclear Regulatory Commission, the National Academy of Sciences, the American Society of Mechanical Engineers, the American Institute of Chemical Engineers, the American Chemical Society, and the American Society of Civil Engineers. Incorporating the good advice of these bodies helped and will help DOE chart its RDDT&E course and will also, it is hoped, increase the Plan's chances for success.

This Plan, though still evolving, marks the beginning of the end of environmental restoration and waste management technology stagnation in DOE--the end of "hog and haul" and of "suck, muck, and truck." DOE anticipates that, by creating the Office of Environmental Restoration and Waste Management, and, within that entity, an integrating function for applied R&D across all affected programs, it has taken a significant step, not only toward solving its own problems, but toward a participatory and leadership role in resolving many national and international issues.