Remote Technology for Facility Deactivation and Decommissioning at the Oak Ridge National Laboratory - 8168

P.A. Shoffner, L. E. Lagos, J. Varona
Applied Research Center, Florida International University
10555 West Flagler Street, Suite 2100, Miami, FL 33174

J. A. Faldowski, D. Vesco
NuVision Engineering, Inc.
184B Rolling Hill Road, Mooresville, NC 28117

ABSTRACT

The facilities at the Oak Ridge National Laboratory (ORNL) that will undergo deactivation and decommissioning (D&D) over the next several years include highly contaminated hot cell facilities, reactor facilities, process facilities, and a variety of other buildings. The D&D effort will require physical, chemical, and radiological characterization as well as decontamination, material sorting, size reduction, dismantlement, and waste removal and packaging. D&D planning for ORNL facilities includes recognizing that a significant number of the facilities contain hazards that prevent the use of safe manual D&D techniques. These hazards include seriously deteriorated structural integrity as well as very high dose rates (some in the hundreds of R/hr). The hazards also include high levels of fixed and removable radioactive contamination on facility surfaces and in equipment as well as chemically hazardous materials. Thus, manned entry may be highly restricted. In these situations, remotely operated technologies will be required to complete the necessary D&D activities, minimize dose and protect workers.

To prepare to use remote technologies, it is first necessary to understand the tasks typically required to complete D&D of these facilities as well as the availability, applicability, and sustainability of previously deployed remote technologies. Technologies of specific interest included remote inspection, characterization, decontamination, and dismantlement. The Applied Research Center (ARC) at Florida International University (FIU), in partnership with NuVision Engineering (NVE, formerly AEA Technology), assessed the requirements for remotely operated technologies to support D&D at ORNL. FIU-ARC and NVE then identified existing technologies that can meet the expected requirements and performed a gap analysis between the D&D needs and currently available technologies.

INTRODUCTION

For many years, the Department of Energy (DOE) has operated facilities housing nuclear reactors, process systems, and radioactive materials handling equipment. Many of these facilities required remote handling and remotely operated equipment (e.g. master-slave manipulator or MSM) for day-to-day operations and routine maintenance activities. Over the past few decades, many of these facilities have been taken off-line as a result of changes in scientific and/or military interests. This change in laboratory mission within the DOE complex, along with other developments such as aging facilities that have reached the end of their operating life, has led to increased activity to deactivate and decommission (D&D) surplus and antiquated facilities thereby reducing ongoing surveillance and maintenance costs. Many such facilities exist at ORNL and are currently or will soon undergo D&D.

Facilities that will undergo D&D include highly contaminated hot cells, reactor pools, and a variety of other buildings and process systems. At least some of the facilities contain hazards preventing the use of manual D&D techniques whereby workers perform characterization, decontamination and material

removal by hand. Such hazards include highly contaminated hot cells with both fixed and loose contamination in the hundreds of R/hr, high activity waste that is classified as remote handled (RH), and chemically hazardous mixed waste. D&D of these facilities will require physical and radiological characterization, decontamination, material sorting, size reduction, waste packaging, and possibly spent fuel management. In many cases, as-built drawings of the facilities undergoing D&D do not exist and radiological characterization data is limited. Manual characterization of the subject facilities may prove difficult, costly and time consuming. Knowledge of the physical configuration and contaminant levels within facilities is essential for comprehensive work planning and also to minimize the potential risk to workers and the environment. Because of the potential for high radiation fields and volatile agents that restrict manned entry, many of these activities will require remote operations. Remote technologies have proven in the past to be effective at providing the necessary characterization data that is essential for work planning, ALARA planning, cost estimating, and worker training prior to D&D activities.

Remotely operated technologies have further proven to be an effective means of protecting workers and minimizing dose in hostile environments during D&D activities. While much of the waste material is located in facilities originally fitted with remote operation capability, much of the equipment is no longer functional. Further exacerbating the problem is that some of the more problematic waste may not be adequately characterized to allow for disposal planning which will ensure worker safety. These factors have led to the conclusion that remotely operated technologies will be required to complete the D&D actions safely and effectively.

NVE and FIU-ARC have assessed the requirements for remotely operated systems to support D&D at ORNL, specifically as they pertain to hot cell, process, and reactor facilities. These requirements have permitted the identification of technologies that have been used in the past or have been recently developed to meet the expected requirements. In cases where no applicable technology exists to meet the D&D need, these technology gaps have been identified.

MATERIALS AND METHODS

The project scope was to assess the requirements for remotely operated technologies to support D&D at ORNL, identify existing technologies that can meet the expected requirements, and identify any gaps between the requirements and the currently available technologies. The key steps in completing this scope of work were:

1. Selection of typical ORNL facilities that are scheduled for D&D and that represent difficult sites in each of three major categories (hot cell, process, and reactor facilities).

2. Survey of the selected facilities making use of existing data and collecting additional data where needed.

3. Determination of typical D&D tasks/activities which may benefit from remote operations.

4. Review of existing applicable technologies.

5. Identification of technology gaps.

FIU-ARC participated in the delivery of this scope of work by reviewing facility data collected by NVE, identifying D&D tasks for each facility reviewed, and identifying remote technologies that exist within the DOE Environmental Management Program that may meet D&D needs. To fulfill these tasks, FIU FIU-ARC relied heavily on past successful D&D activities in support of DOE-EM programs. This

included the search for D&D remote technologies using FIU-ARC's D&D databases containing D&D technology information (performance, cost, and ES&H) on over 3,000 D&D technologies. FIU-ARC also reviewed and compiled technical information on technologies under DOE's Office of Science and Technology (OST) databases.

Throughout the project, NVE was primarily responsible for interfacing with ORNL personnel to ensure the outcome of the scope of work meets site needs, collecting facility data from ORNL, identifying remote technologies that exist outside the DOE Environmental Management program that may meet D&D needs and planning to fill identified remote operations technology gaps. To fulfill this task, NVE relied on past successful applications of remotely operated systems. NVE have led technology development for D&D and Tank Clean-up at multiple DOE sites including the successful design, build, and deployment of robotic systems and remotely operated equipment.

A kickoff meeting was held in Oak Ridge on Feb. 11, 2006 to discuss the project and the final output with site personnel. The following methodology was agreed at that meeting.

1. Selection of typical facilities that will be part of the ORNL central campus D&D plan that represent difficult or typical sites to be D&D. These sites were first identified in the project technical plan and reviewed at the kickoff meeting. Following the meeting, a facility list was generated and is discussed in more detail below. This list served as the baseline for the evaluation.

2. Survey of the selected sites using existing characterization data or collecting the data through interviews and walk downs. Many of the facilities had been walked down previously; hence, there was a body of existing documentation. The project made use of this data wherever possible and conducted additional walk downs and literature searches as necessary where adequate information was lacking.

3. Determination of typical activities or tasks that must be performed and may benefit from the use of remote operations during the D&D process. NVE relied on its knowledge of D&D gained by past experience, drew on existing Oak Ridge plans, and partnered with FIU-ARC to identify the common D&D tasks for the typical facilities selected. No recommendations regarding the best practices for specific D&D tasks or comment on the effectiveness of proposed D&D approaches have been made.

4. Identification and review of existing technologies capable of performing the required D&D tasks at ORNL, either within DOE or commercially. Each identified existing technology was evaluated via desk review in light of the current state of the art and the understood need.

5. Identification of any gaps between technology needs and the existing available technologies. Although much technology development has been done in the past, the current state of the art has progressed such that previously employed remote operations may no longer be the safest, most cost effective means to achieve the latest D&D goals.

The assessment focused on the following sites as typical of those at ORNL that may benefit from the use of remote operations during D&D:

- Reactor facilities
  - Oak Ridge Research Reactor (Bldg 3042)
  - Graphite Reactor (Bldg 3001)
- Process facilities
  - Radiochemical Development Facility (Bldg 3019A)

    - High Level Radiation Analytical Lab (Bldg 3019B)
- Hot cell facilities
    - Irradiated Fuels Examination Laboratory (Bldg 3525)
    - Fission Product Development Laboratory (Bldg 3517)

Information inputs/sources to the project included the information from the kick off meeting as well as additional sources including the internet, universities, other government agencies, and other nuclear laboratory sites as deemed appropriate.

For each facility type assessed, a beginning assumption was made that the general steps in the D&D process include:

- Characterization (e.g., preliminary, operations support, post cleanout)
- General decontamination (e.g. fixatives, scrubbers, scrabbling, strippable coatings)
- Waste removal and packaging (e.g. size reduction, super compaction, loading/conveying, pick and place of materials)
- Facility dismantlement (e.g. equipment removal, removal of the structure)

To support this assessment, FIU-ARC performed a literature search for relevant and supportive reports and other documentation to supplement the facility data collected and supplied by NVE. FIU-ARC identified typical D&D tasks for each facility reviewed and identified remote technologies that exist within the DOE Environmental Management (EM) program to meet the future D&D needs. FIU-ARC then relied on previously successful D&D activities in support of DOE EM programs to identify applicable remote technologies. This included searching over 3,000 D&D remote technologies using FIU-ARC's D&D technology databases (www.dandd.org) containing information on performance, cost, and environmental safety and health factors. FIU-ARC also reviewed and compiled technical information on technologies utilizing the DOE Office of Science and Technology's (OST) Information Bridge databases.

NVE provided project management for the assessment effort, including developing the scope of work, providing project controls, providing the primary site and customer interfaces, and leading final report assembly. NVE also supplemented FIU-ARC technology research by utilizing its past experience in successful D&D work as well as searching for commercially available and emerging technologies. Once the data from both the FIU-ARC and NVE research was compiled into the final report, a gap analysis was conducted between the anticipated needs for remotely operated technologies and available technologies to meet those needs.

RESULTS AND DISCUSSION

The results of this assessment was a detailing of the D&D tasks for each of the facility types that would benefit from the use of remotely operated technologies and a detailed matrix summarizing the available technologies applicable to remote D&D activities, including remote inspection, characterization, decontamination and dismantlement. The benefits from the project include providing DOE with the information necessary to complete D&D safely and effectively with remotely operated technologies for facilities containing hazards preventing the use of safe manual techniques. In addition, the gap analysis identifying where an existing technology does not exist for a specific D&D need provides the basis for further planning and technology development. Finally, by providing a thorough understanding of the

existing technologies and the technical approaches used during past D&D projects, the assessment can reduce the future cost, schedule, and safety risks for similar work at ORNL and elsewhere within the DOE complex.

Summary of Remote Operations Required for Hot Cell Facility D&D

Based on the review of buildings 3517 and 3525, several activities related to D&D of hot cell facilities will benefit from the use of remote technologies. Specifically, these include:

- Visual inspection capability to view interior parts of the hot cells that are either not viewable from the viewing windows or where viewing windows are no longer transparent.
- Dose rate surveys in non-accessible areas of the facility, including hot spot identification. (Note: reasons identified for area inaccessibility were high radiation fields, high CO_2 levels, or degraded structural integrity of the building)
- In-situ gamma spectroscopy for isotope identification to support sorting and segregating activities.
- α radiation detection/spectroscopy for sorting and segregating of TRU materials to minimize TRU waste disposal quantity.
- Sampling technologies for remote sampling of liquids, loose materials, and surface smear samples.
- Hazardous materials (e.g. asbestos, PCB, lead) detection capability to isolate and minimize mixed waste disposal quantity.
- Pick-and-place capability for sorting, segregating and packaging waste materials prior to removal from the hot cell. Likely to require heavier duty than in-cell MSM's are capable of providing.
- Cutting or other size reduction technologies to support packaging of materials prior to removal from the hot cell.
- Dismantlement technologies for final demolition of hot cell structures prior to final building demolition, especially in cases where degraded structural integrity is an issue.

Summary of Remote Operations Required for Process Facility D&D

Based on the review of buildings 3019A and 3019B, several activities related to D&D of process facilities will benefit from the use of remote technologies. These include all of the applications previously identified for hot cell facilities and the following additional applications:

- Inspection technologies for investigation of pipes and ducts. Inspection may include visual inspection, liquid detection, and sample/smear collection.
- Dismantlement technologies for size reduction and packaging of glove boxes, including the debris inside the glove boxes.
- Hazardous materials detection, including perchlorates.
- Perchlorate neutralization or removal.
- Large area decontamination due to pervasive plutonium contamination.

Summary of Remote Operations Required for Reactor Facility D&D

Remote operations may be a critical aspect of a typical reactor D&D, however, evaluation of Building 3042 at ORNL reveals that the vast majority of the Curie content has previously been removed. The remaining Curie content is contained in the highly activated components in the ORRR pool. Segmentation and packaging of these metal components will require remote technologies, including underwater cutting, handling, and packaging. Once the water is drained from the pool, remote

technologies may be useful if pool appurtenances (e.g. beam tubes, drains, etc.) have become contaminated or activated.

Summary of Available Remote Technologies Required for Facility D&D

A detailed matrix of available remote technologies for facility D&D applications was compiled in the full project report [1]. Ninety-six technologies were listed and described for the areas of characterization, decontamination, manipulator systems, vehicle systems, tooling, and other technologies. For each remote technology, the matrix included a technology description, previous applications and results, benefits, limitations, potential applications at ORNL, vendor contact and website information, and a photograph of the technology. This level of detail is beyond the scope of this paper to include but a sample of available technologies is included in Table I.

Table I. Selection of Available Remote Technologies

Technology	Description	Application at ORNL
Gamma Rover Crawler (Grover)	A remotely-operated, mini-tracked crawler to obtain visual characterization and dose profiling date in contaminated ventilation ducting that exhausts air from hot cells.	Characterization - HVAC and large piping, hot spot identification
Remote Characterization System (RCS)	A Remotec Andros Mark VI with cameras and lights, modified to incorporate a gamma detector, a smear sample pad, and a deployment station.	Characterization - process cell inspection, hot cell inspection
Remote Underwater Characterization System (RUCS)	A small remotely operated submersible vehicle.	Characterization - fuel pool inspection, underwater inspections, confined space inspections
WallWalker	Resembles a giant wall-sized plotter that is configurable for scabbling operations, hydroblasting, and other cleanup applications	Decontamination - all three facility types where concrete wall surfaces need decontamination.
Climbing Machine with Mechanical Abrader	Held to surface by vacuum force, the machine adheres to essentially any hard surface: metal, concrete, brick, etc.	Decontamination - all three facility types for decontamination of floor, wall, and ceiling surfaces.
Robotic Climber H-1 Model	A free-climbing robot using ultra high pressure water jetting within a contained vacuum shroud for surface decontamination, coating removal, and concrete scabbling.	Decontamination - all three facility types for decontamination of floor and wall surfaces.
Dual Arm Work Platform Teleoperated Robotics System	Manipulates standard tools (i.e., circular saws, jackhammers, etc.) to perform mechanical dismantlement of radioactive structures.	Manipulator system - dismantlement of hot cell internal components
Cybernetix Robotic Work Platform	A robotic work platform that can manipulate tools (grippers, impact wrenches, shears, saws, pipe cutters, grinders, sensors, etc.) to provide remote access to hot cell floors, walls, ceilings, and below-grade pits.	Manipulator system – highly contaminated hot cells, removing equipment, size reduction, sorting/segregating, initial decontamination efforts for metal and concrete surfaces.

PERCHE: underwater pool manipulator	Designed to pick-up and move objects, carry out remote inspection to a depth of 20 feet, and can be used as a carrier for special tools.	Manipulator system - fuel pool inspection and clean out.
Mobile Work Platform	Four-wheel chassis with a multi-articulating folding main boom and 360-degree rotating turret assembly. End effectors can grab, hold in place, crimp, and shear.	Vehicle system - dismantlement/demolition of structures, piping removal
Houdini	Bulldozer-like mobile robot able to perform a variety of tasks.	Vehicle system - size reduction of equipment, tank, piping, and utility and debris removal
Mobile Robot Worksystem (Rosie)	Tethered 50-m robotic system controlled via teleoperation to perform mechanical dismantlement of structures by remotely deploying tools or systems.	Vehicle system - dismantlement/demolition of structures, piping removal and utility removal
Gripper: Handling Tool	Grips by means of 2 parallel jaws.	Tooling - removal of inventory waste and tools, debris, small objects
UHPT tools	Performs remote decontamination with ultra-high-pressure water jet.	Tooling - decontamination of metal and concrete surfaces
Plasma arc cutter	Provides cutting capacity	Tooling - equipment size reduction
Cartogam Gamma Camera (GammaCam)	Relatively small/light-weight real-time gamma camera that provides two-dimensional mapping of gamma emitting sources	Other - gamma emitting source identification
Niton Analyzer 700	Uses x-ray fluorescence spectrum analysis to identify and quantify elements in metal.	Other - identification and characterization of surfaces containing lead paint
SPCETRO XEPOS	An x-ray fluorescence spectrometer to detect elements ranging from sodium to uranium.	Other - analysis and characterization of PCBs

Summary of Identified Gaps in the Available Technologies

The technologies in the previous section cover the majority of the activities needed to complete the D&D of the facilities. However, several technology gaps were identified where a need exists for a remotely operated technology but no technology was found to meet the specific need. These gaps include:

- Technologies for sampling liquids left in various containers in the facilities.
- Adaptation of sensor technologies for remote deployment that have the ability to detect NOx, CO2, asbestos, PCB's, perchlorates, beryllium, and other hazardous substances.
- A single D&D workstation that incorporates tools for multiple common D&D tasks.
- Technologies for the application and removal of strippable coatings.
- Technologies for perchlorate neutralization and removal.

CONCLUSION

Planning for the D&D of facilities at ORNL includes recognizing that a significant number of the facilities contain hazards that prevent the use of safe manual D&D techniques. These hazards include seriously deteriorated structural integrity as well as very high dose rates (some in the hundreds of R/hr), high levels of fixed and removable contamination on/in facility surfaces and equipment, and chemically

hazardous materials. In these situations, remotely operated technologies will be required to complete the D&D safely and effectively. FIU-ARC and NVE have successfully assessed the requirements for remotely operated systems to support D&D at ORNL, identified technologies that have been used in the past or been recently developed to meet the expected requirements, and identified areas where there is a gap between the needs and the existing technology.

REFERENCES

1. *ORNL Remote Operations for D&D Activities Final Report*, AEA Technology Engineering Services, Inc., December 2006.