

# CROSS-CUTTING TECHNOLOGY SUPPORT THROUGH A FOCUSED PROGRAM OF APPLIED R&D FOR ROBOTICS

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## ABSTRACT

In August 1989, the Department of Energy (DOE) Office of Environmental Restoration and Waste Management (ER&WM) published the ER&WM 5-Year Plan, including a section covering applied research and development (R&D). Later, in November 1989, DOE issued a draft Applied Research, Development, Demonstration, Testing, and Evaluation (RDDT&E) Plan to expand on the applied R&D section of the original plan.

Now, a Robotic Technology Development Program (RTDP) 5-Year Plan further describes--and extends--the robotics RDDT&E activities identified in the RDDT&E Plan. The RTDP 5-Year Plan is based on an evaluation of site needs documented in (1) a draft Site Needs & Requirements Document and (2) the Robotics Technology Development Plan, which details the applied RDDT&E needed to develop and deploy robotic systems to meet site needs.

## INTRODUCTION

**Plan Scope:** The RTDP 5-Year Plan covers robotics RDDT&E activities in the Program for the next five years. These range from bench-scale R&D to full-scale hot demonstrations at DOE sites. Within the five-year time frame, this plan outlines applications of existing technology to near-term needs, the development and application of enhanced technology for longer-term needs, and an initiation of advanced technology development to meet those needs beyond the five-year plan.

**Program Objective:** The objective of RTDP is to develop and apply robotics technologies that will enable ER&WM operations at DOE sites to be:

- Safer Reduced worker exposure and increased safety through remote operation and control of equipment,
- Faster Increased speed and productivity for ER&WM operations through enhanced capabilities and automation, and

- Cheaper Faster, more productive systems resulting in quicker completion of remediation operations that, in turn, reduce life-cycle costs.

**Robotics Defined:** In the Plan the word "robotics" spans a broad range of technology ranging from manual and remotely operated systems to advanced and autonomous robots. The category includes master-slave manipulators, electromechanical manipulators, servomanipulators, remotely operated heavy equipment (e.g., bridge cranes, excavators, etc.), special remote tooling, and industrial-type programmable robots, as well as autonomous robots. Also included are mobile platforms and transporters, sensing systems, and control systems.

A broad definition of "robotics" has been used in program planning to ensure no elements of remote technology and robotics are overlooked in selecting the appropriate technology to meet diverse site needs. In most cases, the "robotics" technology applied to a given need will include elements from several of the categories listed. In addition, the Program will rely on existing remote technology, where available, with some robotics development activity to meet near-term site needs. Technology for future applications

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will move increasingly toward robotics with autonomous capabilities.

**FY 1990 Accomplishments:** The RTDP accomplished a number of significant activities in FY 1990 which facilitated a fast start for robotics technology development and established a sound basis for program activities over the next five years.

**Program Planning:** Five priority DOE sites were visited in March 1990 to identify needs for robotics technology in environmental restoration and waste management operations. The 5-Year Program Plan for the RTDP was prepared on the basis of the needs identified at the DOE sites and provides a needs-based road map for detailed annual plans for robotics technology development.

**Initiating Interactions with the Robotics Technology Community:** In July 1990 a forum was held announcing the robotics program. Over 60 organizations (industrial, university, and federal laboratory) made presentation on their robotics capabilities.

**Technology Demonstrations:** To stimulate early interactions with the ER&WM activities at DOE sites, as well as with the robotics community, the RTDP sponsored four technology demonstrations related to ER&WM needs. These demonstrations integrated commercial technology with robotics technology developed by DOE in support of areas such as nuclear reactor maintenance and the civilian reactor waste program.

Rapid swing-free movement of simulated waste containers was demonstrated using control algorithms developed at Sandia National Laboratories (SNL) with technology in computer control of large gantry bridges at Oak Ridge National Laboratory (ORNL). This technology decreases the time for materials movement and increases safety by eliminating the potential for collisions of swinging payloads.

A scaled waste tank remediation demonstration at SNL integrated sensors and advanced computer control into a commercial gantry robot. The extensive use of models for robot system control allowed graphical programming of the system complete with operator-supervised path planning to increase speed of repetitive waste removal tasks.

A teleoperated vehicle with advanced sensing technologies for mapping of buried waste sites was demonstrated at a small buried waste site at ORNL. Navigation technologies were coupled with the sensing information (from radiation, gas, and subsurface large object sensors) to automatically map subsurface materials.

A team consisting of LLNL, SNL, LANL, SAIC, and IBM demonstrated a robotic system for loading powder into a furnace in a plutonium production line and then transferring the product to the next operation in a mock-up facility.

This robotic system eliminates the need for operator hands-on transfer operations and reduces the generation of operator-associated waste materials such as wipes, protective clothing, gloves, and transfer bags.

## PROGRAM ORGANIZATION

The RTDP is an element of DOE's ER&WM Applied RDDT&E Program. It is administered by ER&WM's Office of Technology Development (OTD) through the Robotics Program Manager (RPM).

The RPM is responsible for formulating, implementing, updating, and evaluating the RTDP. To discharge this responsibility, the RPM has the authority to allocate available resources for RDDT&E of robotics technologies for the OTD within DOE's Office of Environmental Restoration and Waste Management.

The RPM is responsible for ensuring that RTDP draws on existing expertise both inside and outside the DOE complex. The RPM also initiates basic R&D, as appropriate, to meet the RTDP objectives. Participation will be based on technical capabilities and the needs of the program.

The Technical Program Officer (TPO) Review Group (RG) is chaired by the RPM at DOE Headquarters. The TPO-RG is composed of the TPO from each of the eight DOE Field Offices or a designated site representative. The TPO-RG is charged with providing information for, and participating in, the development of the Plan's technical requirements and schedules.

The Technical Review Group (TRG), which is chaired by the RPM, is composed of technical experts from DOE national laboratories and field sites, prime contractors, private industry, universities, and other federal agencies. It is charged with evaluating RDDT&E proposals submitted to the PRM and to recommend to the RPM resource allocation among robotics application areas.

A Robotics Applications Coordinator is appointed for each robotics application area reporting to the RPM. This person is responsible for coordinating the flow of technical information relevant to the applications area among those groups having an interest in the area. The coordinator is responsible for keeping the other groups (in the relevant applications areas) apprised of the results of RTDP-funded activities in that area. The coordinators function as advocates for the technologies applicable to their particular problem area. To facilitate application of the best technology (with a high probability of success) to the particular problem area, the coordinators actively solicit proposals from the entire robotics and automation community for routing to the RPM. A thorough familiarity with ER&WM problems and issues will be required of the coordinators

and maintained through site visits, personal contacts, and symposia where appropriate.

The Advanced Technology Coordinator (ATC) reports to the RPM. This person is responsible for coordinating the flow of technical information other than applied research. Areas of future need in robotics and ancillary systems that are not already being addressed in the applied R&D areas are identified by the ATC. The ATC is responsible for working with DOE national laboratories and field sites, prime contractors, private industry, universities, and other Federal agencies to bring proposals for needed advanced technology to the attention of both the TRG and RPM.

### SITE VISITS/NEEDS

In March 1990, RTDP planning teams visited five DOE sites. Additional site visits will be conducted in the future to expand the planning basis.

The purposes of these visits were (1) to understand the needs and requirements of the highest priority environmental restoration projects and waste management operations at the sites, (2) to obtain information for use in planning the Program, and (3) to describe the RTDP to personnel at the site and discuss development of the program plan. Emphasis was placed on both technical and scheduler (i.e., compliance dates) needs and requirements.

An overview of the findings from these site visits is provided in the following pages.

### APPROACH TO NEEDS DIRECTED TECHNOLOGY DEVELOPMENT

The visits to five DOE sites led to selection of six areas of need for robotics technology to support ER&WM activities. These need areas are:

- Remediation of waste storage tanks,
- Retrieval of buried wastes,
- Automation of contaminant analyses,
- Waste minimization,
- Decontamination and decommissioning, and
- Waste facilities operations.

Plans for development and application of robotics technology are based on the need areas listed above. In addition, the plans reflect other aspects of needs at the sites such as regulatory compliance dates, planned remedial actions, and established schedules.

The fundamental approach to developing robotics technology to meet these needs couples available and emerging technology with advanced technology. Near-term needs can be met by integrating available commercial technologies with emerging technologies available in R&D lab-

oratories. At the same time, development of advanced technology will proceed to meet intermediate and long-term needs. In addition, attention will be given to development of cross-cutting technology which will be applicable to multiple need areas. Technology development will be keyed to integrated demonstrations at the DOE sites to further couple the robotics technology development to the site needs and to the deployment of remedial actions technology.

### APPLICATION-SPECIFIC TECHNOLOGY DEVELOPMENT

This 5-Year Plan addresses robotics technology development and applications for the six need areas. The DOE sites are evaluating alternative approaches to remedial actions. The robotics technology developed for each application must meet the needs and match the approach selected by each site. The plans described for robotics technology development are based on reference concepts, selected as reasonable and likely concepts from the alternatives, which form the basis for identifying needed technology development, estimating schedules, and estimating budgets. The robotics technology development plans are also keyed to demonstrations of technology at the DOE sites. Wherever possible, demonstration of the robotics technology will be integrated with larger integrated remediation technology demonstrations.

### CROSS-CUTTING AND ADVANCED ROBOTIC TECHNOLOGY DEVELOPMENT

Near-term applications of robotics to ER&WM activities will necessarily be focused on existing technologies that can be readily adapted to the specific cleanup tasks and environments. As the DOE cleanup activities progress and evolve, a larger body of robotic technology will be needed for application to ER&WM projects. A technology development program targeted at relevant cross-cutting and advanced technology development will make possible a more rapid insertion of beneficial technology into these activities. This technology development will be focused on high payback projects that offer safer, faster, or cheaper approaches to cleanup goals.

An advanced technology development program including a long-term R&D component is a means to effectively incorporate the expertise of the universities, national laboratories, and other basic research organizations into the nation's cleanup projects. Also, this offers educational training opportunities consistent with the DOE emphasis on developing the next generation technical work force.

Needs identified at DOE sites indicate that cross-cutting and/or advanced technology development in the areas listed below would be highly beneficial to application of robotics in ER&WM activities:

- Mechanical Subsystems
  - Manipulators
  - End-Effectors
  - Mobile Systems
- Control Subsystems
  - Computing, Graphics, and Modeling
  - Man-Machine Interfaces
  - Communications
  - Telerobotic Operations
  - Motion Planning and Control
- Sensor Subsystems
  - Environmental Sensors
  - Servo Mechanical Control Sensors
  - Imaging & Vision Systems
  - Multi-Sensor Integration

Cross-cutting and advanced technology developments need to focus on near-term, mid-term, and long-term implementations. By investing in a sustained long-term development program emphasizing a balanced evolution in technology development with implementations continually

encompassing technology advances, steady progress may be assured toward the technology required for the more complicated or demanding tasks of the decades to come. Development of advanced robotics technology that is commonly applicable to many environmental restoration, waste management, and waste minimization activities can lead to higher efficiency, increased reliability, and reduced life cycle costs in these operations.

#### REFERENCES

1. Department of Energy Environmental Restoration and Waste Management Robotics Technology Development Program Robotics 5-Year Program Plan Volume I Executive Summary, in preparation.
2. Department of Energy Environmental Restoration and Waste Management Robotics Technology Development Program Robotics 5-Year Program Plan Volume II Program Plan, in preparation.
3. Department of Energy Environmental Restoration and Waste Management Robotics Technology Development Program Robotics 5-Year Program Plan Volume III Site Needs and Requirements, in preparation.