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OFFICE OF TECHNOLOGY DEVELOPMENT'S INTEGRATED PROGRAM FOR DEVELOPMENT OF IN SITU REMEDIATION TECHNOLOGIES

M. E. Peterson M. Shupe
J. Walker B. Ellis

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Pacific Northwest Laboratory
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OFFICE OF TECHNOLOGY DEVELOPMENT

INTEGRATED PROGRAM FOR DEVELOPMENT OF IN SITU REMEDIATION TECHNOLOGIES

Mary E. Peterson, Pacific Northwest Laboratory
Mel Shupe, U.S. Department of Energy
Jef Walker, U.S. Department of Energy
Bill Ellis, BDM

In August 1989, the U.S. Department of Energy (DOE) issued its first annual five-year plan for Environmental Restoration and Waste Management (ER&WM). This plan expressed DOE's commitment to achieving compliance with laws, regulations, and agreements aimed at protecting human health and safety and the environment. In order to carry out that commitment, DOE stated that it would focus its resources to (1) assess and clean up inactive waste sites and facilities, (2) continue safe and effective waste management operations at present and future facilities, and (3) coordinate an aggressive applied research and development (R&D) program keyed to developing technologies aimed at resolving major technical issues and lowering costs.

The first five-year plan recognized that improved technology tools were required to accomplish DOE's goals and that new technologies could make attainment of these goals less costly, more efficient, and more effective. In November 1989, the Office of Technology Development (OTD) was created within DOE's Office of Environmental Restoration and Waste Management (EM) to manage an aggressive national program for applied R&D, to resolve major technical issues, and to rapidly advance beyond the current state-of-the-art technologies for environmental restoration and waste operations. The OTD has instituted Integrated Demonstrations (IDs) and Integrated Programs (IPs) as a mechanism to rapidly develop and demonstrate remediation technologies for environmental restoration at DOE sites.

INTEGRATED DEMONSTRATIONS

The IDs provide a vehicle to demonstrate, test, and evaluate various technologies for particular environmental restoration or waste management problems. They are designed as full-scale demonstrations in which alternative technical solutions to specific environmental restoration problems can be tested in parallel and in a context that includes consideration of all factors that bear on a full-scale remediation. An ID has three aspects. The operational aspect involves all of the "cradle to grave" phases identified for an environmental restoration project (characterization, assessment, remediation, and monitoring). The technology filtering aspect involves evaluation and selection of technologies from R&D for demonstration, testing, and evaluation based on criteria derived from the aim to implement faster, cheaper, safer, and better technologies. The technology integration aspect involves early and continued interaction among interested States, federal regulatory bodies, and respective communities to expedite regulatory and public acceptance of technologies in time for implementation. Demonstrated technology is transferred within EM to the Office of Environmental Restoration and the Office of Waste Operations and to other federal agencies, as well as the industrial and international sectors.

INTEGRATED PROGRAMS

The IPs provide the mechanism for ensuring that applied R&D is conducted to facilitate technology development. An IP addresses one or more specific sets of environmental restoration and waste management needs; and provides a continuing mechanism to focus R&D activities to develop new technologies; evaluate their relative merit and suitability for various ID, environmental restoration, and waste management needs, and advance the technologies rapidly to the demonstration, testing and evaluation phase. An IP coordinates multiple technical resources to ensure that technical work receives maximum benefit from common activities and applies to the broadest possible range of problems. The IP involves both R&D and technology assessment. The R&D aspect involves conducting experimental studies for promising technologies, with the goal of developing the technologies to the point where they can be selected for demonstration. When selecting technology development activities, special emphasis will be placed on filling technology development gaps among the end users and eliminating duplicate activities. The technology assessment aspect involves performing technology evaluations and assessments and providing recommendations of technologies for specific EM cleanup problems. In this role, the IP serves as a technology resource to the end user.

The OTD's objectives for instituting IDs and IPs to rapidly develop and demonstrate new technologies focus on the three EM goals: cleaning up past practice sites, improving management of current (stored and generated) waste, and preventing poor waste management practices in the future. Integrated Demonstrations and IPs have been implemented for the cleanup of contaminated groundwater and soils, the retrieval and processing of waste, and the minimization of waste generation. The relationship of the IDs and IPs for achieving OTD's objectives is shown in Figure 1. The ID will demonstrate technologies for all aspects of remediation (i.e., characterization, remediation, secondary waste treatment, closure, post-closure monitoring, etc.), while the IP will focus on a specific single problem category (e.g., characterization or in situ treatment) and will develop technologies to permit their demonstration at many DOE sites.

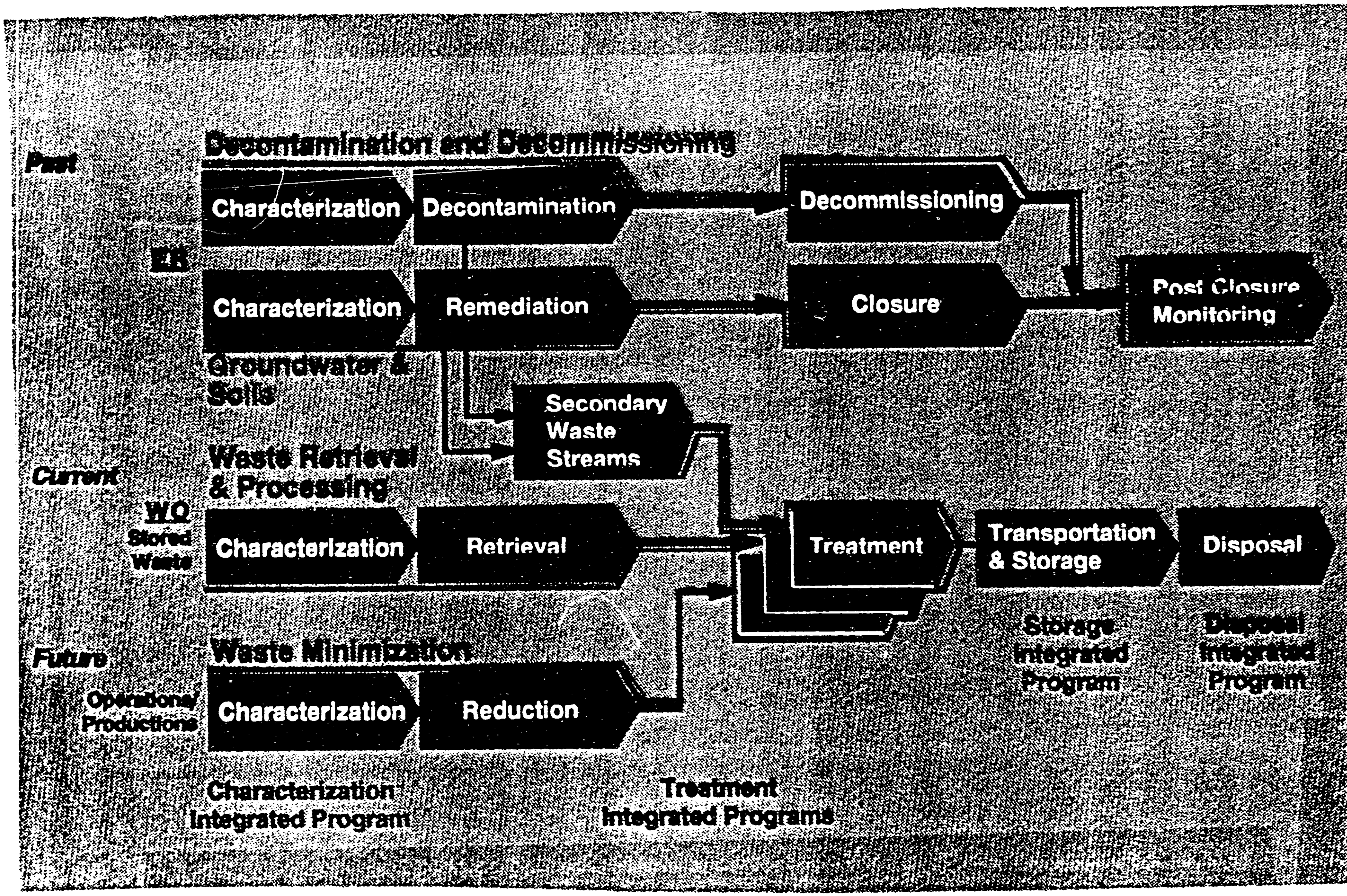

FIGURE 1. Mapping of the Integrated Demonstrations and Integrated Programs on the EM Cleanup Goals

INTEGRATED PROGRAM FOR IN SITU REMEDIATION TECHNOLOGY

In June 1991, the OTD instituted an IP focused on in situ remediation technologies. In situ remediation is defined to include both treatment and containment technologies. In the context of this IP, in situ treatment technologies refer to technologies that will treat the contaminated areas without requiring excavation or removal of the material, and to technologies that will enhance the removal of the containments from the subsurface. In situ containment technologies refer to technologies that slow or stop the migration of contaminants to the surrounding environment. The implementation of in situ remediation technologies for cleanup of DOE sites offers the benefits of 1) minimizing the health effects on workers and the public by reducing contact exposure; 2) reducing the costs for cleanup by orders of magnitude by eliminating the need for waste excavation, transport, and disposal; and 3) enabling the remediation of areas that currently are not accessible, such as the subsurface and areas beneath structures.

The objectives of the ISR IP are to 1) develop and manage the R&D activities for in situ remediation technologies, including in-place treatment and containment technologies for hazardous wastes, radioactive wastes, and mixed wastes in soils, groundwater, and storage tanks at DOE sites; 2) coordinate technology development to avoid duplication of effort and to maximize information feedback needed to focus and integrate the R&D program; 3) conduct applied R&D on in situ remediation technologies to develop the technology to the demonstration point, then transfer the technology to users such as the Office of Environmental Restoration, Office of Waste Operations, other federal agencies, and industry; 4) support the advancement of innovative technologies to assess their potential benefit; and 5) provide additional scope to ongoing in situ remediation technology development activities so that additional data can be collected and the technology can be extended to other DOE sites. In order to accomplish these objectives, the ISR IP has established 1) a program planning group to provide the "user's perspective" by representing the needs of the DOE sites; 2) technical support groups consisting of technical experts in specific program areas to assist in identifying technology needs, prioritizing R&D activities, and reviewing progress and performance of the R&D activities; and 3) independent review groups comprised of technical experts with the scientific, technology development, and implementation experience to evaluate the technical approach, scope, and progress for the IP and the R&D activities.

PROBLEM DESCRIPTIONS AND TECHNOLOGY NEEDS

In order to focus the R&D activities for in situ remediation technologies, the ISR IP has been extracting problem descriptions, technology functional requirements, and technical issues from the IDs, waste operations, and environmental restoration. In addition, technology development activities within other DOE organizations, EPA, DOD, and industry are being evaluated for applicability to the ISR IP. The ISR IP will prioritize DOE problem groups and contaminants and then focus the available R&D resources on developing technologies for the high-priority problems. The problem contaminants existing throughout the DOE complex include both volatile and non-volatile organics such as trichloroethylene (TCE), polychlorinated biphenyls (PCBs), perchloroethylene (PCE), carbon tetrachloride (CCl_4), chloroform, gasoline components, and diesel fuel components; radionuclides including plutonium, uranium, tritium, transuranic elements, radium, thorium, cesium, and strontium; inorganics such as antimony, arsenic, beryllium, cadmium, chromium (VI), lead, mercury, and nitrates; and high explosive materials. These contaminants are found in a variety of matrices and waste forms, including ground and surface water, arid and nonarid soils, and a variety of liquid and solid waste forms.

In situ remediation technologies have applicability to seven DOE problem groups as described below: buried waste, soils found in basins/ponds, soils in high use areas, soils from contaminant-specific events, groundwater, containerized waste, and underground detonation sites. These problem groups were identified in conjunction with a technology needs assessment performed under the direction of the Office of Environmental Restoration (1).

Burial Waste

This category includes landfills, trenches, and other types of burial grounds. They may be unlined and may or may not be capped, and provide a current or potential source of vadose zone and groundwater contamination. The burial grounds typically contain heterogeneous contaminants and contaminated media. Burial grounds can be contaminated with low-level radioactive waste and non-hazardous waste, such as animal carcasses, sewage sludge, construction debris, etc. They may also contain mixed radioactive (high-level, low-level, and TRU) and hazardous waste (organic, inorganic, or metals) materials. The buried materials are generally heterogeneous and potentially reactive if mixed. Wet solids, including sludges, absorbed liquids, resins, and cemented sludges, can have a high organic content, along with hazardous metals and radionuclides. Homogeneous dry solids, including grout, concrete, asphalt, brick, soils, salt, and ash, are contaminated with hazardous chemicals, hazardous metals, and/or radionuclides. Large heterogeneous dry solids, including equipment, gloveboxes, glass, construction debris, and metal, are contaminated with hazardous chemicals, hazardous metals, and/or radionuclides. Small heterogeneous dry solids, including filters, glass, laboratory equipment, plant equipment, combustibles, ceramics, glassware, leaded rubber gloves, and lead, are contaminated with hazardous chemicals, hazardous metals, and/or radionuclides. Mercury-contaminated equipment and sludges also exist.

Contaminated Soils

Contaminated soils are found in basins and ponds, around high-use areas associated with existing facilities, and at sites affected by contaminants-specific events. This problem group is described in the following paragraphs:

Basins/Ponds. Basins and ponds consist of percolation, evaporation, and/or seepage basins and ponds; trenches; sumps; drainfields; and cribs. These formations usually received effluent generated from site activities. They are unlined and pose a current or potential source of vadose zone and groundwater contamination. The basins and ponds can consist of low-level radioactive waste with RCRA metals, such as chromium, lead and mercury, and/or organics, and hazardous waste that includes organic and/or inorganic constituents.

High-Use Areas. The high-use areas include contaminated soil associated with aboveground or underground storage tanks, piping sewer lines, and buildings. Characterization and remediation is complicated by location of the soil around tanks, piping, and beneath buildings. The contaminated soil is often localized and associated with piping and sewers located in or near areas that are used daily. Generally, the subsurface contamination does not provide an opportunity for direct contact, but presents a current or potential source of groundwater and vadose zone contamination. The soils around piping, tanks, and buildings can be contaminated with radioactive (high-level waste, low-level waste and/or TRU) and hazardous waste (metals, organics, and inorganics).

General Soils. The general-soil problem category includes soils contaminated by a contaminant-specific episode or event (leak, spill, effluent discharge, or weapons-testing explosion). It provides a current or potential source for vadose zone and groundwater contamination. These soils can contain organics such as PCBs, volatile organic carbons (primarily TCE and carbon tetrachloride), and petroleum-related constituents (sometimes free product in the subsurface). These soils can also be contaminated with mixed low-level radioactive waste and hazardous waste such as organic, inorganic, and metal (chromium, cadmium, lead, and mercury) contaminants, and high explosives. Sediments in ponds, streams, and rivers are contaminated with low-level radioactive waste received through runoff from surrounding areas or from discharge of contaminated ground water. The potential exists for sediment transport to other surface water bodies used for drinking water and/or recreational purposes.

Groundwater. Contaminated groundwater plumes range in area from several acres to hundreds of square miles, and the extent of contamination is unknown in many cases. Contaminants may be present in perched zones and/or more continuous aquifers, including regional and sole-source aquifers. Contaminant concentrations in most cases exceed standards, and off-site contamination may exist. Groundwater may be contaminated with organic hazardous constituents, predominantly TCE and its associated degradation products, but it also may include petroleum products, CCl_4, and high-explosive compounds. Groundwater is also contaminated with organics, metals, uranium, tritium, and other radiological constituents. The contamination resulted from leaking tanks or piping, surface spills, injection wells, or discharge from disposal sites, and is located several hundred feet below the surface.

Containerized Wastes

Containerized waste consists of sludges in tanks with radioactive waste (high-level waste, low-level waste, and TRU), hazardous waste, and drummed waste. Sludges or similar types of mixed wastes in partially aboveground or below underground storage tanks are usually low-level waste forms, but high-level wastes also may be present. The waste may be sludge-like, dust-like, liquid, or solid, and will require removal or stabilization in the tanks prior to decontamination and decommissioning of the tanks. The tank integrity is questionable, and tank leaks present a current or potential source of surface soil, vadose zone, and groundwater contamination.

Underground Detonation Sites with Low-Level Waste, Low-Level Mixed Waste, and Hazardous Waste

This problem category includes underground weapon or nuclear test sites. The contaminants include low-level radioactive and hazardous (RCRA metals, organics, and/or inorganics) constituents. The contaminated areas are generally isolated from the surface. They represent a current or potential source of groundwater contamination because detonations were above and below the water table.

PROGRAM TECHNICAL AREAS

The problem areas described above led to the identification of specific technical program areas for developing in situ remediation technologies. The ISR IP encompasses three major program areas: treatment, containment, and subsurface manipulation. These major program areas are described in the following sections.

Treatment Technologies

In situ treatment technologies will be developed and evaluated for the remediation of volatile and nonvolatile organics, radionuclides, and inorganics in a variety of matrices. The focus will be on technologies associated with in situ destruction, enhanced in situ removal and extraction, and in situ immobilization. Process monitoring and control technologies will be developed for the specific remediation technologies developed under the ISR IP to ensure that technical and regulatory requirements of the end user are satisfied.

In Situ Destruction Technologies. Biological, chemical, and thermal technologies will be reviewed, and the R&D activities required to support demonstration of these technologies for the destruction of organics and nitrates will be identified. Special emphasis will be placed on the treatment of these contaminants in the presence of radionuclides and heavy metals. The goal is to develop technologies that will reduce toxicity through destruction of contaminants without adversely impacting the environment. Technologies under consideration include, but are not limited to, in situ bioremediation, in situ chemical oxidation, and in situ electrochemical oxidation.

The ISR IP will be investing in R&D activities associated with in situ bioremediation. This technology area relies on the transformation of organic contaminants either under aerobic or anaerobic conditions for the cleanup of the vadose zone and groundwater. The emphasis will be on the stimulation of indigenous micro-organisms for the degradation of the organic contaminants. The R&D activities will provide data to support the demonstration of this technology at two DOE sites for the cleanup of volatile organics in the vadose zone and in the groundwater. This technology has broad application to contaminated soils and groundwater throughout the DOE system, and to organic contamination in buried waste and explosives associated with detonation sites.

Research and development activities for other in situ destruction technologies will be evaluated and investments will be determined in FY 1992.

In Situ Removal and Extraction Technologies. This program area will review physical methods that can be enhanced by thermal, chemical, or biological subsurface treatments to extract contaminants from the subsurface for their destruction or immobilization in above-ground treatment facilities. R&D activities required to support demonstration of these technologies will be identified. The emphasis will be placed on the extraction of radionuclides from soils and on the extraction of mixtures of mobile organics and metals from soils. The goal is to develop technologies that will reduce toxicity by removing contaminants from the affected environment to meet acceptable levels. Technologies under consideration include, but are not limited to, in situ soil flushing, vapor extraction, dynamic steam stripping, in situ heating, and electrokinetics.

The ISR IP will be investing in R&D activities in the area of electrokinetics. Electrokinetics refers to processes that use a direct electrical current to achieve the separation of contaminants and/or water from soil (and sludge) by causing the water and contaminants to flow between the electrodes. This technology has application to the separation of heavy metals and radionuclides, such as uranium and strontium, from contaminated soils.

Research and development activities for other enhanced in situ removal and extraction technologies will be evaluated and additional investments will be determined in FY 1992.

In Situ Immobilization Technologies. This program area will focus on 1) thermal or chemical methods that immobilize contaminants and soils matrices in a waste form created in place, and 2) biological or chemical methods that can alter redox conditions in soil or groundwater to chemically immobilize the contaminants. The goal is to develop technologies that will reduce the exposure hazard by immobilizing contaminants within the environment. The technologies under consideration include, but are not limited to, in situ precipitation, in situ redox manipulation, in situ solidification, and in situ grouting.

Investments in this program area have not been finalized at this time. Technologies developed in this program area can be linked to all of the problem groups identified previously.

Containment Technologies

This program area will evaluate physical techniques that will isolate or contain contaminants in a defined zone prior to treatment and/or during treatment. The focus will be on four areas: 1) the remediation of heterogeneous waste sites such as landfills, inactive burial trenches, and surplus facilities; 2) the closure of engineered waste systems such as grout vaults and active burial trenches; 3) interim containment to "leaking structures"; and 4) the surface control of contaminant dispersal during in situ remediation. The goal is to develop physical systems to prevent offsite dispersal of contaminants into the environment through air, surface water, or groundwater pathways. The technologies under consideration include, but are not limited to, hydraulic isolation, cryogenics, in situ grouting technologies, vitrified subsurface barriers, and the permanent isolation barrier system. Process monitoring and control technologies will be developed for the specific remediation technologies developed under the ISR IP to ensure that technical and regulatory requirements of the end user are satisfied. Investments in R&D activities for this program area have not been finalized.

Subsurface Manipulation

This program area will evaluate physical systems that can be used to avoid dispersal of contaminants, in addition to being used for the dispersal of treatment agents during in situ remediation processes. These systems must be compatible with in situ remediation processes. This program area will cross-cut the treatment and the containment technologies, as many of the physical systems can be used for technologies in each program area. The goals are to develop physical containment systems to assure that adequate control of the subsurface remediation process is maintained. Technologies under consideration include, but are not limited to, electrokinetic migration of contaminants, hydraulic isolation, auger or jet mixing, hydro- or cryofracturing, and vacuum-vaporizer well systems. Investments in this program area have not been finalized.

INTERFACES

A primary emphasis of the ISR IP is the establishment of interfaces and the coordination of the development and demonstration of ISR technologies. The ISR IP will establish interfaces with the fundamental R&D organizations and the clients. Figure 2 depicts the interfaces and clients. Basic R&D provides for the advancement of fundamental knowledge and the discovery of new concepts and principles. The ISR IP will link with the fundamental R&D organizations to promote the transfer of knowledge for focusing applied R&D activities and extending the application of the technology. Technical issues requiring fundamental R&D efforts will be identified by the ISR IP and discussed with the appropriate organization for resolution. The ISR IP will also interact with other organizations and/or programs that are conducting applied R&D to minimize duplication of effort and identify technology gaps. The ISR IP has three primary clients: the IDs, the Office of Environmental Restoration, and the Office of Waste Operations. Problem descriptions and technology functional requirements will be identified for each of the clients and used to determine the program areas for initiation of R&D activities. The ISR IP will provide the clients with developed technologies for demonstration.

CONCLUSIONS

The ISR IP was initiated in FY 1991 and is progressing through the planning stages. As described earlier, the ISR IP currently plans to invest in the development of in situ bioremediation for the cleanup of volatile organics in the vadose zone and in groundwater, and in R&D activities to support the development of electrokinetics. Additional investment decisions will be made as a result of convening technical support groups to evaluate and recommend R&D activities for other in situ remediation technologies.

The major activities for this fiscal year include the overall planning for the ISR IP. A five-year program plan to be prepared later this year will establish the long-term goals for the program. To support the preparation of this plan, interfaces with the integrated demonstrations, environmental restoration and waste operations have been formed to assure that the R&D activities are focused on the priority problem descriptions and technology needs.

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(1) Chem-Nuclear Geotech, Inc. 1991. Technology Needs Assessment - Final Report. DOE/ID12584-92. Prepared for the Office of Environmental Restoration by Chem-Nuclear Geotech, Inc. Grand Junction, Colorado.

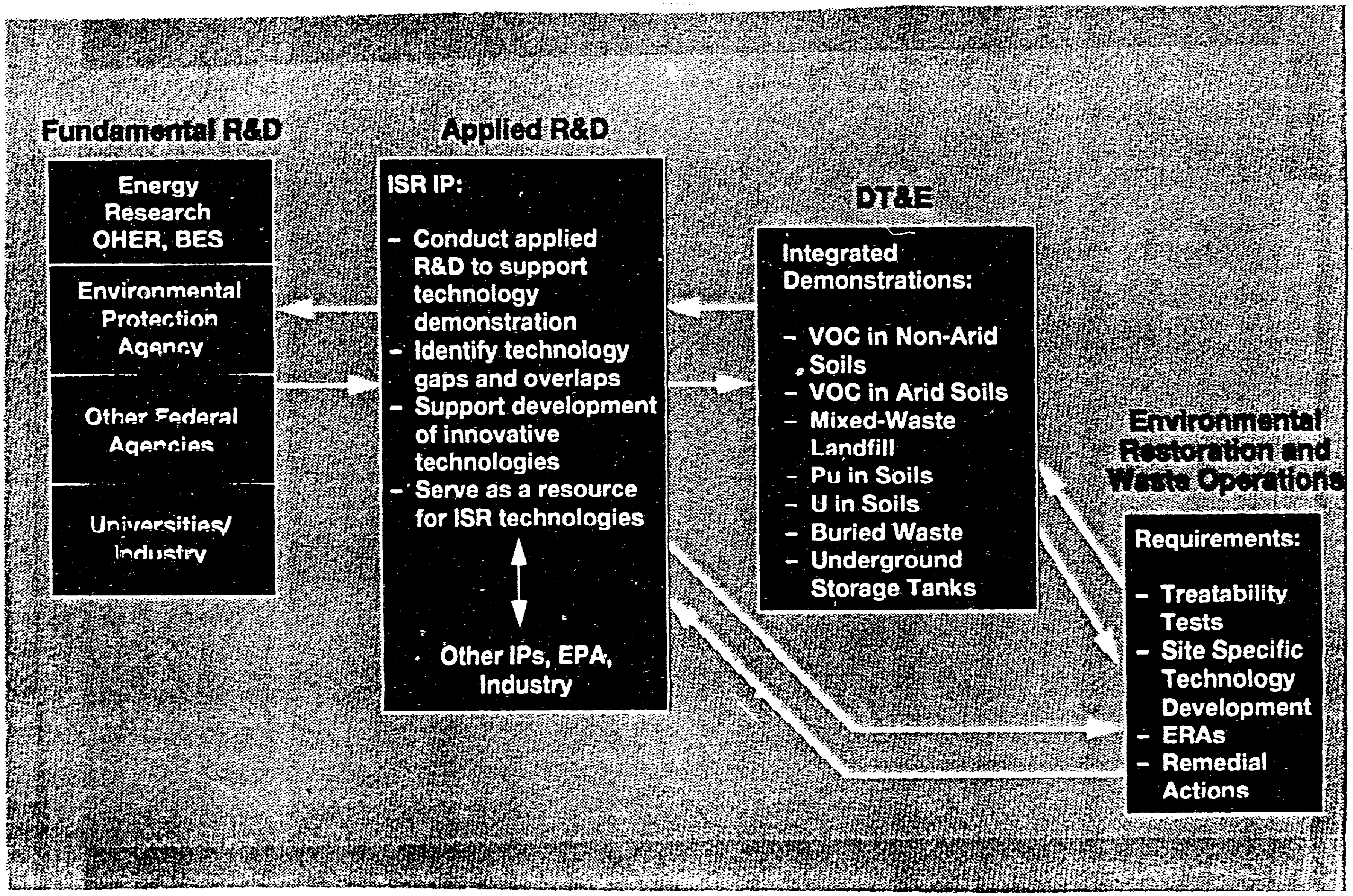

FIGURE 2. Interfaces and Clients for the In Situ Remediation Integrated Program

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