ORNL Remote Operations for D&D Activities
Final Report

Prepared for
US DOE

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Page 1 of 116

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NuVision Engineering, Inc.
Executive Summary

Increased emphasis continues to be placed on deactivation and decommissioning (D&D) of unnecessary and/or unusable facilities across the DOE complex. Many of these facilities pose hazards which prevent the use of traditional industrial demolition techniques. Such hazards include radiological, chemical, and hazardous materials contamination and structural instability. Efficient and safe D&D of the facilities will almost certainly require the use of remotely operated technologies, many of which have been developed and used successfully in the past.

NuVision Engineering (NVE) and Florida International University – Applied Research Center (FIU-ARC), have conducted an assessment of several facilities slated for D&D at the Oak Ridge National Laboratory (ORNL) with a view toward understanding what likely D&D operations will require remotely operated technologies to complete. These facilities include hot cell, process, and reactor facilities that have become substantially contaminated and, hence, represent challenges for future D&D.

The assessment began with a review of existing characterization data from buildings 3019A, B, 3517, 3525, and the Oak Ridge Research Reactor. From this review, many hazards were identified that cause the D&D effort to be challenging. These include areas of high radiation dose rate in the 10’s to 100’s of R/hr, high radiation contamination areas, chemical contamination such as perchlorates, PCB’s, beryllium, and lead, asbestos building materials, degraded building structural integrity, and atmospheres not suitable for human habitation due to high levels of CO2. Any one of these hazards may justify the use of remotely operated D&D technologies, but in many cases these hazards exist in combinations of two or more.

The characterization data was then compared against a list of typical D&D actions to identify the most challenging tasks to be undertaken as the facility is D&D. These actions were then compared against current and past remotely operated technologies that have been used either in the DOE complex or elsewhere in industry. The remotely operated technologies were tabulated with a brief description of the technology, the previous applications, the benefits and limitations of the technology, the technology vendor, and a picture of the technology.

Finally, 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 and other dry decontamination methods.
- Technologies for perchlorate neutralization and removal. It should be noted that work in this area has been done at ORNL which could form the basis for follow-on work.
Contents

EXECUTIVE SUMMARY .......................................................................................................... 3
1. INTRODUCTION ............................................................................................................. 8
2. BACKGROUND ............................................................................................................... 9
3. SCOPE ............................................................................................................................. 10
4. METHODOLOGY ......................................................................................................... 11
5. REMOTE OPERATIONS FOR HOT CELL FACILITIES D&D ................................... 13
  5.1. DESCRIPTION OF TYPICAL FACILITIES FOR D&D ...................................................... 13
    5.1.1 BUILDING 3525 – Irradiated Fuels Examination Laboratory (IFEL) ...................... 13
    5.1.2 BUILDING 3517 – Fission Product Development Laboratory (FPDL) .................. 16
  5.2. IDENTIFICATION AND DESCRIPTION OF REQUIRED D&D ACTIVITIES FOR HOT CELL
    FACILITIES ......................................................................................................................... 27
    5.2.1 Hot Cell Facility Characterization ........................................................................... 28
    5.2.2 Hot Cell Decontamination ..................................................................................... 30
    5.2.3 Hot Cell Waste Removal and Packaging .................................................................. 32
    5.2.4 Hot Cell Facility Dismantlement ............................................................................ 33
  5.3. IDENTIFICATION OF TASKS REQUIRING REMOTE OPERATIONS FOR HOT CELL
    FACILITIES ........................................................................................................................ 34
    5.3.1 Characterization ....................................................................................................... 34
    5.3.2 Decontamination, Stabilization and Dismantlement ............................................... 35
  5.4. SUMMARY OF REMOTE OPERATIONS AND AVAILABLE TECHNOLOGIES REQUIRED FOR HOT
    CELL D&D ........................................................................................................................ 37
  5.5. IDENTIFICATION OF TECHNOLOGY GAPS IN EXISTING TECHNOLOGIES ............. 42
6. REMOTE OPERATIONS FOR PROCESS FACILITIES D&D ................................. 43
  6.1. DESCRIPTION OF TYPICAL FACILITIES FOR D&D ..................................................... 43
    6.1.1 BUILDING 3019A – Radiochemical Development Facility ........................................ 43
    6.1.2 BUILDING 3019B – High Level Radiation Analytical Lab ....................................... 46
  6.2. IDENTIFICATION AND DESCRIPTION OF REQUIRED D&D ACTIVITIES FOR PROCESS
    FACILITIES ........................................................................................................................ 47
    6.2.1 Process Facility Characterization ............................................................................. 47
    6.2.2 Process Facility Decontamination ............................................................................ 48
    6.2.3 Removal of Utilities ................................................................................................... 49
    6.2.4 Final Decontamination ............................................................................................ 49
    6.2.5 Demolition .............................................................................................................. 50
    6.2.6 Typical decontamination, stabilization, and dismantlement steps for Process Cells ... 50
  6.3. IDENTIFICATION OF TASKS REQUIRING REMOTE OPERATIONS FOR PROCESS FACILITIES
    D&D .................................................................................................................................. 50
    6.3.1 Characterization ....................................................................................................... 50
    6.3.2 Source Term Removal & Stabilization ..................................................................... 51
    6.3.3 Decontamination .................................................................................................... 52
    6.3.4 Demolition .............................................................................................................. 52
6.4. SUMMARY OF REMOTE OPERATIONS AND AVAILABLE TECHNOLOGIES REQUIRED FOR PROCESS FACILITY D&D ................................................................................................... 52
6.5. IDENTIFICATION OF TECHNOLOGY GAPS IN EXISTING TECHNOLOGIES ........................................ 54
7. REMOTE OPERATIONS FOR REACTOR FACILITIES D&D.............................................. 55
7.1. DESCRIPTION OF TYPICAL FACILITIES FOR D&D ................................................................. 55
7.2. IDENTIFICATION AND DESCRIPTION OF REQUIRED D&D TASKS .................................................. 57
7.3. IDENTIFICATION OF TASKS REQUIRING REMOTE OPERATIONS FOR REACTOR FACILITY D&D.......................................................................................... 62
7.3.1 Characterization ........................................................................................................... 62
7.3.2 Decommissioning ........................................................................................................ 63
7.3.3 Summary of Remote Operations Required for Reactor Facility D&D ................................ 65
7.4. IDENTIFICATION OF TECHNOLOGY GAPS IN EXISTING TECHNOLOGIES .................................. 66
8. REMOTE OPERATIONS FOR PIPELINE D&D AND SOIL REMEDIATION ... 67
9. CONCLUSION .................................................................................................................. 69
10. REFERENCES .................................................................................................................. 70
APPENDICES ............................................................................................................................. 72
APPENDIX 1 AVAILABLE REMOTE TECHNOLOGIES FOR FACILITY D&D APPLICATIONS........................................................................................................ 73
APPENDIX 2 UNIVERSITIES WITH ROBOTICS PROGRAMS ........................................ 108
APPENDIX 3 WEBSITE LINKS RELATED TO D&D.............................................................. 112
Table of Figures

Figure 1  Building 3525 Layout (Reference 8) ................................................................. 14
Figure 2 Pictures of Debris inside Building 3525 Hot Cells ............................................. 15
Figure 3 Building 3517 – Fission Product Development Laboratory ................................. 16
Figure 4 Floor plans for the first and second floor of Building 3517 (Reference 7) .......... 17
Figure 5 Building 3517 – Cell Descriptions (Reference 7) ............................................... 19
Figure 6 General Status of Building 3517 (Reference 7) .................................................. 21
Figure 7 Estimated quantities of contaminated materials .................................................. 27
Figure 8 3019A basement level floor plan (Reference 16) ............................................... 43
Figure 9 3019A First Level Floor Plan (Reference 16) ...................................................... 44
Figure 10 3019A Second Level Floor Plan (Reference 16) .................................................. 45
Figure 11 3019B floor plan (Reference 16) ..................................................................... 46
## Acronyms & Abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>ALARA</td>
<td>As Low As Reasonable Achievable</td>
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<td>CH</td>
<td>Contact Handled Waste</td>
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<tr>
<td>D&amp;D</td>
<td>Deactivation and Decommissioning</td>
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<td>DOE</td>
<td>Department of Energy</td>
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<td>FPDL</td>
<td>Fission Product Development Laboratory</td>
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<td>FY</td>
<td>Fiscal Year</td>
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<td>HRAL</td>
<td>High Radiation Analytical Laboratory</td>
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<td>IFEL</td>
<td>Irradiated Fuels Examination Lab</td>
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<td>LLLW</td>
<td>Liquid Low Level Waste</td>
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<td>MSM</td>
<td>Master-slave manipulator</td>
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<td>NVE</td>
<td>NuVision Engineering, Inc.</td>
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<td>ORNL</td>
<td>Oak Ridge National Lab</td>
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<td>ORRRR</td>
<td>Oak Ridge Research Reactor</td>
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<td>PCB</td>
<td>Polychlorinated biphenyls</td>
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<td>RCRA</td>
<td>Resource Conservation and Recovery Act</td>
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<td>RDF</td>
<td>Radiochemical Development Facility</td>
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<td>RTG</td>
<td>Radio-thermoelectric generator</td>
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<tr>
<td>S&amp;M</td>
<td>Surveillance and Monitoring</td>
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<tr>
<td>TSCA</td>
<td>Toxic Substance Control Act</td>
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<td>WAC</td>
<td>Waste Acceptance Criteria</td>
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1. 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 manipulators and associated tooling) 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 the Oak Ridge National Laboratory (ORNL) and are currently or will soon undergo D&D.

As planning progressed for the D&D of numerous facilities at ORNL, it was recognized that at least some of the facilities contain hazards preventing the use of manual D&D techniques whereby workers perform 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. While much of this waste 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. These factors have led to the conclusion that remotely operated technologies will be required to complete the D&D actions safely and effectively.

NuVision Engineering (NVE) and Florida International University, Applied Research Center (FIU-ARC) have assessed the requirements for remotely operated systems to support D&D operations 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, a gap has been identified to facilitate development of a solution to fill the identified need.

This work has been funded by the Department of Energy through the International Agreement Number DE-G101-M6EW56054 under Project Technical Plan OR/Remote Operations/01/v1. FIU-ARC participation and support has been funded by the Department of Energy through Agreement Number DE-FG01-05EW07033.
2. Background

The main campus of ORNL will be undergoing closure in the near future. The facilities that will undergo D&D as part of the Environmental Management Closure Program include highly contaminated hot cells, reactor pools, and a variety of other buildings and process systems. These sites have housed work involving varying levels of radioactivity over the past 50 years. 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.

In order to properly understand and prepare for use of remote technologies to meet future needs, it is necessary to research the availability and sustainability of previously deployed technologies. NVE and FIU-ARC have partnered together to complete this assessment.
3. Scope

The project scope was to assess the requirements for remotely operated technologies to support D&D operations at ORNL, identify existing technologies that can meet the expected requirements, and develop a plan to fill any gaps identified 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 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 will require remote operations.
4. Review of existing applicable technologies and identification of technology gaps.
5. Provide recommendations to fill these 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-ARC relied heavily on past successful D&D support activities, including the remote technologies database developed and managed there.

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 identifying 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. Among others, these efforts have included:

- Power Fluidics™ equipment for mobilization and consolidation of radioactive waste from Tanks T-1 and T-2 located in the Melton Valley of ORNL campus
- ARTISAN® power manipulator deployment at Hanford 324 building for characterization and D&D activities.
- ARTISAN® power manipulator deployment at Battelle Columbus for characterization and D&D activities.
- Remote sampling system for the STS columns/post filter at West Valley.
4. Methodology

The tasks of the project are listed below as taken from the Project Technical Plan (PTP), Reference 1.

| TASK 1 | Kick-off meeting to define project milestones, and strategy for defining remote operations for D&D activities. |
| TASK 2 | Review of current plans for near and long-term D&D activities |
| TASK 3 | Identification of relevant technologies for D&D activities |
| TASK 4 | Identification of technology gaps and potential solutions |
| TASK 5 | Final report detailing results. |

The following is a description of how those tasks were performed.

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 and documented in the Meeting Minutes (Reference 2).

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 PTP and reviewed at the kickoff meeting. Following the meeting, a facility list was generated and documented in the meeting minutes and are 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. It is expected that NVE and FIU-ARC expertise offered through this project will be complimentary to that required to plan, prepare for, and execute the D&D activities at ORNL.

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 study concentrated on “Typical to Difficult” sites that may benefit from the use of remote operations during D&D at ORNL. The sites were discussed to decide which facilities/areas likely bound the remote operations needs. The selected sites for concentration include:

1) Reactor Facilities – The ORRR
2) Process (Chemical Development) Facilities – Bldg 3019A, B
3) Hot Cell Facilities – 3517 and 3525
4) Soil Remediation – Some pipe line and the soil between buildings 3515 and 3517, the soil under 3047, 3025E and 3019A

Information inputs/sources to the project included the information from the sources listed in the Kick Off Meeting Minutes (Reference 2) 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:

- Initial Cleanout
- 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)
- Soil Remediation (Optional)
5.  Remote Operations for Hot Cell Facilities D&D

5.1.  DESCRIPTION OF TYPICAL FACILITIES FOR D&D

The typical hot cell facility contains a number of hot cells which are constructed of high density concrete walls of ranging thickness [e.g. 3’ in Bldg 3525 (Reference 6), 1’ to 4.5’ in Bldg 3517 (Reference 7)] with oil filled lead glass viewing windows. The inside surfaces of the cell bank are lined with stainless steel to provide containment of particulate matter and to facilitate decontamination (Reference 6). Special penetrations are typically provided for the sealed entry of services such as instrument lines, lights, and electrical power (Reference 6).

Usually hot cells are equipped with a pair of manipulators located at each of the window stations, used for remote cell operations and periscopes allow for magnified views of in-cell objects. Heavy objects within each cell bank were moved by electromechanical manipulators and/or a crane (Reference 6).

The remainder of the facility outside the hot cells can consist of: the charging area; the equipment maintenance air lock areas; the operating area; the truck unloading area; the changing room; mechanical equipment rooms; the decontamination area; the hot equipment storage area; and office space (References 5 and 6).

Gases and particulates exhausted from the hot cells are completely contained and shielded until subjected to sufficient filtration to ensure safe stack disposal. The cell air is typically maintained at negative pressure with respect to the operating areas to ensure confinement. Liquid effluent from the hot cells is handled in a batch mode for disposal to the ORNL liquid low-level waste system (Reference 6).

5.1.1  BUILDING 3525 – Irradiated Fuels Examination Laboratory (IFEL)

The Irradiated Fuels Examination Laboratory (IFEL), Building 3525, has a long history of fuel research and examination. It is in the Bethel Valley portion ORNL. Over a period of three decades this facility has handled a wide variety of fuels including aluminum clad research reactor fuel, both stainless and zircaloy clad LWR fuel, coated-particle gas cooled reactor fuel, and numerous one of a kind fuel test experiments. In addition, the facility has also done iridium isotope processing and irradiated capsule disassembly (Reference 6).

5.1.1.1  BUIDING 3525 – Facility Description and Layout

The IFEL contains a large horseshoe-shaped array of hot cells which are divided into three work areas. Figure 1 presents a layout of this facility. The hot cells are constructed of 3-ft thick high density concrete walls with oil filled lead glass viewing windows. The inside surfaces of the cell bank are lined with stainless steel. Special penetrations are provided for the sealed entry of services such as instrument lines, lights, and electrical power. A pair of manipulators is located at each of 15 window stations for remote cell operations and periscopes allow for magnified views of in-cell objects. Heavy objects within each cell bank can be moved by electromechanical manipulators or a 3 ton crane. Fuel materials enter and leave the cells through three shielded transfer stations provided at the rear face of the North cell. Two small diameter (6.5 & 14.5 in)
horizontal transfer stations are used for small objects (less than 8 ft in length). Items up to 4 by 4 by 6 ft in size can be transferred through the shielded air-lock door system. In addition, with minor modifications for cask handling, full length light water reactor fuel rods can be handled.

The remainder of the laboratory outside the hot cell complex is subdivided into: (1) the charging area; (2) the equipment maintenance air lock areas; (3) the operating area; (4) the truck unloading area, the change room, and a work room; (5) the rooms housing supporting mechanical equipment; (6) the decontamination area; and (7) the hot equipment storage area (Reference 8).

Figure 1  Building 3525 Layout (Reference 8)

Many of the hot cells in the facility are cluttered with miscellaneous debris ranging from small laboratory items to large pipe sections to bottles of liquid. Pictures of some of the cells are below in Figure 2.
Figure 2 Pictures of Debris inside Building 3525 Hot Cells
5.1.2 BUILDING 3517 – Fission Product Development Laboratory (FPDL)

Building 3517 pictured in below, the Fission Product Development Laboratory (FPDL) was constructed for the following purposes:

1. To recover long-lived fission products (i.e. 90Sr, 137Cs) from aqueous; wastes generated in processing irradiated reactor fuel elements,
2. To purify feed materials from other DOE sites, and;
3. To prepare radioactive sources.

Figure 3 Building 3517 – Fission Product Development Laboratory

5.1.2.1 Building 3517 – Facility Description and Layout

The building is a three-story, braced steel framework structure with metal deck roofs and 12 in. non-reinforced-concrete masonry walls on the lower two stories. The building is about 120 ft long (east-west), and the first two stories are about 60 ft wide (north-south) and 27 ft. high. A third story, referred to as the crane bay, supports a 20-ton bridge crane and services the top access plugs to Cell 1 through 15. The crane bay has aluminum siding. Floor plans for the first and second floor are provided in the Figure 4.
The main cell block, Cells 1 through 15, is a double cell block located on the first level of the building. These hot cells are massive, steel-bar reinforced concrete boxes with wall thicknesses of 3 and 4.5 ft. The access to the cells consists of removable reinforced concrete blocks in the tops of the cells. Each individual cell within the hot-cell structure is isolated by 2-ft thick concrete walls. There are four tank farm cells, cell 21 through 24, that are located underground adjacent to the building. Cells 21 and 22 at one time housed storage tanks for fission products.
solutions. Cell 21 is empty; the tanks and piping have been removed. Cell 22 still contains a tank (inactive) and associated piping. Cell 23 and 24 contain collection tanks for liquid low level waste (LLLW). Specifically, Cell 24 contains a 600 gallon tank (Tank S424) used for LLLW collection. This tank has been isolated (Reference 8).

Cell number 19 was removed. The process cells (cells 1 through 9), the storage cells (cells 21 through 24), and high-level manipulator cells (cells 10 through 15) are shielded from the nearest accessible area by the equivalent of 4 ft of ordinary concrete. The low-level manipulator cells and services areas have less shielding (cells 16, 18, and cells 17 and 20 respectively). Cells 1 through 15 have stainless steel linings to facilitate decontamination. Cells 16 and 18, the service cells, and the tank farm cells have Amercoat coatings (coating for corrosion control and industrial uses).

Cells 1 through 9 (north row of main cell block) were process cells with no viewing windows. Except the north side of cell 1, which has been used for decontamination. These cells have been inactive since 1975. Some equipment has been removed but Cells 4 through 7 still contain a variety of tanks, piping, samplers, services, and instrumentation. A service tunnel runs along the north side of the cell bank.

Cells 10 through 15 (south row of the main cell block) are manipulator cells for handling high-level beta-gamma radioisotopes. These cells are equipped with viewing windows. Cells 10 and 14 are divided by steel plate into cells 10E and 10W and Cells 14E and 14W respectively. The interior of Cells 10W, 11, 14E, 14W, 23, and 24 are highly contaminated. Each cell has been swept out to remove the gross levels of contamination. Based on process knowledge, 1,000 Ci $^{90}$Sr equivalent, is judged to bound the contamination level in each of these cells (Reference 8). The manipulator cells have interconnecting shielded doors to enable materials to be passed from one cell to another. All except the large door between Cells 14 and 15 can be opened from the manipulator operating gallery. The large door is handled by the overhead crane. Cask transfers or transfers of large items in an out of the cell block are handled via the cell top plugs using the overhead 20-ton crane. Cell 10W has a water-cooled well for storage of radioisotopes capsules. This cell contains $^{90}$Sr (approximately 63,300 Ci), $^{137}$Cs (approximately 51,800 Ci) sources. These sources are stored in a below-grade pit (3-ft long by 1-ft wide by 4-ft deep) (Reference 8). The well is cooled with chilled water with backup from once-through process water. Radioisotopes processing was conducted in the manipulator cells until April 1989, when the facility was placed in standby.

The building contains four additional cells:

- Cell 16 – a manipulator cell used for decontaminating equipment
- Cell 17 – used for storage of fission products (xenon)
- Cell 18 – a manipulator cell (once an analytical cell but piping stripped out), and
- Cell 20 – inactive off-gas scrubber used when process Cells 1-9 were operational.

There is also a currently inactive glove box, which was installed for decontamination of equipment. A description of the Building 3517 cells is provided in Figure 5.
A total of 10M Ci of fission products material was processed at the FPDL during this operational period. At the conclusion of the program in 1975, the chemical processing cells were shut down and maintained in protective storage. Some initial decontamination was performed, but subsequent funding restrictions limited the scope of this effort. The initial program included the encapsulation and storage of approximately 500,000 Ci of $^{90}$Sr titanate powder and hot chemical flushes of process equipment and piping within all nine process cells. Some equipment has been removed, but cells 4 through 7 still contain processing tanks, piping, and equipment and are considered to be very high radiation areas.

Radioisotopes processing continued in the manipulator cells after 1975 at a reduced level of operation until April 1989, when the building was placed in standby. The principal operations during this period involved the production of $^{90}$Sr and $^{137}$Cs sources from separated product from Hanford. Other special operations (various short-term periods) include:

- Processing of $^{60}$Co, $^{192}$Ir, and $^{235}$U;
- $^{241}$Am target preparation;

### Figure 5 Building 3517 – Cell Descriptions (Reference 7)

<table>
<thead>
<tr>
<th>Cell type</th>
<th>Cell No.</th>
<th>$L^*$ (ft)</th>
<th>$W^*$ (ft)</th>
<th>$D^*$ (ft)</th>
<th>Minimum equivalent standard concrete shielding for walls (ft)$^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>1</td>
<td>9</td>
<td>12.5</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>Process</td>
<td>2</td>
<td>9</td>
<td>12.5</td>
<td>12</td>
<td>4.5</td>
</tr>
<tr>
<td>Process</td>
<td>3</td>
<td>9</td>
<td>12.5</td>
<td>12</td>
<td>4.5</td>
</tr>
<tr>
<td>Process</td>
<td>4</td>
<td>9</td>
<td>12.5</td>
<td>12</td>
<td>4.5</td>
</tr>
<tr>
<td>Process</td>
<td>5</td>
<td>9</td>
<td>12.5</td>
<td>12</td>
<td>4.5</td>
</tr>
<tr>
<td>Process</td>
<td>6</td>
<td>7.5</td>
<td>12.5</td>
<td>12</td>
<td>4.5</td>
</tr>
<tr>
<td>Process</td>
<td>7</td>
<td>7.5</td>
<td>12.5</td>
<td>12</td>
<td>4.5</td>
</tr>
<tr>
<td>Process</td>
<td>8</td>
<td>7.5</td>
<td>12.5</td>
<td>12</td>
<td>4.5</td>
</tr>
<tr>
<td>Process</td>
<td>9</td>
<td>7.5</td>
<td>12.5</td>
<td>12</td>
<td>4.5</td>
</tr>
<tr>
<td>Manipulator</td>
<td>10</td>
<td>7.5</td>
<td>7</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>Manipulator</td>
<td>11</td>
<td>13</td>
<td>8</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Manipulator</td>
<td>12</td>
<td>7</td>
<td>8</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Manipulator</td>
<td>13</td>
<td>7</td>
<td>8</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Manipulator</td>
<td>14</td>
<td>6.5</td>
<td>8</td>
<td>12</td>
<td>4.5</td>
</tr>
<tr>
<td>Manipulator</td>
<td>15</td>
<td>10</td>
<td>4</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>Manipulator</td>
<td>16</td>
<td>8</td>
<td>6</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Service</td>
<td>17</td>
<td>8</td>
<td>6</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Manipulator</td>
<td>18</td>
<td>6</td>
<td>6.5</td>
<td>10.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Service</td>
<td>20</td>
<td>6.5</td>
<td>7.5</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>Tank farm</td>
<td>21</td>
<td>25</td>
<td>12</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>Tank farm</td>
<td>22</td>
<td>25</td>
<td>12</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>Tank farm</td>
<td>23</td>
<td>30</td>
<td>12</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>Tank farm</td>
<td>24</td>
<td>30</td>
<td>12</td>
<td>14</td>
<td>2.5</td>
</tr>
</tbody>
</table>

$^*L = \text{length}; W = \text{width}; D = \text{depth}.$

$^*\text{Cells 1-9, 10W, and 11-13 have two layers of 2-ft-thick, reinforced-concrete blocks in the top of the cell; total thickness of top equivalent to 5 ft of concrete. Cell 10E has one layer of 4-ft-thick blocks; Cell 14, one layer of 3-ft-thick blocks; and Cell 15, one layer of 2-ft-thick blocks.}$
- Purification of $^{152/154}$ Eu; and,
- Separation of $^{99}$Tc from crude concentrate received from the Paducah Gaseous Diffusion Plant.

Building 3517 Containment and Ventilation

The building ventilation is operated in a “containment” mode (as least – 0.3 in w.g. relative to the outside atmosphere), and the cells are maintained at a pressure of at least -0.3 in w.g. relative to the building pressure. The building is sealed and equipped with air-lock entries for personnel and a truck air lock. Air-lock doors are gasketed. Each operating area is enclosed and can be isolated from the other areas of the building, except where piping and conduit come through floor and wall openings. Air flows from areas with lesser potential for contamination to areas of higher potential. Thus, ventilation air flows from the operating areas to the in-leakage openings into the cells and service tunnel. There are roughing filters on the inlet in the service tunnel and Cell 15. Ventilation exhaust flows in reinforced concrete ducts underground to a filter pit outside the building containing a set of testable HEPA filters, to an above-ground enclosure containing a second set of testable filters, and then through to the new filter house containing a third stage of testable HEPA filters. The exhaust is then discharged to the ORNL Building 3039 stack cell ventilation system. All of the exhaust fans are in the 3039 system. Additionally, there are in-cell HEPA filters on the manipulator cell, but these cannot be tested.

Building 3517 Liquid Waste System

Radioactive liquid waste drains from the cells and the electropolisher glove box are routed through a common header to stainless steel collection tanks (S-223, S-324, S-523). These tanks are located in shielded underground storage vaults (Cells 23 and 24) located adjacent to the building. Cell 24 contains a 600 gallon tank (Tank S424) used for LLLW collection. This tank has been isolated (Reference 8). The wastes are jetted from Building 3517 tanks to the ORNL LLLW evaporator facility through a doubly contained stainless steel line after it leaves the outside wall of the building. There is a short section of this line that is not doubly contained. According to the report (Reference 8), these tanks are in good conditions and are contained in a concrete vault; they are vented to the process off-gas system. The process waste system receives normal effluent from building sinks and floor drains in operating areas, steam condensate traps, and emergency cooling water from the storage well in Cell 10W and provides disposal of non-radioactive liquids (except sanitary waste). The waste is monitored before it is discharged to the ORNL central process waste system. If radioactivity is detected at levels above the limits for process waste, the material is diverted to the LLLW system.

Building 3517 – General Facility Status and Estimated Quantity of Contaminated Materials

No radioactive operations are being conducted in Building 3517 except the removal and disposal of some solid and liquid LLW. Daily surveillance is being carried out. A programmed maintenance is being conducted as well. The general status of this facility as of May 1995 (the date of ORNL/ER-249/R1 report) is summarized in Figure 6. The estimated quantity of contaminated materials (excluding inventory) requiring removal/disposal is provided in Figure 7.
<table>
<thead>
<tr>
<th>Facility/area</th>
<th>Comments</th>
</tr>
</thead>
</table>
| **Building**                          | **Type**  
Steel frame, first two levels, masonry walls; crane bay, aluminum siding; hot cells, massive steel-bar reinforced concrete boxes. |
| **Roof and exterior walls**           | Good condition.                                                                                                                            |
| **Building containment and ventilation** | Building sealed; air locks with gasketed doors; building operates in a "contained" state to maintain at least 0.3 in. w.g. negative pressure relative to the outside atmosphere; air flows from operating areas into the cells; cells exhaust through underground ducts to filter pit outside the building with single-stage HEPA filtration (testable); second-stage HEPA filtration (testable) in above-ground filter house; third-stage HEPA filtration in new filter house; exhaust to 3039 stack. |
| **Liquid waste systems**              | Cell floor drains and electropolisher glove-box drain: drain to stainless steel collection tanks (S-223, S-324, and S-523) located in shielded underground cells adjacent to building; wastes jetted to ORNL LLW evaporator facility as necessary. |
| **Monitoring**                        | Building floor drains and sinks, steam condensate, and emergency cooling water for storage well: monitored at Manhole 209 before discharge to ORNL process waste system. |
| **Cask handling**                     | Facility Radiation and Contamination Alarm System: locally alarming monitors; central alarm panel for building; monitored at the WOCC. |
| **Process Cells**                     | 20-ton bridge crane; truck air lock, and forklift trucks.                                                                                   |
| **Cells 1-4 used to process ²²⁴Pu**   | Cells 5-8 used to process ¹⁹⁷Ir (out of service); and Cells 5-8 used to process ¹⁹⁷IrCs (out of service). |

Figure 6 General Status of Building 3517 (Reference 7)
## Facility/area

### Comments

**Process Cells (continued)**

<table>
<thead>
<tr>
<th>Facility/area</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cells 1, 2, 3, 8, and 9</td>
<td>High radiation area; contamination area. Cells stripped of tanks and lines; Cells 1 and 9 contain equipment; Cells 2, 3, and 8 are empty.</td>
</tr>
</tbody>
</table>

**Manipulator Cells**

**General comments for Cells 10-15**

- Very high radiation area; contamination area. Manipulator boots require frequent changes to maintain confinement.

**Cell 10E**

- Used as a transfer cell; material normally entered into manipulator cells and manufactured sources removed via Cell 10E top hatch using the overhead crane.
- Past experience manipulators were contaminated with $^{90}$Sr when removed for maintenance.
- Removable plug in manipulator room wall to pass small items in.
- Electrically operated hoist (500 lb).
- Empty.

**Cell 10W**

- Used as storage cell.
- Inventory: $^{90}$Sr, ~22,000 Ci; $^{137}$Cs, ~88,000 Ci; and $^{244}$Cm, ~450 g.
- Past experience shows that manipulators were contaminated with $^{90}$Sr when removed for maintenance.
- Water-cooled storage well for storage of radiisotope capsules; chilled-water cooling with backup from once-through process water.

---

**Figure 6 General Status of Building 3517 (Cont.)**
<table>
<thead>
<tr>
<th>Facility/area</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manipulator Cells (continued)</strong></td>
<td></td>
</tr>
<tr>
<td>Cell 10W (continued)</td>
<td>Air-operated hoist (1000 lb).</td>
</tr>
<tr>
<td></td>
<td>Capsule welding machine.</td>
</tr>
<tr>
<td>Cell 11E and 11W</td>
<td>Highly contaminated with $^{90}$Sr and $^{137}$Cs. Past experience shows that manipulators were contaminated with $^{90}$Sr and $^{137}$Cs when removed for maintenance.</td>
</tr>
<tr>
<td></td>
<td>East and west windows are cloudy.</td>
</tr>
<tr>
<td>Cell 12</td>
<td>Highly contaminated with $^{90}$Sr and $^{137}$Cs. Past experience shows that manipulators were contaminated with $^{90}$Sr and $^{137}$Cs.</td>
</tr>
<tr>
<td></td>
<td>Window in good condition; water lines cut off; no electrical service; hot drain may be plugged with glass and/or lead shot, and/or trash but could not be confirmed.</td>
</tr>
<tr>
<td>Cell 13</td>
<td>Highly contaminated with $^{137}$Cs.</td>
</tr>
<tr>
<td></td>
<td>Window leaking; hot drain may be plugged with glass and/or lead shot, and/or trash but could not be confirmed.</td>
</tr>
<tr>
<td>Cell 14E</td>
<td>Highly contaminated with $^{137}$Cs; may find $^{137}$Cs-glass.</td>
</tr>
<tr>
<td></td>
<td>Window leaks and is cloudy; no electrical service.</td>
</tr>
<tr>
<td></td>
<td>Left manipulator presently shielded with lead blankets around through tube opening. In 1979, manipulator repair, $^{137}$Cs powder observed in pull bag and manipulator at high radiation readings. Manipulator will probably need to be pushed into cell and replaced.</td>
</tr>
<tr>
<td>Cell 14M and 14W</td>
<td>Used as waste transfer cell.</td>
</tr>
</tbody>
</table>

Figure 6 General Status of Building 3517 (Cont.)
<table>
<thead>
<tr>
<th>Facility/area</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manipulator Cells (continued)</strong></td>
<td></td>
</tr>
<tr>
<td>Cell 15</td>
<td>Used to load LLW out of the manipulator cell block. LLW is normally removed via cell top hatch using the overhead crane. Lower contamination. Electric hoist for operating small door between Cells 14 and 15.</td>
</tr>
<tr>
<td>Cell 16</td>
<td>Decontamination cell (inactive). Can be entered by personnel. Limited transferable contamination; may find alpha contamination in cracks.</td>
</tr>
<tr>
<td>Cell 18</td>
<td>Former analytical cell; all piping removed; still a very high radiation area; contamination area. Empty.</td>
</tr>
<tr>
<td><strong>Service Cells and Service Tunnels</strong></td>
<td></td>
</tr>
<tr>
<td>Cell 17</td>
<td>Used for storage. Inventory of stored xenon isotopes contaminated with trace levels of $^{85}$Kr; stored in gas cylinders.</td>
</tr>
<tr>
<td>Cell 20</td>
<td>Off-gas scrubber (inactive) used when all cells were operational. Roughing filters (operational) for cell ventilation system located in pump compartment. Pump compartment: general area of 200 mR/h. Scrubber compartment: very high radiation area.</td>
</tr>
</tbody>
</table>

Figure 6 General Status of Building 3517 (Cont.)
<table>
<thead>
<tr>
<th>Facility/area</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Service Cells and Service Tunnels (continued)</strong></td>
<td></td>
</tr>
<tr>
<td>Service tunnel (for process cells)</td>
<td>High radiation area; airborne radioactivity area; contamination area (but can work in area with protective equipment); almost all $^{90}$Sr; airborne radioactivity generated with any activity in area; &quot;hot&quot; spot (8000 mR/H at 1 in.; 2000 mR/h at 1 ft); levels behind lead brick shielding could be much higher.</td>
</tr>
<tr>
<td></td>
<td>Installed pipe, valves, and equipment are deteriorated.</td>
</tr>
<tr>
<td></td>
<td>Insulation (probably asbestos) is loose.</td>
</tr>
<tr>
<td></td>
<td>Many lights nonfunctional.</td>
</tr>
<tr>
<td>Service tunnel for Cell 10</td>
<td>Gamma radiation (300 mR/h at 1 in.) from overhead tank.</td>
</tr>
<tr>
<td>Cell 21 (tank farm)</td>
<td>Empty.</td>
</tr>
<tr>
<td></td>
<td>At one time, housed storage tanks (fission product solutions); tanks and piping removed.</td>
</tr>
<tr>
<td>Cell 22 (tank farm)</td>
<td>Inactive. Contains storage tank (S-122) and piping. At one time, used to store fission product solutions.</td>
</tr>
<tr>
<td><strong>Operating and Service Areas</strong></td>
<td></td>
</tr>
<tr>
<td>Manipulator-operating gallery</td>
<td>Fixed contamination on cell face area; lead installed to cover nontransferable contamination and provide additional shielding.</td>
</tr>
<tr>
<td></td>
<td>Most of dose rate is radiation from manipulator through tubes and hot spots covered with lead.</td>
</tr>
</tbody>
</table>

Figure 6 General Status of Building 3517 (Cont.)
<table>
<thead>
<tr>
<th>Facility/area</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operating and Service Areas (continued)</strong></td>
<td></td>
</tr>
<tr>
<td>First level north</td>
<td>Chiller room and air lock; air lock floor contaminated (300 mR/h on contact) from past pipe leak; covered by lead sheet; chiller room floor contaminated; nontransferable.</td>
</tr>
<tr>
<td>High bay area</td>
<td>Radiation sources are penetrations and fixed contamination on floor; transferable contamination presently low but can change with any operation involving cell.</td>
</tr>
<tr>
<td>General</td>
<td>Spots of nontransferable contamination at various places.</td>
</tr>
<tr>
<td><strong>Outside</strong></td>
<td></td>
</tr>
<tr>
<td>&quot;Old&quot; filter house and filter pit area</td>
<td>Filters inside house, 20 to 30 R/h. Top of house is high radiation area (gamma) due to less shielding on top than sides. Pit penetrations covered with lead shield.</td>
</tr>
<tr>
<td>Pump (solid waste)</td>
<td>Transfer pump for old product recovery from waste tank.</td>
</tr>
<tr>
<td></td>
<td>No longer used; removal and disposal desirable.</td>
</tr>
<tr>
<td></td>
<td>*Sr-contaminated; base reads 2 R/h at 1 in.; sits in rusted box; plywood overpack. Box shields most of radiation.</td>
</tr>
</tbody>
</table>

Figure 6 General Status of Building 3517 (Cont.)
5.2. IDENTIFICATION AND DESCRIPTION OF REQUIRED D&D ACTIVITIES FOR HOT CELL FACILITIES

In order to carry out the decontamination and decommissioning of a hot cell facility, a number of assumptions need to be made early on in the D&D process. For the purpose of this exercise the following assumptions have been made:

Starting point assumptions:

- Deactivation has not yet occurred and will be part of the action
  - Materials, waste, equipment, research debris is still being stored in the facility as shown in photographs of Building 3525 facility and detailed information as presented for Building 3517
  - Substantial loose contamination exists

<table>
<thead>
<tr>
<th>Location</th>
<th>Material/status</th>
<th>Estimated quantity (ft³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell 1</td>
<td>One vacuum hot press and other miscellaneous items</td>
<td>~100</td>
</tr>
<tr>
<td>Cell 2</td>
<td>Empty</td>
<td>~</td>
</tr>
<tr>
<td>Cell 3</td>
<td>Empty</td>
<td>~</td>
</tr>
<tr>
<td>Cell 4</td>
<td>Processing tanks and equipment</td>
<td>~430</td>
</tr>
<tr>
<td>Cell 5</td>
<td>Processing tanks and equipment</td>
<td>~430</td>
</tr>
<tr>
<td>Cell 6</td>
<td>Processing tanks and equipment</td>
<td>~430</td>
</tr>
<tr>
<td>Cell 7</td>
<td>Processing tanks and equipment</td>
<td>~430</td>
</tr>
<tr>
<td>Cell 8</td>
<td>Empty</td>
<td>~</td>
</tr>
<tr>
<td>Cell 9</td>
<td>Armor plate</td>
<td>~60</td>
</tr>
<tr>
<td>Cell 10E</td>
<td>Empty</td>
<td>~</td>
</tr>
<tr>
<td>Cell 10W</td>
<td>Canned waste, tools, and equipment</td>
<td>~7</td>
</tr>
<tr>
<td>Cell 11E</td>
<td>Empty</td>
<td>~</td>
</tr>
<tr>
<td>Cell 11W</td>
<td>Canned waste, tools, and lights</td>
<td>~7</td>
</tr>
<tr>
<td>Cell 12</td>
<td>Vacuum hot press, ejection press, equipment</td>
<td>~100</td>
</tr>
<tr>
<td>Cell 13</td>
<td>Press RAM, tools, and equipment</td>
<td>~7</td>
</tr>
<tr>
<td>Cell 14E</td>
<td>Contaminated lead and left manipulator</td>
<td>~30</td>
</tr>
<tr>
<td>Cell 14M</td>
<td>Contaminated lead (sheet and shot), vacuum pump</td>
<td>~20</td>
</tr>
<tr>
<td>Cell 14W</td>
<td>Miscellaneous waste</td>
<td>~7</td>
</tr>
<tr>
<td>Cell 15</td>
<td>Drum rack</td>
<td>~27</td>
</tr>
<tr>
<td>Cell 16</td>
<td>Ladder and bucket</td>
<td>~7</td>
</tr>
<tr>
<td>Cell 17</td>
<td>Metal rack and wooden box</td>
<td>~100</td>
</tr>
<tr>
<td>Cell 18</td>
<td>Empty</td>
<td>~</td>
</tr>
<tr>
<td>Crane bay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>area</td>
<td>Movable lift and miscellaneous items</td>
<td>~160</td>
</tr>
<tr>
<td>Outside</td>
<td>Contaminated pump in rusted box with plywood overpack</td>
<td>~100</td>
</tr>
</tbody>
</table>

Figure 7 Estimated quantities of contaminated materials
• Maximum dose rates inside cells on the order of magnitude of hundreds of R/hr, precluding human entry (worst case scenario)
• Able to use minimization techniques (sorting/segregating) to reduce amount of TRU waste (best management practices)

Ending point assumptions (Reference 5):

• Action to include demolition and removal of all above slab structures only
• Stabilization of residual contamination below slab, including plugging drains and decontaminating and/or covering of the slab as needed to protect on-site workers and the environment
  o 80% of removable contamination from pit walls and remaining floor slab would be removed prior to stabilization/covering
  o maximum general area exposure rate would be less than or equal to 1.2 mrem/hr [assumed number] after coating or capping material is in place (measured 1 m above slab)
  o removable contamination on the floor slab cap would not exceed limits the DOE surface contamination limits for release without radiological restrictions
  o Characterization and removal of soil as well as pipelines to or from the building beyond the building slab boundary are outside the scope of the action

5.2.1 Hot Cell Facility Characterization

Characterization is the measurement or sampling and analysis required to gather needed information, usually about the type and/or quantity of contaminants present in or on a material. Characterization in a decommissioning process (of any facility) has typically been divided into four processes (Reference 10):

• Safety characterization
• Initial site Characterization
• In-process characterization
• Characterization for material disposition

Characterization involves the collection of all relevant data concerning the status of a facility, including an inventory and location of radioactive and other hazardous materials in the buildings, equipment, and other materials. The characterization data for the facility forms the basis for determining the decommissioning strategy, decontamination and dismantling needs, radiological protection requirements, and final waste classification (Reference 11).

An adequate number of radiation and contamination surveys should be conducted to determine which radionuclides are present, maximum and average dose rates, and contamination levels of inner and outer surfaces of structures or components throughout the hot cell facility. For completeness, contamination in shielded or self-shielded components, such as inside pipes and pumps, should be characterized. Furthermore, special surveys to determine the penetration depth
and the extent of contamination may be required to adequately plan for decontamination or dismantling.

The radiological inventories of hot cells are usually significant and the selection of the most appropriate strategy is a challenging process. Due to the activities conducted in the hot cells several high radiation areas may be found inside and outside these structures.

Building 3517 facility currently stores a substantial inventory of surplus radioisotopes, which primarily consist of approximately 150,000 Curies of $^{137}$Cs and 100,000 Curies of $^{90}$Sr. Also, small quantities of Co, Eu, Gd are also stored in the building. Also, approximately 450 grams of $^{244}$Cm is stored in this facility. In addition, four radio-thermoelectric generators (RTGs) which contain in excess of 1,000,000 Curies of $^{90}$Sr are stored next to the building (Reference 7).

Process Cells 11E, 11W, and Cell 12 are highly contaminated with $^{90}$Sr and $^{137}$Cs. As well as Cells 13 and 14E which are highly contaminated with $^{137}$Cs. Mainly, the interior of Cells 10W, 11, 14E, 14W, 23, and 24 are highly contaminated. Each cell has been swept out to remove the gross levels of contamination. Based on process knowledge, 1,000 Ci $^{90}$Sr equivalent, is judged to bound the contamination level in each of these cells (Reference 8). Manipulators in these cells were also found to be contaminated. Another area showing high levels of contamination is the service tunnel area contaminated with $^{90}$Sr. Hot spots of 8000 mR/H at 1 inch and 2000 mR/H at 1 foot have been detected. Outside Building 3517, at the old filter house and filter pit area contamination levels range between 20 and 30 R/h (Reference 7).

An inventory of all non-radioactive hazardous materials present in the facility should also be conducted. Hazardous materials require special consideration to prevent harm to human health (Reference 12). In addition, hazardous materials such as asbestos, lead, and polychlorinated biphenyls (PCBs) will require consideration for waste packaging, transportation, and disposal. In the case of Building 3517, asbestos is present throughout the facility. Asbestos is present in general areas of the building such as the 1st and 2nd floor mens change room, lunchrooms, stairwells, chiller room, equipment room, etc. Surveys of this building have also indicated that there are several areas with high carbon dioxide (CO2) readings. These areas include passways behind hot cells, 1st floor manipulator rooms, 2nd floor hallways, etc. (Reference 15). Also, there is approximately 36,000 lbs of lead in the form of bricks and 1-inch sheets located within Building 3517 [13]. In addition the lead glass window in Cell 15 contains zinc bromide (Reference 8).

Characterization of a hot cell facility is a phased process, with additional characterization being performed throughout the D&D project as previously inaccessible areas become accessible. Typical characterization tasks are presented below:

- Gather and review existing radiological data (dose rates, contamination levels on the facility, building contents, and its ancillary facilities.
- Radiological smear surveys to establish levels of removable surface contamination.
- Radiological direct surveys to establish total level of fixed and removable surface contamination.
- Dose rate measurements to facilitate ALARA work planning.
• Samples of any water, sludge, or residues for lab analysis (chemical and radiological).
  Characterize liquids from sumps, equipment pits, tanks, and process piping.
• Characterize fluids in transformers, capacitors, and other equipment and sample for
  presence of PCBs.
• Visual survey and samples for potential asbestos-containing materials
• Visual inspection for other potential chemical hazards.
• Samples to characterize waste streams for segregation, packaging and transportation
  purposes. Analyze for RCRA metal to determine waste disposal site.
• Samples for analysis to meet WAC requirements for potential disposal facilities.
• Structural assessment of facility walls, stairs, elevated areas, and roofs to determine
  structural condition.

5.2.2 Hot Cell Decontamination

The D&D of a hot cell facility requires that each of the hot cells be cleaned and stabilized to
allow demolition to occur while maintaining worker radiation exposure ALARA and without
spreading radioactive contamination. A four-step process for decommissioning each hot cell
includes (Reference 1):

   (1) Source Term Removal (addressed under section 5.2.3);
   (2) Initial Remote Decontamination;
   (3) Utility Removal; and
   (4) Final (i.e., manual) Decontamination/Stabilization.

The following sections detail the actions required to accomplish each of these steps. An analysis
of which activities would require remote operations and to identify remotely operated systems is
provided in Section 5.3.

5.2.2.1 Initial Remote Decontamination

After completion of waste and source term removal, the hot cells may remain highly
contaminated with dose rates preventing manned entry. The goal of the initial decontamination
stage is to reduce the dose rates and airborne contamination levels within the hot cell to levels
permitting manned entry for future decommissioning efforts. To gain access into the cell to
remove utilities, remote decontamination techniques are typically utilized. The major concerns
during this stage are to manage secondary wastes and to achieve a sufficient decontamination
factor to meet the target contamination levels.

Decontamination efforts usually begin by using “dry” methods with in-cell manipulators to
concentrate on visible residues and debris. Dry decontamination methods are effective at gross
decontamination while generating only limited amounts of secondary wastes. The goal for this
initial stage of decontamination is to collect all visible debris and eliminate “hot spots.” HEPA-
filtered vacuum systems and hand tools can be modified for use with the in-cell manipulators, if operable. Operators can “dry” wipe and vacuum all accessible hot cell surfaces and monitor progress using an in-cell dose rate meter. At this point, “hot spots” identified during decontamination efforts can be marked for additional cleaning. It should be noted that a drawback to using the in-cell manipulators is the inability to reach all surfaces of the cell. This could result in high dose rates or levels of contamination remaining after initial decontamination if hot spots exist on the inaccessible surfaces.

When dose rate monitoring determines that dry decontamination techniques are no longer effective, operators use more aggressive wet techniques to further decontaminate the hot cell. Pressure washing tools and scrub brushes are fitted for use with manipulators, if operable, and all reachable hot cell surfaces are cleaned. After all manipulator reachable surfaces have been cleaned, additional remote decontamination is completed using “reach-in” techniques and/or crane mounted robotic manipulators. Long-handled tools (e.g., brushes and pressure wash wands) may also be used from the hot cell door to complete this stage of the decontamination effort. Adding water into the hot cell requires deploying a system to manage the secondary waste. Wet vacuums and a water filtration system collect the wash water and remove solids in preparation for evaporation.

5.2.2.2 Removal of Equipment and Utilities

The utility removal stage of the hot cell decommissioning effort addresses removing the hot operating equipment, including in-cell cranes, hoists, shielding plugs/windows/doors, manipulators, and service lines (e.g., electrical, air, plumbing). Work on this stage is often complicated by the interface between radiation protection and industrial safety controls. Very close interaction between Health Physics and Safety staff is required to ensure that work progresses safely. Much of this stage can be completed using project staff, with specialty contractors being used for the more hazardous and/or technically challenging work. Of special concern is the removal of large overhead items such as the in-cell cranes and hoists.

Operating systems on the inside of the hot cell typically present unique radiological challenges, including airborne contamination and elevated dose rates. Despite the initial decontamination efforts, dose rates and airborne contamination levels may remain at elevated levels inside the hot cell. Prior to manned entries, the hot cell can be fogged with an aerosol to hold down airborne contamination; then all hot cell surfaces can be painted with a strippable coating. The strippable coating is removed and reapplied; reducing the in-cell dose rates to below 100 mR/hr and airborne contamination levels to less than 1,000 DAC. After the radiological conditions inside the hot cell are stabilized, the remaining hot cell operating systems can be removed by manned entries.

With the remote decontamination stage complete, the hot cell operating systems represent the largest source term remaining in the cell. Typically, these systems are removed by project staff using bag-out techniques when necessary and packaged for disposal. If needed, specialty contractors can be used to remove and size reduce the higher hazard hot cell systems such as the in-cell cranes and lead glass shielding windows.
5.2.2.3 Final Decontamination

The final decontamination/stabilization stage of the hot cell decommissioning effort focuses on leaving the hot cell in a condition conducive to demolishing the hot cell and transporting the resulting waste to an off-site disposal facility. This focus requires further lowering the general area dose rates and fixing residual contamination in place (i.e., eliminating airborne contamination).

The final decontamination activity can begin by removing the strippable coating applied during the utility removal activities. A dose rate map of the hot cell can be generated to identify any areas requiring further decontamination. Areas identified can be cleaned using a portable de-surfacing tool. The final decontamination step typically consists of applying a polyurea coating (or similar material) to all hot cell surfaces. This coating will hold contamination in place during hot cell demolition.

5.2.3 Hot Cell Waste Removal and Packaging

Waste removal and packaging during the D&D of hot cell facilities will consider the waste already in the facility (source term removal) and the waste generated by the D&D process itself.

The goal of the source term removal stage of the decommissioning activity is to remove all research residues, examination equipment, and nonessential systems from the hot cell. This stage allows decontamination efforts to be focused on the hot cell surfaces and operating equipment within the hot cell.

The initial step in the source term removal process is to complete a waste management assessment of the materials in the cell. Prior to initiating work in a hot cell, historical records need to be reviewed to identify any potential for chemical contamination, which might result in generating a mixed waste. Any identified chemical contamination must be isolated as early in the removal process as possible to minimize the volume of mixed waste.

In preparation for removal from the hot cell, each item is evaluated for disposal based on its characterization data, dose rate, and physical size. This information is used to determine the operating restrictions that needed to be overcome to remove the item from the cell. Size reduction, stabilization, and shielding are completed, as necessary, to meet the operating restrictions.

The final consideration during the source term removal stage is the minimization of TRU waste. Due to the difficulty in disposing of TRU waste and the limited storage space available on-site, it is very important to generate as little TRU waste as possible. This minimization is accomplished using sorting/segregating techniques and frequently involves decontaminating equipment to below TRU limits (100 nCi/g transuranic isotopes).
Also, the majority of radioactive solid waste will be a direct result of the decontamination and
dismantlement of activated and contaminated systems, structures, or components. Additional
radioactive wastes will include tools and equipment that become contaminated during D&D
activities and other secondary wastes (wipes, filters, decontamination media, etc). Strategies for
minimizing waste include: source segregation, reuse, decontamination, volume reduction, and
waste stream segregation (Reference 14).

As waste materials are generated throughout the D&D project, the materials should be sorted by
waste category and packaged appropriately for disposal. Historical records and characterization
results are used to identify any potential for chemical contamination which might result in a
mixed waste. For example, at Building 3517’s first level a spot on the floor is painted with a
paint containing lead elements and inorganic compounds (Reference 15). Any identified
chemical contamination must be isolated early in the removal process to minimize the volume of
mixed waste. A thorough understanding of the packaging and transportation regulations as well
as the waste acceptance criteria for the potential disposal sites is critical for waste management.
For example, building materials coated with a paint containing PCBs may be accepted as PCB
bulk product waste without a significant increase in cost for packaging, transportation, and
disposal. However, PCB-containing paint that is removed from surfaces must then be stored and
managed according to the Toxic Substances Control Act (TSCA) regulations for PCB waste,
according to the PCB concentrations in the paint.

5.2.4 Hot Cell Facility Dismantlement

The decommissioning of nuclear facilities largely involves the segmentation of metal
components and the cutting and demolition of concrete structures. This also applies to hot cell
facility dismantlement. In most cases, dismantling and segmenting activities will precede the
demolition of a hot facility. Traditionally, dismantling refers to the physical disassembly, if
necessary, of equipment (i.e. piping, pumps, tanks, robotic manipulators, etc.) in buildings.
Segmenting typically refers to the size reduction of equipment into smaller parts using some type
of cutting tool (mechanical or thermal methods) (Reference 10).

In the case of Building 3517, process cells 1 and 9 contain equipment that may require
dismantlement and segmenting. For example, Cells 4 through 7 still contain a variety of tanks,
piping, samplers, services, and instrumentation needing to be removed. But cells 2, 3 and 9 are
empty. Manipulator cells (cells10-15) contain manipulators that will require dismantlement.
Also, Cell 10E contains an electrically operated hoist (500 lb) and Cell 10W contains an air
operated hoist (1000 lb) which will potentially require dismantling (Reference 7).

Dismantlement and deconstruction techniques, such as cutting and drilling will be implemented
in D&D of the hot cell structures. Coring and drilling equipment, back hoes, and mobile cranes
will be used to remove/dismantle and to size reduce concrete or concrete structures. Steel
reinforcement bars will be torch-cut, sheared, or saw-cut as required for dismantlement, leveling,
or size reduction purposes (Reference 13).
5.3. IDENTIFICATION OF TASKS REQUIRING REMOTE OPERATIONS FOR HOT CELL FACILITIES D&D

A list of typical D&D steps for a general facility are presented in the following sections, this is not a comprehensive list of activities, but it has been tailored to the D&D of hot cells facilities based on information currently obtained for Buildings 3525 and 3517.

5.3.1 Characterization

- Initial survey of accessible areas with additional surveys performed as previously inaccessible areas are made accessible
  - Gather and review existing radiological data (dose rates, contamination levels on the facility, building contents, and its ancillary facilities
  - Direct radiological surveys (including smear surveys and dose rate measurements) to establish total level of fixed and removable surface contamination

Surveys of a typical radiological facility are often performed with personnel carrying hand-held instruments. However, such surveys would not be possible in all areas of a hot cell facility due to the high dose rates associated with certain areas. In these instances, remotely operated survey instruments would be required to collect data on the removable and total surface contamination levels as well as dose rate measurements.

- Identify type, quantity, condition, and location of radioactive and other hazardous materials.
  - Visual survey and sample any water, sludge, or residues for lab analysis (chemical and radiological). Characterize liquids from sumps, equipment pits, tanks, and process piping.
  - Sample and characterize materials and fluids in transformers, capacitors, other equipment, building materials and paints for presence of PCB’s, asbestos or other chemical hazards.

Similarly, remotely deployed visual inspection devices and sensor technologies for the characterization of hazardous substances would be necessary to characterize areas of the hot cell facility where dose rates preclude human entry. Remotely operated sensor technologies capable of in-situ characterization for PCBs, lead, and other hazardous constituents would be especially valuable. Remote operated technologies can be use for characterization of tanks, equipment pits, and process piping. Standard manual techniques can be applied to areas outside the hot cells.

- Surveys and samples to characterize waste streams for segregation, packaging, and transportation purposes, support D&D activities, and Waste Acceptance Criteria (WAC) evaluation.

Where in-situ measurements of radiological and hazardous substances are not available or sufficient to clearly delineate the packaging and transportation requirements or to meet the disposal site WAC, the collection of physical samples for laboratory analysis is required. Remotely deployed sampling techniques would be necessary in the hot cell facility areas with excessively high dose rates that prevent personnel sample collection.
• Structural assessment of facility walls, stairs, ladders, elevated areas, and roofs to determine structural condition and load-bearing capacity

Remotely operated visual inspection devices would be necessary to complete a structural assessment in any areas were human access is restricted due to structural integrity concerns as well as radiological dose rates. Of specific concern are stairs, ladders, elevated areas, and roofs where structural degradation could be especially dangerous.

5.3.2 Decontamination, Stabilization and Dismantlement

• Mobilization
• Preliminary Building Preparations

Mobilization and preliminary building preparations typically do not require use of remote technologies.

• External of hot cells - decontamination and stabilization
  o Asbestos abatement – Building 3517 (General Area – 1st and 2nd floor of men change rooms, lunch rooms, stairwells, chiller room, equipment room)
  o Removal of lead bricks and 1-inch sheets from the building
  o Removal of PCB-contaminated items throughout the facility
  o Removal of equipment, stored items, miscellaneous materials
  o Decontamination and Removal of tank farm (Cell 21-24) – outside building 3517
  o Decontamination Removal of “old” filter house and filter pit area – Building 3517
  o Removal of four radio-thermoelectric generators (RTGs) located outside Building 3517 (if applicable)
  o Removal of lead based paint surfaces (if detected by characterization)
  o Decontamination and stabilization of contamination

Building 3517 contains farm tanks and an “old” filter house and filter pit with high radiation area. Remote technologies may be applicable for the removal of these components. Removal/abatement of asbestos, lead, PCBs, Freon, and batteries could be accomplished by standard means.

• Hot cells - decontamination and stabilization
  o Removal of source terms, chemicals inventory, containers, cylinders, etc.
  o Removal of source terms found in Cell 10W. This cell contains 90Sr (approximately 63,300 Ci), 137Cs (approximately 51,800 Ci) sources stored below-grade (3-ft long by 1-ft wide by 4-ft deep).
  o Removal small/medium size equipment, research residues and debris.
  o Evaluate each item removed based on characterization and physical size.
  o Size reduce larger items (equipment, piping, tanks, plates, etc).
  o Sort/segregate waste (primary and secondary generated wastes).
  o Initial (remote) decontamination/stabilization of hot cell surfaces.
Inspection and remote decontamination of stainless steel liners – Building 3517 (Cells 1-15).
Final hot cell decontamination, decontamination of concrete surfaces as required to eliminate hot spots.
Final hot cell stabilization (fogging agents and/or polyurea type coatings- prior to manned entry and dismantlement/demolition activities).

Removal of source terms, chemical inventory, containers, cylinders, etc should be done making use of existing manipulators as much as possible. Remote technologies maybe needed for areas where there is no manipulator available, the manipulator is not functional or the manipulator cannot reach all surfaces of the hot cell. Several cells (Cells 11E and 11W, Cell 12, Cell 13, Cell 14E, Cell 18) in Building 3517 are highly contaminated and remote technologies would apply for removing equipment, size reduction, sorting/segregating, and initial decontamination efforts for metal and concrete surfaces. Stainless steel liners are present in Cells 1-15, the liner surfaces would need to be remotely inspected for contamination and decontaminated accordingly. Removal of source terms found in Cell 10W in below grade pit will may required the use of remote technologies to remove inventory, remove liquid, and decontaminate the below grade storage area. Concrete surfaces underneath the stainless steel liners would have to be remotely characterized and decontaminated once liners are removed.

- Dismantlement/demolition of structures
  - Dismantlement of hot cells ventilation system.
  - Dismantlement and removal of in-cell cranes, hoists, shielding, manipulators, service lines etc.
  - Dismantlement of large pieces of equipment.
  - Demolition and/or segmenting of hot cells.
  - Demolition and/or dismantlement of rest of facility (general areas, air locks, etc).

Dismantlement of hot cell internal components may require the use of remote operated equipment. A crane mounted robotic manipulator can potentially be used for this operation. Remote operated technologies can also apply for the demolition of hot cell structures and demolition of the rest of the facility.

- Stabilization of residual contamination below slab (drains, pits, trenches, etc.)
- Final compliance verification survey and documentation
- Demobilization

The above activities do not require remote operations.
5.4. SUMMARY OF REMOTE OPERATIONS AND AVAILABLE TECHNOLOGIES REQUIRED FOR HOT CELL 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. These are listed below. Previous remotely operated technologies that have been used successfully in other D&D applications and locations are listed below each activity heading.

1. 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. Available technologies include:
   1.1. **Gamma Rover Crawler (Grover)** – an electronically powered, dual tracked crawler equipped with gamma radiation sensors and video cameras. The Grover has been used at Hanford for exhaust ducting characterization. See technology summary table index 1.1 for a complete description.
   1.2. **Remote Characterization System (RCS)** – a Remotec Andros Mark VI with cameras and lights, modified to incorporate a gamma detector, smear sample pad and a deployment station. The RCS has been used at Hanford for inspection. See technology summary table index 1.2 for a complete description.
   1.3. **Versatrax 100/150/300** – a miniature crawler system capable of internal inspection within extremely small pipe sizes from a minimum internal diameter of 4 inches to 12 inches. See technology summary table index 1.7 through 1.9 for a complete description.
   1.4. **Dispersible Removal System** – a small crawler (24in X 24in) equipped with stainless steel tracks, lighting, a light-duty telescoping boom and two jaw gripper. The DRS has been used successfully at Hanford for removal of dispersible materials. See technology summary table index 4.9 for a complete description.
   1.5. **Various cameras** suitable for use in conjunction with remote deployment platforms. See the technology summary table indexes 5.17 through 5.20 for a complete description.

2. 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 CO₂ levels, or degraded structural integrity of the building). Available technologies include:
   2.1. **Cartogam Gamma Camera (GammaCam)** – a relatively small (3.2 inches in diameter by 16 inches long) and relatively lightweight (35 pounds), real-time, gamma camera that provides two-dimensional mapping of gamma emitting sources. See technology summary table index 6.1 for a complete description.
   2.2. **In-Situ Object Counting System (ISOCS)** – a field portable unit that is capable of collecting data from very large surfaces in-situ, and can average any non-homogeneity of the contamination over the entire object or surface area of interest. The ISOCS has been used at Hanford for inspection. See technology summary table index 6.2 for a complete description.
2.3. Neutron Instrument Pod – a portable unit that incorporates fission chamber
detectors for neutron detection, a Cadmium/Tellurium detector for gamma
spectroscopy, and an Eberline R07 ion chamber for measuring gamma dose
rates. Has been used successfully at Hanford. See Technology summary table
index 6.3 for a complete description.

2.4. Remote Characterization System (RCS) – a Remotec Andros Mark VI with
cameras and lights, modified to incorporate a gamma detector, smear sample
pad and a deployment station. The RCS has been used at Hanford for
inspection. See technology summary table index 1.2 for a complete description.

2.5. Radscan 700 – a gamma spectroscopy unit that can be deployed from an
overhead crane or robotic platform. The Radscan 700 has been used
successfully at West Valley. See technology summary table index 1.4 for a
complete description.

2.6. Mobile Automated Characterization System (MACS) – a characterization
system that can detect alpha and beta contamination and moves over floors at a
speed of one inch per second. MACS are a commercially available, battery
powered, autonomous robot base supplemented by a laser positioning system
and a scintillation detector array. See Technology summary table index 1.5 for
a complete description.

3. In-situ gamma spectroscopy for isotope identification to support sorting and
segregating activities.

3.1. Neutron Instrument Pod – a portable unit that incorporates fission chamber
detectors for neutron detection, a Cadmium/Tellurium detector for gamma
spectroscopy, and an Eberline R07 ion chamber for measuring gamma dose
rates. Has been used successfully at Hanford. See Technology summary table
index 6.3 for a complete description.

3.2. Radscan 700 – a gamma spectroscopy unit that can be deployed from an
overhead crane or robotic platform. The Radscan 700 has been used
successfully at West Valley. See technology summary table index 1.4 for a
complete description.

4. Alpha radiation detection/spectroscopy for sorting and segregating of TRU materials
to minimize TRU waste disposal quantity.

4.1. Neutron Instrument Pod – a portable unit that incorporates fission chamber
detectors for neutron detection, a Cadmium/Tellurium detector for gamma
spectroscopy, and an Eberline R07 ion chamber for measuring gamma dose
rates. Has been used successfully at Hanford. See Technology summary table
index 6.3 for a complete description.

4.2. Mobile Automated Characterization System (MACS) – a characterization
system that can detect alpha and beta contamination and moves over floors at a
speed of one inch per second. MACS are a commercially available, battery
powered, autonomous robot base supplemented by a laser positioning system
and a scintillation detector array. See Technology summary table index 1.5 for
a complete description.
5. Sampling technologies for remote sampling of liquids, loose materials, and surface smear samples.
   5.1. Remote Characterization System (RCS) – a Remotec Andros Mark VI with cameras and lights, modified to incorporate a gamma detector, smear sample pad and a deployment station. The RCS has been used at Hanford for inspection. See technology summary table index 1.2 for a complete description.
   5.2. Mobile Automated Characterization System (MACS) – a characterization system that can detect alpha and beta contamination and moves over floors at a speed of one inch per second. MACS are a commercially available, battery powered, autonomous robot base supplemented by a laser positioning system and a scintillation detector array. See Technology summary table index 1.5 for a complete description.

6. Hazardous materials (e.g. asbestos, PCB, lead) detection capability to isolate and minimize mixed waste disposal quantity.
   6.1. Niton Analyzer 700 – uses X-Ray fluorescence (XRF) spectrum analysis to identify and quantify elements in metal and then compares the readings to a built-in library to determine the alloy. See technology summary table index 6.5 for a complete description. This technology would require adaptation for remote deployment.

7. Cutting or other size reduction technologies to support packaging of materials prior to removal from the hot cell.
   7.1. Various tooling is available and has been used in conjunction with master-slave-manipulators or other manipulator systems. A selection of these has been catalogued in the technology summary table, Appendix 1, Section 5.

8. Deployment platforms and tools for decontamination of surfaces
   8.1. Dual Arm Work Platform Teleoperated Robotics System (DAWP) – used to perform mechanical dismantlement of the radioactive reactor and bio-shield structures. Successfully used at CP-5 Research Reactor Argonne National Lab. See technology summary table index 3.1 for a complete description.
   8.2. Cybernetix Robotic Work Platform – a robotic work platform that is designed to provide remote access to hot cell floors, walls, ceilings and below-grade pits. Has been used successfully at Hanford in pipe removal and removal of contaminated items. See technology summary table index 3.2 for a complete description.
   8.3. Mobile Work Platform – a multi-articulating, folding main boom attached to a chassis by means of a 360-degree rotating turret assembly. Has been used successfully at Fernald. See technology summary table index 4.1 for a complete description.
   8.4. Houdini - a tethered, hydraulically powered, track-driven work platform. See technology summary table index 4.2 for a complete description.
   8.5. Mobile Robot Worksystem “Rosie” – performs mechanical dismantlement of radiologically contaminated structures by remotely deploying others tools or systems. See technology summary table index 4.4 for a complete description.
8.6. **Climbing Machine with Mechanical Abrader** – a climbing machine with flexible tracks held to the surface by suction that is capable of overcoming obstacles as it climbs and transitioning from horizontal to vertical surfaces autonomously. Can deploy a variety of tools. See technology summary table index 2.2 for a complete description.

8.7. **WallWalker** – a decontamination tool suspended and held to the wall via computer controlled cables which also control the machines motion. Able to deploy a variety of tools. See technology summary table index 2.1 for a complete description.

8.8. **En-Vac Robotic Wall Scabbler** – an abrasive blasting technology that uses abrasive steel grit or steel shot as the surface removal media and can scabble on both horizontal and vertical surfaces. See technology summary table index 2.5 for a complete description.

9. Pick-and-place capability for sorting, segregating and packaging waste materials prior to removal from the hot cell. Likely to require higher payload capacity and more mobility than in-cell MSM’s provide.

9.1. **Dual Arm Work Platform Teleoperated Robotics System (DAWP)** – used to perform mechanical dismantlement of the radioactive reactor and bio-shield structures. Successfully used at CP-5 Research Reactor Argonne National Lab. See technology summary table index 3.1 for a complete description.

9.2. **Compact Remote Operator console** – provides an economical solution to remote systems control in a portable and modular fashion. Has been used successfully at Idaho National Laboratory. See technology summary table index 6.19 for a complete description.

9.3. **Cybernetix Robotic Work Platform** – a robotic work platform that is designed to provide remote access to hot cell floors, walls, ceilings and below-grade pits. Has been used successfully at Hanford in pipe removal and removal of contaminated items. See technology summary table index 3.2 for a complete description.

9.4. **ARTISAN Telerobotic Manipulator** – a manipulator with six degrees of freedom and a payload limit of 220 pounds when horizontally extended. Successfully used at Hanford. See technology summary table index 3.9 for a complete description.

9.5. **RAPTOR Manipulator** – a manipulator for hazardous environments with good payload capacity of 150 to 300 pounds at full reach depending on the model. See technology summary table index 3.8 for a complete description.

9.6. **PERCHE Underwater pool manipulator** – designed to pick up and move objects up to 5 daN and carry out remote underwater inspection up to a depth of 20m. See technology summary table index 3.3 for a complete description.

9.7. **RODDIN: crane deployed work platform** – a modular work platform deployed with a crane. See technology summary table index 3.4 for a complete description.

9.8. **MAESTRO:Advanced hydraulic telemipnulator** – a teleoperated hydraulic robot dedicated to extreme environment applications. See technology summary table index 3.5 for a complete description.
9.9. ROMAIN 50/125: Master/slave electric telemanipulator – master/slave manipulators dedicated to intervention in nuclear environments for maintenance and work for which a high level of resolution and dexterity are required. See technology summary table index 3.6 for a complete description.

9.10. TMTC: Electrical manipulator arm – a heavy duty bridge mounted manipulator electric arm dedicated to intervention in irradiated and contaminated hot cells. See technology summary table index 3.7 for a complete description.

9.11. Shilling manipulators – a variety of manipulator models available depending upon the application. See technology summary table indexes 3.11 through 3.16 for a complete description.

9.12. Dispersible Removal System – a small crawler (24in X 24in) equipped with stainless steel tracks, lighting, a light-duty telescoping boom and two jaw gripper. The DRS has been used successfully at Hanford for removal of dispersible materials. See technology summary table index 4.9 for a complete description.

10. Dismantlement technologies for final demolition of hot cell structures prior to final building demolition, especially in cases where degraded structural integrity is an issue.

10.1. Mobile Work Platform – a multi-articulating, folding main boom attached to a chassis by means of a 360-degree rotating turret assembly. Has been used successfully at Fernald. See technology summary table index 4.1 for a complete description.

10.2. Modified Brokk Demolition Machine with Remote Operator Console – a modified BROKK demolition system that is used for remote viewing and long tether remote operation that provides a portable facility camera pod and interfaces with the Compact Remote Operator Console to extend the BROKK system to projects that require removal of the operator from the work area due to exposure to radiological, chemical or industrial hazards. See technology summary table index 4.5 for a complete description.

10.3. Remote Control Concrete Demolition System – a remotely operated articulated hydraulic boom with various tool head attachments that is designed primarily to drive a hammer and has a reach of 15 feet. See technology summary table index 4.6 for a complete description.

10.4. Remote Controlled Demolition Equipment KT-15 and KT30 – track mounted mobile telescopic boom type machines that can be equipped with a variety of head attachments to perform dismantlement or demolition work. See technology summary table index 4.7 for a complete description.

11. Remote application of strippable coatings and/or fogs and strippable coating removal. No remotely operated technologies were found to meet this need. This has been identified as a gap between the identified needs and available technologies.
5.5. IDENTIFICATION OF TECHNOLOGY GAPS IN EXISTING TECHNOLOGIES

The technologies in the previous section cover the majority of the activities needed to complete the D&D of the hot cell facilities. However, there are gaps in the above listed technologies that do not address the need for the remote operations listed below.

- Liquid sampling from miscellaneous containers left in the hot cells.
- Sensors that are adapted for remote application and have the ability to detect asbestos, NOx, CO, CO2, Beryllium, Perchlorate and other hazardous materials.
- A D&D workstation incorporating multiple tools for multiple applications.
- Removal of strippable coatings
6. Remote Operations for Process Facilities D&D

6.1. DESCRIPTION OF TYPICAL FACILITIES FOR D&D

The typical nuclear material process facility consists of a complex arrangement of piping and tanks associated with the conversion or recovery of processed nuclear materials. Building 3019 was originally commissioned in 1943 to serve as a pilot plant in the development of several radiochemical processes. Processes that were originally tested in the building include: Bismuth Phosphate, Redox, Purex, Thorex, and Floride Volatility. Besides the pilot plant activities, the building was most recently used in the reprocessing of irradiated thorium. The building was transferred to S&M activities in 1994. ISOTEK is under contract to disposition the remaining quantity of U233 located in the storage vaults. The project is still currently in progress, and it is expected that the building will be transferred to the D&D program for final decommissioning (Reference 19).

6.1.1 BUILDING 3019A – Radiochemical Development Facility

The RDF building (3019A) consists of process cells, storage wells, glove box laboratories, miscellaneous service and support labs, storage areas and office spaces. The main process cell consists of 6 cells; each cell providing a specific function in the pilot plant testing. The first cell consists mainly of a large tank where U slugs and Al jackets were dissolved. The next four cells contained tanks, centrifuges, and piping for successive oxidation-reduction cycles. The 6th cell (identified as cell 6 and 7 in Figure 8 below) was used primarily for storing of contaminated equipment. The basement level also contains a canal trench that was grouted in the 1990s.

Figure 8 3019A basement level floor plan (Reference 16)
Based on the available information on legacy equipment and materials (Reference 20), Table 1 below lists areas of potential concern in the basement level.

### Table 1 Known areas of contamination on Basement Level 3019A.

<table>
<thead>
<tr>
<th>Area Name</th>
<th>Potential Contaminants</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 26</td>
<td>Radiological (U, Pu, Th)</td>
<td>N/A</td>
</tr>
<tr>
<td>Room 27</td>
<td>asbestos</td>
<td>N/A</td>
</tr>
<tr>
<td>Room 28</td>
<td>asbestos</td>
<td>N/A</td>
</tr>
<tr>
<td>Room 29</td>
<td>asbestos</td>
<td>N/A</td>
</tr>
<tr>
<td>Room 33</td>
<td>lead (Pb)</td>
<td>N/A</td>
</tr>
<tr>
<td>Process Cells</td>
<td>Radiological (U, Pu, Th), lead, PCB, Hg</td>
<td>N/A</td>
</tr>
</tbody>
</table>

The first floor level (see Figure 9 below) consists mainly of offices, storage areas, laboratories, research control room, and utility areas. Viewing and access ports to the process cells are also provided. Potential areas of concern are listed in the Table 2 below.

![Figure 9 3019A First Level Floor Plan (Reference 16)](image-url)
Table 2 Known areas of contamination on First Floor Level 3019A.

<table>
<thead>
<tr>
<th>Area Name</th>
<th>Potential Contaminants</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 107</td>
<td>lead (Pb)</td>
<td>N/A</td>
</tr>
<tr>
<td>Room 110</td>
<td>Radiological (U, Pu, Th) - High</td>
<td>Labeled &quot;High Rad&quot; (Reference 20)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB – alpha: 361 dpm/100 cm²</td>
</tr>
<tr>
<td>Room 113</td>
<td>Radiological (U, Pu, Th) - High</td>
<td>Labeled &quot;High Rad&quot; (Reference 20)</td>
</tr>
<tr>
<td>Room 114</td>
<td>Radiological (U, Pu, Th) - High</td>
<td>Labeled &quot;High Rad&quot; (Reference 20)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB – F dose: 6 mR/h</td>
</tr>
<tr>
<td>Room 142</td>
<td>Radiological (U, Pu, Th) – High</td>
<td>Labeled &quot;High Rad&quot; (Reference 20)</td>
</tr>
<tr>
<td>Room 147</td>
<td>asbestos</td>
<td>N/A</td>
</tr>
<tr>
<td>Room 150</td>
<td>asbestos</td>
<td>N/A</td>
</tr>
<tr>
<td>Room 167</td>
<td>lead (Pb)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

The second level (Figure 10 below) consists of equipment rooms, glove boxes and access ports to the process cells and sampling conveyor between 3019A and 3019B. The only information available on its condition is the presence of lead and asbestos, and references to the sample conveyor being a source of contamination to the exterior of the building (Reference 19).

Figure 10 3019A Second Level Floor Plan (Reference 16)
6.1.2 BUILDING 3019B – High Level Radiation Analytical Lab

The High Level Radiation Analytical Lab (called building 3019B; referred to HRAL herein) mainly consists of several hot cells used for chemical and radiological analysis, as well as staging and equipment support areas for those hot cells. This building contains several subsurface pits that will require clean-out.

![Figure 11 3019B floor plan (Reference 16)](image)

Table 3 Known areas of contamination in 3019B.

<table>
<thead>
<tr>
<th>Area Name</th>
<th>Potential Contaminants</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room 15</td>
<td>asbestos, lead (Pb), Hg</td>
<td>N/A</td>
</tr>
<tr>
<td>Hot Cells</td>
<td>Radiological (U, Pu, Th) - High</td>
<td>N/A</td>
</tr>
</tbody>
</table>
6.2. IDENTIFICATION AND DESCRIPTION OF REQUIRED D&D ACTIVITIES FOR PROCESS FACILITIES

In order to carry out the decontamination and decommissioning of such a process facility, a number of assumptions need to be made early on in the D&D process.

Starting point assumptions:

- Process cells and Storage wells being used as part of ISOTEK thorium extraction will undergo initial characterization and decontamination steps at conclusion of work, with equipment removal and packaging for disposal
- Deactivation has not yet occurred and will be part of the action
  - Materials, waste, equipment, research debris is still stored in the facilities
  - Loose contamination exists
- Maximum dose rates inside main process cells, the hot cells, and adjacent rooms on the order of magnitude of hundreds of R/hr, limiting human entry (worst case scenario)
- Able to use minimization techniques (sorting/segregating) to reduce amount of TRU waste (best management practices)

Ending point assumptions (Reference 3):

- Action to include demolition and removal of entire structures. Soil surrounding process vaults and transfer canal will require removal.
- Stabilization of residual contamination below slab, including plugging drains and decontaminating and/or covering of the slab as needed to protect on-site workers and the environment
  - 80% of removable contamination from walls and remaining floor slab would be removed prior to stabilization/covering
  - Maximum general area exposure rate would be less than or equal to 1.2 mrem/hr [assumed number] after coating or capping material is in place (measured 1 m above slab)
  - Removable contamination on the floor slab cap would not exceed the DOE surface contamination limits for release without radiological restrictions
  - Characterization and removal of soil as well as pipelines to or from the building beyond the building slab boundary are outside the scope of the action

6.2.1 Process Facility Characterization

The pilot plant testing conducted in the process cells typically leaves the facility full of contaminated equipment, research residues, and debris. The goal of the source term removal stage of the decommissioning activity is to remove all research residues, examination equipment, and nonessential systems from the cells and rooms. This stage allows later decontamination efforts to be focused on surfaces and operating equipment left within the facility.
The initial step in the source term removal process is to complete a waste management assessment of the materials in the cells and adjacent rooms. Prior to initiating work in a hot cell, historical records need to be reviewed to identify any potential for chemical contamination, which might result in generating a mixed waste. Any identified chemical contamination must be isolated as early in the removal process as possible to minimize the volume of mixed waste. Some of this work has been accomplished as part of the legacy equipment initiative (Appendix B) at Oak Ridge. For the process facility, this includes remaining chemical contamination in tanks, piping and other process equipment. Specific chemical contamination activities include the identification of remaining liquids in tanks and piping located throughout the building, and identification of any chemical contaminants located within glove boxes in adjacent rooms. Also, characterization of paints for identification of lead or PCBs is also required. The basement canal trench may require paint sampling for identification of PCBs.

In addition to chemical characterization, all potentially contaminated areas must also be subjected to a radiological characterization process. The characterization of these areas is based on historical information collected during previous work, and surveillance and monitoring activities performed after facility shutdown. Since this facility is currently considered in use for the thorium extraction program (Reference 19), limited current characterization data is available. Based on this data, a dose-to-curie model can be developed for the adjacent rooms surrounding the process cells. Evaluating the current building information available, several areas would require extensive radiological characterization for the dose-to-curie model. On the basement level, Room 26 is labeled as having "High Rad" contamination (Reference 20). The room would require characterization of the glove box and its internal components. Rooms 22, 29 and 34 on the basement level will also require radiological characterization of process piping, tanks, and additional equipment. On the first level, similar activities will be required for adjacent rooms to the process cells. Glove boxes located in rooms 110, 113, 114, and 142 are labeled "High Rad" equipment, and will require characterization. A chemical explosion in 1959 released plutonium contamination throughout the interior and exterior of the building [1,4]. In order to address this concern, paints were used to bond the alpha contamination to the surface. This will require paint and surface sampling & characterization throughout the building.

6.2.2 Process Facility Decontamination

In preparation for removal from the room, each item is evaluated for disposal based on its characterization data, dose rate, and physical size. This information is used to determine the operating restrictions that needed to be overcome to remove the item from the room. There are several large items in the process facility that require careful evaluation. Large glove boxes located on the first floor level will require some size reduction, or disassembly, prior to removal. In order to perform such an activity, the glove boxes will first have to be stabilized prior to removal. This includes removal of internal debris, decontamination of internal surfaces, and grouting or void filling. Also, a number of large tanks will require similar consideration to be removed from the rooms and cells. These tanks will require some level of internal decontamination and size reduction to remove them from the facility.

The final consideration during the source term removal stage is the minimization of TRU waste. Due to the difficulty in disposing of TRU waste and the limited storage space available on-site, it
is very important to generate as little TRU waste as possible. This minimization is accomplished using sorting/segregating techniques and frequently involves decontaminating equipment to below TRU limits (100 nCi/g transuranic isotopes). This will require careful sort/segregation activities within the process cells, and hot cells in the HRAL.

At the completion of the source term removal stage, the process cells and adjacent rooms will remain highly contaminated. The major concerns during this stage are to manage secondary wastes and to achieve a sufficient decontamination factor to meet the target contamination levels. In order to address these contamination issues, several remote techniques can be employed to reduce contamination levels to allow worker access to the areas. Typical remote decontamination activities include debris removal and surface wipe-down from the cells and contaminated rooms. Specific activities for the cells will be surface wipe down of locations where contaminated equipment was once set. The use of multiple dry and wet methods for decontamination can be used to perform these activities.

6.2.3 Removal of Utilities

Utility removal activities often present a major hazard in process facilities, where these utilities and systems can have considerable rad and chemical contamination. Building 3019 still has numerous utilities available, mainly due to the current thorium extraction operations located in the building. Assuming that these utilities would still be available at the completion of those activities, they will present a large risk during D&D operations. For the HRAL, these hazards are limited to electrical utilities and process wastes still located in the lab. The HRAL contains sinks with low levels of Hg and rad contamination, meaning that plumbing lines may be contaminated. Also, subsurface pits below the hot cells in HRAL will require clean-out and in places grouting (as possible).

Off-gas ducts and stacks may contain considerable contamination, and will require stabilization of the contaminants to the surface prior to any size reduction or disassembly taking place. All utility piping and ductwork may require asbestos removal prior to any decontamination, stabilization and size reduction can take place. Also, ensuring all lines have been properly drained will be important, as the building contains several active LLLW system drains and piping. Use of in-situ liquid detection technologies can help ensuring empty lines prior to D&D activities. Finally, removal of in-cell cranes, manipulators and end effectors will pose a significant risk, as operations would have exposed them to large amounts of contamination.

Additional utility removal activities that may pose risks include electrical systems, where transformers and switches containing PCBs and Hg are possible. Removal of instrument and compressed air will require piping wipe downs before activities, to ensure contamination is not made airborne by the removal process.

6.2.4 Final Decontamination

The final decontamination/stabilization phase will focus on removal or encapsulation of remaining contamination. This phase will prepare the building for demolition activities. Final
decontamination activities in the process building will include wall and floor coating removal, wall and floor decontamination, and fixed contamination stabilization. One issue during this phase will be the partial lead shielding in process cell 3, and Room 33. This will require stabilization using a fixative, and size reduction for packaging and disposal. One final step will be the grouting or void filling of the trench canal.

6.2.5 Demolition

Facility demolition will require the size reduction of the un-reinforced concrete walls that make up the process building and HRAL. Several methods can be employed depending on the remnant fixed contamination. Techniques such as concrete diamond saws allow for very controlled demolition via remote methods, although the time and manpower required to implement it make it viable only for situations where the threat of an uncontrolled release is high. Other techniques, such as wrecking balls and jackhammers have been successfully used to demolish a building with little to no release. The uses of dust suppression systems reduce the nuisance dust, agglomerating particles and reducing the potential for a release.

6.2.6 Typical decontamination, stabilization, and dismantlement steps for Process Cells

A list of typical D&D activities for Building 3019 are presented in Section 6.3, this is not a comprehensive list of activities, but it has been tailored to the D&D of process facilities based on information currently obtained for Buildings 3019A and 3019B.

6.3. IDENTIFICATION OF TASKS REQUIRING REMOTE OPERATIONS FOR PROCESS FACILITIES D&D

A list of typical D&D steps for a general facility are presented in the following sections, this is not a comprehensive list of activities, but it has been tailored to the D&D of process facilities based on information currently obtained for Buildings 3019A, B.

6.3.1 Characterization

- Dose rate estimation
  - Basement level: Room 22, 26, 29, 34
  - First Floor: Room 110, 113, 114, 142, 144, 107/108
  - Process Cells

Dose rate estimation activities are limited to areas where insufficient historical information exists to define the radiological hazards of a room or equipment. Remotely deployed technologies can remedy this by providing information on the "state" of the area/equipment. Technologies such as Gamma cameras can be easily placed on a manipulator grapple, or inserted on a platform that allows for pan/tilt operation, providing the necessary high dose sources quantification, and overlays the information on a picture as a visual marker for location of the sources.

- Radiological characterization
Surveys of a typical radiological facility are performed with personnel carrying hand-held instruments. However, such surveys would not be possible in all areas, or on all equipment, of a process facility due to the high dose rates. In these instances, remotely operated survey instruments would be required to collect data on the removable and total surface contamination levels.

- Chemical characterization (asbestos, PCBs, lead, perchlorates)
  - Piping covers and floor tile sampling: 3019A & 3019B
  - Line draining and liquid characterization: Room 22, 29, 34, 142, 144, 107/108
  - Process Chemicals characterization: Room 110, 113, 114

Where in-situ measurements of radiological and hazardous substances are not available or sufficient to clearly delineate the packaging and transportation requirements or to meet the disposal site WAC, the collection of physical samples for laboratory analysis is required. Remotely deployed sampling techniques would be necessary in the process facility areas with excessively high dose rates that prevent personnel sample collection. These techniques would also be useful in the sampling of tanks, piping internals, and glove boxes.

### 6.3.2 Source Term Removal & Stabilization

- Piping/ductwork sealing: Room 26, 22, 29, 34, 110, 113, 114, 142, 144, 107, 108
- Piping/ductwork segmentation and packaging: Room 26, 22, 29, 34, 110, 113, 114, 142, 144, 107, 108
- Glove box internal debris/equipment removal: Room 26, 110, 113, 114
- Glove box internal loose contamination stabilization/decontamination: Room 26, 110, 113, 114
- Glove box internal grouting/foaming (if decontamination not possible): Room 26, 110, 113, 114
- Equipment stabilization and size reduction for packaging
- Process Cells lines and tank drain
- Process Cells ductwork/piping sealing, stabilization, segmentation and packaging
- Process Cells equipment & tanks stabilization/decontamination and size reduction for packaging
- Manipulators and Crane removal
Removal of source terms, chemical inventory, containers, tanks, etc should be done making use of existing manipulators and cranes as much as possible. Remote technologies maybe needed for areas where there is no manipulator available or the crane cannot reach all surfaces of the process and hot cells. Several glove boxes, tanks and piping within the first floor level of 3019 are highly contaminated and remote technologies would apply for removing equipment/debris, size reduction, sorting/segregating, and initial decontamination efforts for metal and concrete surfaces.

### 6.3.3 Decontamination

- **Wall Decontamination**
  - Coating removal
  - Concrete and/or metal decontamination
- **Floor Decontamination**
  - Coating removal
  - Concrete and/or metal decontamination

Decontamination activities within the process cells will benefit from the use of remote technologies, considering the release of Plutonium in 1959 was stabilized through coatings. Use of "wall-walking" remote technologies would expedite decontamination activities, as well as collecting most particulate generated during the activities. Concrete and metal decontamination activities after coating removal can be performed via remote technologies depending on the remaining contamination levels.

### 6.3.4 Demolition

- Cell wall concrete size reduction

Demolition activities will require more passive techniques, due to the potential for Plutonium release, based on the quantities trapped after the 1959 explosion. Assuming that this hazard can be addressed by reapplying a new fixative or stabilizing agent, use of standard demolition equipment (cranes, wrecking balls, jackhammers) and several dust suppression techniques can control the potential for release.

### 6.4 SUMMARY OF REMOTE OPERATIONS AND AVAILABLE TECHNOLOGIES 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 identified in section 5.4 for hot cell facilities and the following additional applications:

1. Inspection technologies for investigation of pipes and ducts. Inspection may include visual inspection, liquid detection, and sample/smear collection. Available technologies include:
   1.1. **Versatrax 300/150/100** – a miniature crawler system capable of internal inspection within extremely small pipe sizes from a minimum internal diameter of 4 inches to 12 inches. See technology summary table index 1.7, 1.8 and 1.9 for a complete description.
1.2. Gamma Rover Crawler (Grover) – an electronically powered, dual tracked crawler equipped with gamma radiation sensors and video cameras. The Grover has been used at Hanford for exhaust ducting characterization. See technology summary table index 1.1 for a complete description.

1.3. Dispersible Removal System – a small crawler (24in X 24in) equipped with stainless steel tracks, lighting, a light-duty telescoping boom and two jaw gripper. The DRS has been used successfully at Hanford for removal of dispersible materials. See technology summary table index 4.9 for a complete description.

2. Dismantlement technologies for size reduction and packaging of glove boxes, including the debris inside the glove boxes.
   2.1. Dual Arm Work Platform Teleoperated Robotics System (DAWP) – used to perform mechanical dismantlement of the radioactive reactor and bio-shield structures. Successfully used at CP-5 Research Reactor Argonne National Lab. See technology summary table index 3.1 for a complete description.
   2.2. Mobile Work Platform – a multi-articulating, folding main boom attached to a chassis by means of a 360-degree rotating turret assembly. Has been used successfully at Fernald. See technology summary table index 4.1 for a complete description.
   2.3. Houdini – a tethered, hydraulically powered, track-driven work. See technology summary table index 4.2 for a complete description.
   2.4. Mobile Robot Worksystem “Rosie” – performs mechanical dismantlement of radiologically contaminated structures by remotely deploying others tools or systems. See technology summary table index 4.4 for a complete description.
   2.5. Remote Control Concrete Demolition System – a remotely operated articulated hydraulic boom with various tool head attachments that is designed primarily to drive a hammer and has a reach of 15 feet. See technology summary table index 4.6 for a complete description.

3. Hazardous materials detection as identified in section 5.4 with the addition of perchlorate detection. No remotely operated technologies were found to meet this need. This has been identified as a gap between the identified needs and available technologies.

4. Perchlorate neutralization or removal. No remotely operated technologies were found to meet this need. This has been identified as a gap between the identified needs and available technologies. It should be noted that work in this area has been done at ORNL and this could form the basis for follow-on work from this study.

5. Large area decontamination due to pervasive Pu contamination.
   5.1. WallWalker – a system that resembles a giant, wall-sized plotter that is configurable for scabbling operations, hydroblasting, carbon dioxide, baking soda, chemicals, lasers, flashlamps, abrasive blasting technology, and other cleanup applications. See technology summary table index 2.1 for a complete description.
5.2. Climbing Machine with Mechanical Abrader – Held to the surface by vacuum force, the machines adhere to essentially any hard surface: metal, concrete, brick, etc. See technology summary table index 2.2 for a complete description.

5.3. Robotic Climber H-1 – A remote controlled, free climbing robot using Ultra High Pressure Water Jetting within a contained vacuum shroud. This technology employs a self-propelled, joy-stick operated robotic device designated for surface decontamination, coating removal and concrete "scabbling". See technology summary table index 2.3 for a complete description.

5.4. MOOSE OST No. 2099 – A remotely operated floor scabbler designed to scarify large concrete floor slabs in environments that require strict control of airborne contamination and debris. See technology summary table index 2.4 for a complete description.

5.5. En-Vac Robotic Wall Scabbler – an abrasive blasting technology consisting of the En-vac robot, a recycling unit, a filter, and a vacuum unit. See technology summary table index 2.5 for a complete description.

6.5. IDENTIFICATION OF TECHNOLOGY GAPS IN EXISTING TECHNOLOGIES

The technologies in the previous section cover the majority of the activities needed to complete the D&D of the hot cell facilities. However, there are gaps in the above listed technologies that do not address the need for the remote operations listed below.

- Sensors that are adapted for remote application and have the ability to detect asbestos, NOx, CO, CO2, Beryllium, Perchlorate and other hazardous materials.
- Technologies for perchlorate neutralization and removal
7. Remote Operations for Reactor Facilities D&D

7.1. DESCRIPTION OF TYPICAL FACILITIES FOR D&D

Research reactors have historically been centers of innovation and productivity for nuclear science and technology. The multi-disciplinary research that research reactors support has spawned new developments in nuclear power, radioisotope production, neutron beam research, nuclear medicine, materials development, component testing, computer code validation, and pollution control (Reference 21).

Research reactors comprise a wide range of different reactor types, which are generally not used for power generation. The primary use of research reactors is to provide a neutron source for research and other applications. They are small relative to power reactors whose primary function is to produce electricity. Research reactors are also simpler than power reactors and operate at lower temperatures. They need far less fuel and far less fission products build up as the fuel is used. On the other hand, their fuel requires more highly enriched uranium. Research reactors also have a very high power density in the core, which requires special design features. Like power reactors, the core needs cooling, and usually a moderator is required to slow down the neutrons to enhance fission. Research reactors also need a reflector to reduce neutron loss from the core and to sustain the chain reaction (Reference 21).

A common design is the pool type reactor, where the core is a cluster of fuel elements sitting in a large pool of water. Between the fuel elements are control rods and empty channels for experiments. The water moderates and cools the reactor, and graphite or beryllium is generally used for the reflector, although other materials may also be used. Apertures to access the neutron beams are set in the wall of the pool. Other designs are moderated by heavy water or graphite (Reference 21).

Located at ORNL, Building 3042 was built to house the Oak Ridge Research Reactor (ORRR) and covers approximately 11,000 ft². The building is a semi-airtight, steel-frame structure covered with insulated metal panels. The pool in which the reactor was placed has a minimum shield of 4 feet of barite concrete with a 10-feet thickness at the east end where the experimental beam ports were located (Reference 22).

The ORRR was a light-water moderated and cooled, beryllium- and water-reflected research reactor using highly enriched uranium-aluminum alloy plate fuel. The reactor was designed to produce high neutron fluxes for basic research in the fields of physics and chemistry and to test materials and potential fuels for power-producing reactors. The principal radionuclides of concern are Cobalt-60, Iron-55, and Nickel-63 (Reference 23). Removal of all fuel and fuel bearing components has been completed. In addition, hazardous chemicals and equipment associated with past operations have been removed. Building 3042 contains an estimated 2.6E-02 Ci of total beta gamma surface contamination and 5.6E-03 Ci of alpha surface contamination (Reference 24).

The ORRR pool in which the reactor operated also provided storage for spent fuel and activated components. The pool is comprised of three sections and is approximately 11 feet wide by 60
feet long and 30 feet deep (Reference 25). The two dams for the pool have been removed such that it is one large pool rather than three separate pools (Reference 23). The massive structure is constructed of high-density reinforced concrete and lined with 1/4-inch-thick aluminum plates (Reference 24). Many of the radiological items present in the pool have become activated due to their proximity to the reactor core. Three items (lower reactor grid plate, small thermal shield, and large thermal shield) are highly activated and account for approximately 95% of the total radiological activity in the pool (Reference 25). The components contain an estimated 2,660 curies of Cobalt-60 (Reference 23). The reactor grid plate is constructed of type 303 stainless steel and weighs approximately 150 pounds (Reference 25). The maximum cross-sectional dimension of the reactor grid plate and each thermal shield is 2.1 feet x 2.25 feet and 2.25 feet x 1.83 feet, respectively (Reference 24). Disassembly, packaging, and removal of the bottom support grid and the two thermal shields will be a critical task in support of the facility D&D activities.

The Graphite Reactor, Building 3001, was designed and built as an air-cooled, graphite-moderated reactor using natural uranium. This pilot plant was used to test the control and operating procedures of the proposed larger production reactors and to provide needed quantities of plutonium. There were 7 feet of concrete shielding between the reactor and the front wall of the shield where operators would work. The principal radionuclides of concern at the Graphite Reactor include mixed fission/activation products and natural uranium (Reference 22).

The Building 3001 Canal is an approximately 150 feet long “L” shaped below grade concrete reinforced structure running from the west face of the reactor to a hot cell in Building 3019. At the north end, the canal contains a 22.25 feet deep ceramic tile lined pit. The concrete walls of the canal are contaminated with radionuclides that have penetrated the surface of the walls, creating a potential problem of exposure for workers in the area to airborne radionuclide contamination if the water is removed and the exposed walls are allowed to dry (Reference 26). In 1992, all RCRA materials and sludge were removed from the canal and in 1996, all other stored materials were removed from the canal (Reference 26). The concentration of contamination in the water is below the waste acceptance criteria for the ORNL Process Waste Treatment System (Reference 26).

Assumptions

The decontamination and decommissioning (D&D) of a reactor facility requires that a number of assumptions be made early in the D&D planning process.

Starting Point Assumptions

- Reactor fuel has been removed
- Materials, waste, equipment, and debris may still be stored in the facility
- Substantial loose contamination may exist
- Highly activated components may be stored in the reactor pool
- Dose rates vary widely throughout the facility with maximum expected dose rates associated with the reactor vessel and activated components stored in the reactor pool
Ending Point Assumptions

- All equipment will be removed and all above ground structures will be dismantled and removed
- Foundations, concrete slabs, and contaminated soil will be removed to 2 feet below grade
- Stabilization of residual contamination 2 feet below grade, including reactor pool decontamination or removal, grouting below grade areas with clean debris, plugging drains, and decontaminating and/or covering the site as needed to protect on-site workers and the environment
  - Removable contamination on the site cap would not exceed limits the Department of Energy surface contamination limits for release without radiological restrictions
  - Characterization and removal of soil beyond 2 feet below grade as well as pipelines to or from the building beyond the building boundary are outside the scope of the action
- Oak Ridge Graphite Reactor activities will maintain the outer shell intact, preserving the building and appropriate equipment and systems as a Registered National Historic Landmark

7.2. IDENTIFICATION AND DESCRIPTION OF REQUIRED D&D TASKS

Section 7.3 contains an outline detailing specific tasks typically included in the D&D of reactor facilities and identifies which activities would require remote operations.

Characterization

Characterization involves the collection of all relevant data concerning the status of a facility, including an inventory and location of radioactive and other hazardous materials in the buildings, equipment, and other materials. The characterization data for the facility forms the basis for determining the decommissioning strategy, decontamination and dismantling needs, radiological protection requirements for the works, the public and the environment, and final waste classification. On the basis of the history of the facility, existing records, computational methods, and guidance from personnel experienced with the facility, the characterization is carried out by performing both direct in-situ measurements and taking samples for analysis (Reference 27).

The radiological inventories of research reactors are usually significant and the selection of the most appropriate strategy is a challenging process. When the fuel is evacuated, most activity is associated with highly irradiated parts and components (e.g. reactor internals and vessels) or with components contaminated by strong gamma and/or alpha emitters, which requires additional shielding (Reference 28).

An adequate number of radiation and contamination surveys should be conducted to determine the radionuclides, maximum and average dose rates, and contamination levels of inner and outer surfaces of structures or components throughout the reactor facility. For completeness, contamination in shielded or self-shielded components, such as inside pipes and pumps, should
be characterized. In addition, all process tanks in Building 3042 will be checked for remaining contents and sampled as needed. Furthermore, special surveys to determine the penetration depth and the extent of contamination may be required to assist in the selection of appropriate procedures for decontamination or dismantling. For activated components, calculations should be used together with selective verification sampling (Reference 29).

An inventory of all non-radioactive hazardous materials present in the facility should also be conducted. Hazardous materials such as asbestos, which covers extensive runs of piping and several tanks in Building 3042, require special consideration to prevent harm to human health (Reference 29). In addition, hazardous materials such as asbestos, lead, and polychlorinated biphenyls (PCBs) will require consideration for waste packaging, transportation, and disposal. Building 3042 contains significant quantities of lead for use as radiation shielding and various pieces of equipment may contain PCBs and mercury. Fluids in transformers, capacitors, and other equipment will be sampled for the presence and concentration of PCBs (Reference 23).

In addition to the characterization for radioactive contamination and other hazardous materials, a thorough understanding of the materials of construction and the quantities of additives or impurities present in those materials (e.g., cobalt in stainless steel, rare earth elements or chlorine in graphite, etc.) can provide a profound advantage in predicting activation products that may have developed during reactor operations. Mathematical modeling can be effective in predicting the extent of activation. These activation products can significantly impact D&D activities, such as worker dose received, waste handling and disposal plans, and design of dismantling methods (Reference 30).

It is important to note that the characterization, determining the true nature and extent of radiological and non-radiological contamination, is the basic element in defining the scope of a decommissioning project. From a risk management perspective, accurate characterization data does more to fix the scope of a project than any other activity that project staff can control. Failure to properly characterize a facility can lead to poor decisions on cost and schedule, decontamination strategy, and final status survey (Reference 31). Characterization of a reactor facility is a phased process, with additional characterization being performed throughout the D&D project as previously inaccessible areas become accessible.

**General Decontamination**

Decontamination covers the broad range of activities (wiping, washing, heating, chemical or electrochemical action, mechanical cleaning, or other techniques) to remove radioactive contamination in or on materials, structures, and equipment. The objectives of decontamination include (Reference 29):

- A reduction of exposures during decommissioning activities
- A minimization of the volume of materials to be classified and disposed of as radioactive waste
- The increase in possibility of recycle or reuse of equipment or materials

A number of decontamination techniques have been developed which may be applicable to reactor facility decommissioning. Examples of standard industry dismantling and
decontamination tools include wire saw, high pressure water, needle guns, jack hammers, torches/plasma arc torches, hydraulic cutters, hand tools, and other tools. Remotely operated systems are needed where direct human efforts are precluded due to limited access, radioactive dose levels, or other hazards to human health. Evaluation of decontamination techniques should include the following considerations (Reference 29):

- Target decontamination level and likelihood that techniques will achieve the target level on particular components
- Estimated doses to workers
- Possible generation of aerosols
- Cost of the application compared with the expected benefit (transportation and disposal costs must be traded against decontamination and survey costs)
- Estimate of the volume, category, and activity of any primary and secondary wastes
- Possible deleterious effect on decontamination on equipment or system integrity
- Non-radiological hazards (e.g. the toxicity of solvents used)

General cleanup activities should be performed in preparation for decommissioning activities, including the collection, surveying, and appropriate disposition of any non-reactor related equipment and materials situated throughout the reactor facility and adjacent controlled yard areas (Reference 32).

All systems that are currently inactive and all systems that are not required by later decommissioning activities may be de-energized and isolated or removed at this stage. Such systems would include portable water lines, drain lines, supply lines, heating, air conditioning, ventilation, other utilities, etc. (Reference 33). Building 3042 is currently supplied with electrical power to support lighting and electrical outlets as well as process water for the reactor pool and fire water for the wet-pipe-tupe sprinkler system. Negative air pressure is maintained on the main reactor building and the normal off-gas system is maintained (Reference 23).

Radioactively contaminated asbestos-containing material should be removed, packaged, and disposed of in accordance with applicable regulations. Non-contaminated asbestos-containing materials may also be removed, surveyed, and disposed.

Uncontaminated equipment and materials could be released for unrestricted use or disposal as clean waste. Contaminated equipment should be decontaminated and handled as other uncontaminated material or removed and packaged for processing and direct disposal as radioactive waste. Ventilation systems can be removed and packaged for processing and disposal or direct disposal as radioactive waste. Concrete walls/floors can be decontaminated by removing a portion of the outer concrete surface, as necessary (Reference 32).

**Reactor Pool and Highly Activated Components**

For segmenting and removing the highly activated components from the reactor pool, long-reach tools, remotely operated equipment, human divers, or a combination of these techniques may be used. The approach performed at the University of Virginia Reactor Facility should be considered. The reactor pool water was utilized to provide shielding during the segmenting and removal of the highly activated components in the pool. [Note that at least one reference was
found to a control rod that read 10R/hr (Reference 32). The contact readings on the liner after loading and removing it from the pool reached 1.4R/hr (Reference 36). The component segmentation process began with the placement of a cask liner in the reactor pool. Segmentation was performed underwater using hydraulic shears and plasma arc cutting equipment. A vacuum filtration system was used during pool cutting operations to prevent water clarity problems from developing. An overhead crane was used to assist in loading the components into a steel liner. The liner was loaded underwater with the higher activity items loaded near the center of the cask and the lower activity material loaded in the liner annulus to provide shielding. A CNS 9-120B shipping cask was used to ship the activated components to the Barnwell disposal site. Since air sampling performed while segmentation was occurring demonstrated that airborne contaminants were not produced, a confinement structure was not required (References 34 and 35).

Once the activated components are removed from the reactor pool, the water can be sampled, analyzed, and treated if necessary to meet the discharge/disposal criteria. Once the pool is drained, the structure can be characterized to determine the extent and depth of activation and contamination in the reactor pool floor, walls, and embedded beam port tubes. Characterization results may be used to select pool removal or pool decontamination based on ALARA, safety, structural, cost, schedule, and future use considerations (Reference 33).

A water jet cutting process was used to decontaminate the reactor pool at the University of Virginia Reactor Facility. The cleaning water produced by the water jet cleaning was collected, large solids settled out, and the remaining water was evaporated off the concrete and epoxy fines. The solids were dried and disposed of as low level waste. Once the pool surfaces had been cleaned to bare concrete, a structural evaluation was performed, potential leakage paths were investigated, and soil sampling under the pool floor and horizontally through the pool walls was performed (Ref. 13). Any holes drilled through the concrete need to be sealed or plugged to prevent the hole from becoming a potential pathway to the environment (Reference 33).

Contaminated pipes, drains, and conduit embedded in concrete can be decontaminated or removed. Sludge, scale, and other waste generated should be treated or stabilized and packaged to meet waste acceptance criteria at the disposal site.

If pool removal is the option chosen, the reactor pool walls and floor would be cut into large blocks and sized for packaging and disposal. Removal of materials embedded in the concrete (beam port tubes, drain pipes, conduit, etc.) is not required unless necessary to meet transportation requirements and the disposal site waste acceptance criteria (Reference 33).

**Waste Removal and Packaging**

It is important that the radioactive waste management policy and waste acceptance criteria be established before dismantling the reactor. The decommissioning and dismantling of research reactors will produce large amounts and various types of waste. However, most materials generated from dismantling fall into categories of non-radioactive waste and potentially contaminated material that must be surveyed prior to free release (Reference 28).
The majority of radioactive solid waste will be a direct result of the decontamination and dismantlement of activated and contaminated systems, structures, or components. Additional radioactive wastes will include tools and equipment that become contaminated during D&D activities and other secondary wastes. Waste disposal costs are directly related to the activity, volume, and weight of materials requiring disposal. Strategies for minimizing waste include: source segregation, reuse, decontamination, volume reduction, and waste stream segregation (Reference 33).

As waste materials are generated throughout the D&D project, the materials should be sorted by waste category and packaged appropriately for disposal. Historical records and characterization results are used to identify any potential for chemical contamination which might result in a mixed waste. Any identified chemical contamination must be isolated early in the removal process to minimize the volume of mixed waste. A thorough understanding of the packaging and transportation regulations as well as the waste acceptance criteria for the potential disposal sites is critical for waste management. For example, the paint on exterior and interior wall surfaces of Building 3042 contain lead, asbestos, and PCBs (Reference 23). Building materials coated with a paint containing PCBs may be accepted as PCB bulk product waste without a significant increase in cost for packaging, transportation, and disposal. However, PCB-containing paint that is removed from surfaces must then be stored and managed according to the Toxic Substances Control Act (TSCA) regulations for PCB waste, according to the PCB concentrations in the paint.

Water from the reactor pool and water generated as secondary waste during decontamination and dismantling activities should be characterized for suitability to be discharged directly to the on-site liquid low-level waste system. Pre-treatment of the water should be performed, as necessary, to meet the acceptance criteria of the liquid low-level waste system.

**Facility Dismantlement**

The dismantling and size reduction processes often require significant investment costs and sometimes infrastructure changes or modifications. The necessary tools and equipment for remote handling and for shielding must be available when dealing with highly activated components or with materials contaminated by strong gamma and/or alpha emitters (Reference 28). For example, dismantlement of the reactor vessel and its concrete radiation shielding would generate high potential exposure rates.

Care should be taken to retain containment systems as long as necessary and feasible. However, the containment may require changes during decommissioning as radioactive materials are removed from the facilities or as the facility is modified (in order to increase accessibility, for example). When containment related barriers or devices are removed or altered in the course of dismantling, acceptable confinement of residual radioactive materials should be implemented. Similarly, adequate containment should be planned when cutting and dismantling operations are carried out that may give rise to airborne contamination (Reference 29).

There are many available dismantling techniques applicable to reactor decommissioning. Each technique carries some advantages as well as some disadvantages in comparison with others.
For example, where remote dismantling is necessary owing to fields of high radiation, thermal cutting methods allow the use of relatively simple holding mechanisms. However, these methods generate large quantities of radioactive aerosols requiring local ventilation with filtration systems. This results in the generation of secondary wastes (Reference 29).

In contrast, mechanical cutting methods need robust and elaborate holding mechanisms, but these methods usually result in smaller quantities of secondary wastes. Underwater cutting methods have the advantage of enhanced radiation protection, because of reduced generation of aerosols and the shielding effect of the water. However, these methods require special tools and control mechanisms that can operate safely underwater and usually generate secondary wastes in the form of a liquid slurry (Reference 29).

Selection of methods and techniques to be used in safe dismantling should take into account such aspects as (Reference 29):

- Types and characteristics (size, shape, and accessibility) of materials, equipment, and systems to be dismantled
- Availability of proven equipment
- Radiation hazards to the worker and the general public (level of activation and surface contamination, production of aerosols, and dose rates)
- Environmental conditions of the workplace (temperature, humidity, etc.)
- Radioactive and non-radioactive waste produced
- Requirement for development work

Each dismantling task should be analyzed to determine the most effective and safe method for its performance. Some considerations are as follows (Reference 29):

- Equipment should be simple to operate, decontaminate, and maintain
- Effective methods for controlling airborne radionuclides should be implemented
- Effective control of discharges to the environment
- When underwater dismantling and cutting is used, provision should be made for water processing to ensure good visibility and assist in effluent treatment
- Effect of each task on adjacent systems and structures
- Waste containers, handling systems, and routes should be defined before the start of dismantling work

7.3. IDENTIFICATION OF TASKS REQUIRING REMOTE OPERATIONS FOR REACTOR FACILITY D&D

A list of typical D&D steps for a general facility are presented in the following sections, this is not a comprehensive list of activities, but it has been tailored to the D&D of reactor facilities based on information currently obtained for the ORRR.

7.3.1 Characterization

- Initial survey of accessible areas with additional surveys performed as previously inaccessible areas are made accessible
  - Radiological direct surveys to establish total level of fixed and removable surface contamination
Radiological smear surveys to establish levels of removable surface contamination
Dose rate measurements to facilitate ALARA work planning

Surveys of a typical radiological facility are performed with personnel carrying hand-held instruments. However, such surveys would not be possible in all areas of a reactor facility due to the high dose rates associated with certain areas, especially the reactor vessel and the highly activated components stored in the reactor pool. In these instances, remotely operated survey instruments would be required to collect data on the removable and total surface contamination levels as well as dose rate measurements.

- Identify type, quantity, condition, and location of radioactive materials and other hazardous materials
  - Visual survey and samples for analysis of any water, sludge, or residues
  - Visual survey and samples for potential lead, PCB, asbestos, or other hazard-containing materials

Similarly, remotely deployed visual inspection devices and sensor technologies for the characterization of hazardous substances would be necessary to characterize areas of the reactor facility where dose rates preclude human entry. Remotely operated sensor technologies capable of in-situ characterization for PCBs, lead, and other hazardous constituents would be especially valuable.

- Surveys and samples to characterize waste streams for segregation, packaging, and transportation purposes
- Surveys and samples for analysis to meet waste acceptance criteria (WAC) for potential disposal sites

Where in-situ measurements of radiological and hazardous substances are not available or sufficient to clearly delineate the packaging and transportation requirements or to meet the disposal site WAC, the collection of physical samples for laboratory analysis is required. Remotely deployed sampling techniques would be necessary in the reactor facility areas with excessively high dose rates that prevent personnel sample collection.

- Structural assessment of facility walls, stairs, ladders, elevated areas, and roofs to determine structural condition and load-bearing capacity

Remotely operated visual inspection devices would be necessary to complete a structural assessment in any areas were human access is restricted due to structural integrity concerns as well as radiological dose rates. Of specific concern are stairs, ladders, elevated areas, and roofs where structural degradation could be especially dangerous.

### 7.3.2 Decommissioning
- Pre-mobilization
Pre-mobilization activities would not require remote operations.

- Mobilization

Mobilization activities would not require remote operations.

- Preliminary site and facility preparation

Preliminary site and facility preparation would not require remote operations.

- Initial facility decontamination and stabilization
  - Asbestos abatement
  - Removal of loose equipment, stored items, miscellaneous materials
  - Removal of residue and debris, including any liquids, sludges, and solids remaining in tanks, sumps, piping, or other equipment
  - Removal of non-radiological hazardous materials from facility
  - Decontamination and stabilization of radioactive contamination on general accessible facility surfaces

Minimal remote operations would be expected during initial facility decontamination and stabilization. These activities generally impact accessible areas without excessive radiological or hazardous concerns. Possible exceptions include asbestos abatement and the removal of non-radiological hazardous materials if these materials are located in areas of high dose rates.

- Subsequent decontamination and dismantlement
  - Dismantle and remove tanks, pumps, and accessible piping
  - Dismantle and remove fixed equipment and associated plumbing, ductwork, and drainlines
  - Dismantle and removal of highly activated components
  - Dismantle and remove of reactor
  - Drain and flush all process piping to the reactor area
  - Decommissioning of reactor pool
  - Decontaminate or remove embedded piping
  - Dismantle and remove remaining shielding (lead/steel/concrete), piping, and physical support structures around the perimeter of the reactor, hot cells, and pool
  - Apply a fixative to the interior surfaces of the hot cell, size reduce and remove hot cells, pool bridges, tanks, pool, and related infrastructure items.
  - Dismantle and remove ventilation system

Remote operations will be critical to the management of the highly activated components stored in the reactor pool as well as the decommissioning of the reactor pool structure. Underwater segmentation of the highly activated components and subsequent packaging of the components into a cask liner and shipping cask as well as the provision of sufficient shielding would require remotely operated systems. Once the highly activated components are removed from the pool
and the water drained, the characterization, decontamination, stabilization or removal of the pool structure may also require remote operations, depending on the results of the characterization.

Remote operations would be required during the decontamination and dismantlement of highly contaminated and activated components, equipment, piping, and shielding. The reactor vessels and its internals are especially problematic with very high dose rates expected. In addition, the dismantlement of containment and shielding barriers can be expected to increase potential worker dose rates.

- Dismantlement/demolition of reactor building and other remaining structures

Dismantlement and demolition of buildings and structures would be performed remotely.

- Stabilization of residual contamination

Access and radiological dose would both be a concern for below slab structures. Remote operations would be needed when either of these concerns precludes the presence of personnel to decontaminate, stabilize, plug and grout.

- Waste management

Waste management activities of highly contaminated materials and the highly activated components stored in the reactor pool would need to be remotely operated, including the characterization, segregation, size reduction, and packaging of these materials.

- Final compliance verification survey and documentation

Final compliance verification survey and documentation would not require remote operations.

- Demobilization

Demobilization activities would not require remote operations.

7.3.3 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 from this particular facility. 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.
7.4. IDENTIFICATION OF TECHNOLOGY GAPS IN EXISTING TECHNOLOGIES

Final D&D of Building 3042 should be able to be completed using currently available technologies. For example, long reach tools and commercially available underwater cutting tools for size reduction of the activated metal components in the pool. No gaps have been identified for remotely operated technologies.
8. Remote Operations for Pipeline D&D and Soil Remediation

The intent of this section is to evaluate and outline the technical requirements and possible technologies for use in the excavation of contaminated soil and underground pipelines at the ORNL. Many aggressive remotely operated remediation technologies have been used in the past.

Conventionally remotely operated excavation-type machinery has played a significant role in pipeline D&D and remediation of contaminated soil. This method has been used commonly for the removal of contaminated soil and remediation of underground appurtenances at hazardous waste sites across the DOE complex. Excavation is carried out by using heavy construction equipment to dig out contaminated soil and debris and place them into shipping containers. The containers are then shipped to an appropriate site for treatment or disposal, which may include designated onsite locations. Backfilling the excavation is required and necessitates the availability of clean backfill material for careful and safe placement so that cross-contamination is avoided. All of these activities require extensive physical access to the contaminated area.

The primary advantage of mechanical excavation is that source materials are taken out of the groundwater system very quickly. Migration of contaminants out of the source area is cut off as soon as excavation is finished. Excavation may be inexpensive compared to in situ treatments, and is often preferred by DOE and other stakeholders because of its perceived simplicity.

The areas under review are the underground soil and pipelines between 3515 and 3517 facilities and the soil under the 3047, 3025E and the 3019A facilities. The following assumptions were used as a baseline for the development of this section:

- The facilities and building foundations have been removed prior to the soil and pipeline removal campaigns.
- Maximum dose rates under the top soil layer preclude manual digging or excavation.
- Mechanical dry retrieval of the soil and pipelines is the selected method for removal of the source material. Other remotely operated “pump and treat”-type technologies may play an important role for soil removal if an hydraulic liquid containment barrier is present to prevent additional ground water contamination, but these have not been considered here.
- Clean up of the soil is solely based on radiological contamination. If chemical contaminants are present, other treatment technologies may be necessary.

For a mechanical excavation to succeed it is essential to know the size of area to be remediated and the depth and general distribution of the source term materials. This suggests an extensive source characterization effort prior to the commencement of excavation. Incomplete or inadequate pre-excavation investigations may result in either a portion of the source zone being left in place or excess material being removed. Characterization is also necessary later in the D&D process to verify that all of the source material has been removed and to classify materials.
encountered during the excavation as contaminated or uncontaminated. Additional information beyond the size and shape of the contamination zone, such as basic geological information, is also important to predicting the success of excavation. For example, determination of whether bedrock is present will determine the difficulty of the excavation and the type of equipment required. Excavation below the water table is difficult due to the influx of groundwater, which is contaminated by contact with the source material and must be treated. Saturated sandy soils tend to liquefy during excavation and can dramatically increase the complexity of excavation. In some cases sheet piling or dewatering systems must be employed around the source materials to reduce the water flow and to stabilize the side walls and bottoms of excavations. Finally, the ability to completely excavate source term material is highly dependent on having adequate physical access to the source zone. If physical access is restricted by nearby foundations or buildings, complete removal may not be possible without structural damage to surrounding buildings.

Many of the disadvantages associated with excavation can be overcome through the use of remotely operated technologies. Some of these disadvantages include:

- Need for a controlled area that can receive the excavated contaminated material.
- Industrial hazards associated with working with heavy excavation equipment.
- Worker exposure to radiological and other hazardous materials.
- Inability to predict source term or other hidden hazardous material volumes.
- When water tables are lowered for excavation, it is possible that dense non-aqueous phase liquid (DNAPL) will be mobilized and will flow into the excavation, creating a worker exposure hazard.

In order to reduce such hazards, remotely operated technologies, (e.g. excavators) provide a safe alternative approach to improving worker safety and eliminating delays due to unforeseen difficulties which may be encountered after field operations begin. Several applicable remote technologies for excavation of contaminated soil and buried appurtenances are listed in the technology summary table in Appendix 1.
9. Conclusion

NVE and FIU-ARC have conducted a review of several facilities slated for D&D at ORNL and identified many remotely operated technologies that are commercially available as tools for completing the most hazardous activities. Those technologies have been catalogued and tabulated in Appendix 1. Additionally, internet links to active university robotics programs which may provide support to development of remote technologies for D&D tasks have been listed in Appendix 2. Finally, a list of internet links to websites related to D&D of facilities is included in Appendix 3.

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.
10. References

3. Florida International University, Hemispheric Center for Environmental Technology, Comprehensive Work Plan for the D&D of the Metal Recovery Facility (MRF), Building 3505 at ORNL.
6. Irradiated Fuels Examination Laboratory (Building 3525).
9. LMDI – Reported Legacy Challenges, updated on 04/06.
15. Building 3517 – IH Data Central Campus, 8/05.
34. P.F. Ervin, “Decommissioning Results and Lessons Learned at the University of Virginia Reactor Facility”, Waste Management 2004 Conference.
36. Email for P. Shoffner to J. Faldowski, subject: “UVA reactor pool component information,” February 20, 2007
Appendices

Appendix 1  Available Remote Technologies for Facility D&D Applications
Appendix 2  Universities with Robotics Programs
Appendix 3  Website Links Related to D&D
Appendix 1  Available Remote Technologies for Facility D&D Applications
## 1.1 Gamma Rover Crawler (Grover)

The Gamma-Rover is a remotely-operated, mini-tracked crawler that has been assembled to obtain visual characterization and dose profiling data in contaminated ventilation ducting that exhausts air from hot cells. It is an electrically powered, dual-tracked crawler equipped with gamma radiation sensors and video-camera. The deployment platform is made of 1-inch steel to provide radiation shielding. Gamma Rover is a skid-steered vehicle, whereby turning is accomplished by having one track move forward while the other track moves backward or remains stationary. The crawler has been designed to drive and automatically track in round duct. However, to provide an indication of stability, a white-line dangle meter is provided in the forward directed camera; if the vehicle should tilt, this line moves to either the lower right or lower left. A hand-held pendant has rocker switches for vehicle/camera control and a master on/off switch. A second pendant provides controls for a winch/hoist drive.

Deployed at Hanford’s Building 324 B-Cell exhaust ducting characterization as part of the Building Stabilization/Deactivation Project with a device to visually inspect and characterize the radiological conditions in the B-Cell ventilation exhaust duct.

### Benefits
- Ability to remotely characterize ducting structures. The system is remotely operated therefore increasing ALARA principles.
- The crawler has been designed to drive and automatically track in round duct. However, to provide an indication of stability, a white-line dangle meter is provided in the forward directed camera; if the vehicle should tilt, this line moves to either the lower right or lower left.

### Limitations
- Operator interface was cramped and tiring for operators.

### Potential Application(s) at ORNL
- HVAC and large piping Characterization (hot spot identification)

### Vendor/Website
- Mechanical Solutions Group at Pacific Northwest National Lab (PNNL)

### Photograph

![Gamma Rover Crawler (Grover)](image1.jpg)

## 1.2 Remote Characterization System (RCS) OST No. 2178

The RCS consisted of a Remotec Andros Mark VI™ with camera and lights, modified to incorporate a gamma detector, a smear sample pad, and a deployment station, which was designed to manage deployment of the Andros hardware as it was lowered into the tunnels. The specific tasks for the Andros hardware included traversing the entire length of the tunnels to be inspected, collecting video footage, documenting the physical condition of the tunnel, collecting gross gamma readings during the entire survey, collecting limited smear samples, and returning safely for extraction from the tunnel.

Hanford: deployed at U-plant under CDR. Successfully met all deployment objectives.

### Benefits
- Able to collect visual and characterization info for confined spaces; controlled remotely by operator. Can also be used for limited sample/labra collection; easy to deploy.

### Limitations
- Operator interface was cramped and tiring for operators.

### Potential Application(s) at ORNL
- Process cell inspection and characterization, hot cell inspection.

### Vendor/Website
- This remote characterization system was developed by the Department of Energy Robotics Technology Development Program (RTDP) primarily at PNNL with support from the Idaho National Engineering and Environmental Laboratory and the Oak Ridge National Laboratory.

### Photograph

![Remote Characterization System (RCS)](image2.jpg)

## 1.3 Remote Underwater Characterization System (RUCS) OST No. 2151

The Remote Underwater Characterization System (RUCS) is a small, remotely operated submersible vehicle intended to serve multiple purposes in underwater deactivation and decommissioning (D&D) operations. It is based on the commercially available "Scallop" vehicle produced by Inuktun Services, Ltd., British Columbia, Canada. The U. S. Department of Energy Office of Science and Technology Robotics Crosscutting Program (Rbx) modified the commercially available system to add radiation sensors, auto-depth control, and add vehicle orientation and depth monitoring at the operator control panel. The RUCS is designed to provide visual and gamma-radiation characterization, even in confined or limited-access areas.

INEEL: deployed at TRA-660 facility canal; ITSR DOE-EM-0457 “Remote Underwater Characterization System (RUCS)” September 1999

### Benefits
- Low-cost; easily deployed; allows mapping fuel pool and facility canal walls without human intervention.

### Limitations
- Limited payload capability; cannot access narrow spaces.

### Potential Application(s) at ORNL
- Fuel pool inspections, underwater inspections, confined space inspections.

### Vendor/Website
- National Labs and Industry and Inuktun Services LTD

### Photograph

![Remote Underwater Characterization System (RUCS)](image3.jpg)
## RadScan 700

**Description:** RadScan 700 is a gamma spectroscopy unit. It can be deployed from overhead crane or robotic platform. RadScan™ 700 can be automated from overhead crane, in Process Mechanical Cell (PMC), Gamma-Rays Imaging System (ITSR), DOE/EM-500, November 1998. West Valley-deployed, via overhead crane, in Process Mechanical Cell (PMC). Gamma-Rays Imaging System, ITSR, DOE/EM-5009, November 1998.

**Applications and Results:** West Valley-deployed, via overhead crane, in Process Mechanical Cell (PMC). Gamma-Rays Imaging System, ITSR, DOE/EM-5009, November 1998. Allows for identification of "hot spots" as well as identification of different radionuclides present. Minimize radiation exposure; easy to deploy.

**Benefits:** The major concern encountered during the demonstration was maneuvering the unit in congested areas. Due to physical size and geometry of the RadScan 600 and measurement location geometry, near-corner and wall measurements could not be easily obtained. The demonstrated innovative system is not suitable for surveying areas with low levels of radiation, such as for release surveys.

**Limitations:** The improved accuracy and reliability of the system can provide the public with increased confidence that the various radiation surveys are being conducted in a professional manner. The rich display capabilities of MACS allow various visual presentation of the surveys results, which can increase the public acceptance of the data. The color graphic capability of MACS show the locations and quantities of contamination is a significant asset. It is much easier to analyze data from a color map than from pages of coordinate survey data, with much less likelihood of missing data from the color map. MACS has the potential to have widespread use in characterization surveys. Due to the nature of the final releases surveys, MACS may be used to supplement manual surveys, but will not be able to replace the need for final verification of release status by manual survey. MACS is ideal for large open areas without obstacles or irregular geometries. MACS can be programmed and allowed to run with minimal operator input, reducing dose to the HP personnel while producing easy-to-read color maps of characterization data.

**Vendor/Website:** BNFL, http://apps.ens.doe.gov/ost/publitsr/itsr1793.pdf

## Mobile Automated Characterization System (MACS)

**Description:** The Mobile Automated characterization System (MACS) has been developed by Oak Ridge National Laboratory and the Savannah River Technology Center for the U.S. Department of Energy's Robotics Technology Development Program. MACS are a commercially available, battery-powered, autonomous robot base supplemented by a laser positioning system and a scintillation detector array. MACS can detect alpha and beta contamination, and moves over floors at a speed of one inch per second. MACS was designed to automate the collection, storage and analysis of large, open floor areas, relieving the HP personnel of this portion of the floor characterization task. MACS does not require a dedicated full time operator and can be set up by the normal HP staff to survey the open areas while other techniques are used on the more constrained areas. MACS are designed for unattended operation and has safety and operational monitoring functions which will notify the system down if any difficulties are encountered.

**Applications and Results:** Demonstrated on 5/15/96. OST No. 1798, DOE/EM 0413. "Mobile Automated Characterization System" April 1999

**Potential Application(s) at ORNL:** Hot cell, process cell and research reactor gamma emitting source identification

**Vendor/Website:** N/A, the Mobile Automated Characterization System (MACS) has been developed by Oak Ridge National Laboratory (ORNL) and the Savannah River Technology Center (SRTC) for the U.S. Department of Energy’s (DOE) Robotics Technology Development Program as an automated floor surface Contamination characterization system. http://apps.ens.doe.gov/OST/pubs/itsr1798.pdf

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**Photograph:**

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**Index Page 75 of 116**
<table>
<thead>
<tr>
<th>Index</th>
<th>Technology</th>
<th>Description</th>
<th>Previous Applications and Results</th>
<th>Benefits</th>
<th>Limitations</th>
<th>Potential Application(s) at ORNL</th>
<th>Vendor/Website</th>
<th>Photograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.6</td>
<td>Ripple</td>
<td>Ripple is used to traverse the interior of pipe networks. The robot uses extendible feet to brace itself against the pipe and, an inchworm like motion, move along the pipe length. It can be equipped with a variety of inspection sensors and tools including UT Sensors, Flaw leakage sensors, manipulators, machining equipment or welders. A prototype of the concept was built and tested in mock up to prove the viability of the concept. A conceptual design of a variation of Ripple was developed for NASA for inspection of ductwork inside the space shuttle orbiter. This version used inflatable bladders instead of feet, in order to operate inside the Kevlar ductwork in the shuttle. CAUTION: Not readily available.</td>
<td>N/A</td>
<td>N/A</td>
<td>Not readily available.</td>
<td>Pipe inspection</td>
<td>RedZone Robotics 484 West Seventh Avenue Homestead, Pa.  15120 Phone (412) 476-8980 Fax (412) 476-8981 <a href="http://www.redzone.com/ripple">http://www.redzone.com/ripple</a></td>
<td><img src="Image" alt="Image" /></td>
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<tr>
<td>1.7</td>
<td>Versatrax 300™ VLR</td>
<td>The solution to long range inspection challenges: inspect more than a mile of pipe in a single run. The Versatrax 300™ is compatible with piping of 100 mm / 12 inch external diameter and greater. All Inuktun Versatrax units are configurable for round pipe or flat surface operation. The vehicles are adjustable for a range of pipe diameters. Inuktun products and custom solutions are suitable for a broad range of applications in many different industries. Inuktun's high-quality cameras and crawlers provide detailed video output using variable lighting with pan, tilt and zoom controls.</td>
<td>The Versatrax 300 has performed: Long-run pipe inspection for operations over 6,000 ft.</td>
<td>Durable, Powerful and reliable, Bright illumination and high quality video for precise assessments Remotely or auto focus to decrease foaming Repair facing camera for tighter tachment Modular design for on-site customization Intuitive controls for ease of operation</td>
<td>N/A</td>
<td>Pipe inspection</td>
<td>Inuktun Services LTD Suite C 2560 Kenworth Road Nanaimo, BC Canada V9T 3M4 toll-free 1.877.468.5886 - 1.877.INUKTUN telephone 1.250.729.8080 fax 1.250.729.8077 E-mail: <a href="mailto:inuktun@inuktun.com">inuktun@inuktun.com</a> <a href="http://www.inuktun.com/versatrax300v.htm">http://www.inuktun.com/versatrax300v.htm</a></td>
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<td>1.8</td>
<td>Versatrax 150™</td>
<td>The Versatrax 150™ is a modular, long range internal pipe inspection system capable of operation within a variety of pipe sizes from a minimum internal diameter of 150 mm / 6 in. All Inuktun Versatrax units are configurable for round pipe or flat surface operation. The vehicles are adjustable for a range of pipe diameters. Inuktun's high-quality cameras and crawlers provide detailed video output using variable lighting with pan, tilt and zoom controls.</td>
<td>The Versatrax 150 has performed inspection of: Sewer and storm drains Hydroelectric pipe and infrastructure Steam headers Tanks and pressure vessels Oil &amp; gas refineries and pipelines Pulp and paper Mining</td>
<td>Waterproof to 30 m / 100 feet Long range inspections to 457 m / 1500 ft Low maintenance Pan Tilt and Zoom, high resolution color camera option for 360 view and close-ups Intuitive controls for ease of operation Clutchless tracks for easy retrieval Universal video outputs for compatibility with recording devices</td>
<td>N/A</td>
<td>Pipe inspection</td>
<td>Inuktun Services LTD Suite C 2560 Kenworth Road Nanaimo, BC Canada V9T 3M4 toll-free 1.877.468.5886 - 1.877.INUKTUN telephone 1.250.729.8080 fax 1.250.729.8077 E-mail: <a href="mailto:inuktun@inuktun.com">inuktun@inuktun.com</a> <a href="http://www.inuktun.com/versatrax.htm">http://www.inuktun.com/versatrax.htm</a></td>
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<td>1.9</td>
<td>Versatrax 100™</td>
<td>The Versatrax 100™ is a miniature crawler system capable of internal inspection within extremely small pipe sizes from a minimum internal diameter of 100 mm / 4 in. Despite its compact size, this system has the power to penetrate up to 100 m / 330 ft of pipe and overcome obstacles and offset joints. All Inuktun Versatrax units are easily configurable for round pipe or flat surface operation. The vehicles are adjustable for a range of pipe diameters. Inuktun products and custom solutions are suitable for a broad range of applications in many different industries. Inuktun's high-quality cameras and crawlers provide detailed video output using variable lighting with pan, tilt and zoom controls.</td>
<td>The Versatrax 100 has performed inspection of: Sewer and storm drains Air ducts Steam headers Tanks and pressure vessels Oil &amp; gas refineries and pipelines Pulp and paper Mining</td>
<td>Despite its compact size, this system has the power to penetrate up to 330 ft of pipe and overcome obstacles and offset joints. Some other benefits include: Steerable in the parallel configuration within 20 to 60 cm / 8 to 24 in diameter pipe Waterproof up to 30 m / 100 ft</td>
<td>N/A</td>
<td>Pipe inspection</td>
<td>Inuktun Services LTD Suite C 2560 Kenworth Road Nanaimo, BC Canada V9T 3M4 toll-free 1.877.468.5886 - 1.877.INUKTUN telephone 1.250.729.8080 fax 1.250.729.8077 E-mail: <a href="mailto:inuktun@inuktun.com">inuktun@inuktun.com</a> <a href="http://www.inuktun.com/versatrax100.htm">http://www.inuktun.com/versatrax100.htm</a></td>
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<td>Index</td>
<td>Technology</td>
<td>Description</td>
<td>Previous Applications and Results</td>
<td>Benefits</td>
<td>Limitations</td>
<td>Potential Application(s) at ORNL</td>
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<td>1.10</td>
<td>Internal Duct Characterization System (Tech ID 42)</td>
<td>The Internal Duct Characterization System (IDCS) consists of a control station, a reel-mounted tether for data communication, video, and power; and the duct crawling vehicle. The IDCS vehicle can travel over 200 feet in round ducts 6 inches in diameter and larger and in rectangular ducts 6 inches square and larger. The vehicle visually inspects the interior condition of ducts using a high-resolution color video camera and has an integrated radiation sensor to detect significant levels of radioactivity. The entire vehicle is made from stainless steel and is designed to be decontaminated. The IDCS system also provides limited contaminant sampling and decontamination capabilities.</td>
<td>N/A</td>
<td>Ability to be decontaminated.</td>
<td>N/A</td>
<td>Pipe inspection</td>
<td>This remote characterization system was developed by the Department of Energy Robotics Technology Development Program (RTDP) primarily at PNNL with support from the Idaho National Engineering and Environmental Laboratory and the Oak Ridge National Laboratory. <a href="http://www.robotics.osti.gov/techid-42-dd.htm">http://www.robotics.osti.gov/techid-42-dd.htm</a></td>
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<td>Index</td>
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<td>2.1</td>
<td>WallWalker OST No. 1476</td>
<td>The locomotion system utilizes two gear motors located in the upper corners of the wall to feed cable to a central module. A computer controls the length of the cables, and with the help of trigonometry, moves the central module over a specified path at a specified velocity. The system elevates a giant, wall-sized plotter that is configurable for scabbling operations, hydroblasting, carbon dioxide, baking soda, chemicals, lasers, flashlamps, abrasive blasting technology, and other cleanup applications. Process modules are available to perform 100% skid-free surface preparation, point application, and inspection tasks. Built-in engineering controls keep hazardous emissions, such as lead-based paints, PCBs, and radioactivity, below regulatory limits.</td>
<td>Hammered C Reactor, FIU Test Facility</td>
<td>Multiple uses: cutting, decontamination and characterization; good position accuracy; easy to learn operation.</td>
<td>The Wall Walker model demonstrated was specified to reach wall dimensions of approximately 15 m (50 ft). Since the system would be useful for a variety of tools and Pentek, Inc. has designed only a few holders, additional holders would need to be developed to increase the utility of the system. This technology is not well suited to walls that have many protrusions; rather, it works better on flat or slightly curved surfaces. System requires additional support and rigging.</td>
<td>Remote system for decontamination of wall surfaces. This can potentially be used in all three types of facilities where concrete and/or metal surfaces are contaminated.</td>
<td>Pentek, Inc. 1026 Fourth Avenue Coraopolis, PA 15108 Phone: +1 (412) 262-0725 Fax: +1 (412) 262-0731</td>
<td><img src="http://www.pentekusa.com/wwalker.png" alt="WallWalker OST No. 1476" /></td>
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<tr>
<td>2.2</td>
<td>Climbing Machine with Mechanical Abrader</td>
<td>Held to the surface by vacuum force, the machines adhere to essentially any hard surface: metal, concrete, brick, etc. The patented, highly flexible seal ensures the machine is securely adhered as it locomotes over surface obstacles such as bolt heads, plates, weld seams or virtually any surface irregularity.</td>
<td>Demonstrated at Savannah River Site</td>
<td>System operates on vertical surfaces without support. Can transition from horizontal to vertical surfaces.</td>
<td>Limited testing availability, no previous deployments in high rad areas.</td>
<td>Remote system for decontamination of floor, wall and ceiling surfaces. This can potentially be used in all three types of facilities where concrete and/or metal surfaces are contaminated.</td>
<td>International Climbing Machines (ICM) 969 East Shore Drive Ithaca, NY 14850, USA. 607.288.4004</td>
<td><img src="http://www.icm.cc/" alt="Climbing Machine with Mechanical Abrader" /></td>
</tr>
<tr>
<td>2.3</td>
<td>Robotic Climber II-1 Model</td>
<td>A remote controlled, free climbing robot using Ultra High Pressure Water Jetting within a contained vacuum shroud. This technology employs a self-propelled, joy-stick operated robotic device designated for surface decontamination, coating removal and concrete &quot;scabbling&quot;. Variable water pressures (0 to 36,000 PSI) at low consumption rates is the medium used by the II-1 model. Adhesion to the surface is achieved by using a vacuum, enabling the robot to perform on vertical or inverted surfaces as well as horizontal flats and sloped surfaces. This vacuum also serves to capture the water from the removal process as waste. Once captured, the waste/water is transported to a holding tank for future treatment and processing. The Robotic Climber is a work platform given mobility with two tank-like tracks powered by two independent motors. An Ultra High Pressure rotary nozzle with eight to fourteen spray tips housed beneath the robot spins at a high speed delivering the water jet to the surface which cuts an 8 inch path. A vacuum chamber houses the spray tips and is encircled with a seal which holds the robot to the surface and prevents the escape of water and waste into the environment. Dimension of technology (L x W x H): 2' X 2' X 18&quot; The weight of the technology (lbs): 67</td>
<td></td>
<td>Unit is remote controlled and easy to operate. Unit is not labor intensive. Unit can be easily transferred to another surface media. Unit can operate in wet conditions. Vacuum unit minimizes need for respiratory protection for operating personnel. Vacuum is self-contained and separates solid from water.</td>
<td>Operator has to secure the hoses when working on floors. Technology uses water and creates a considerable amount of secondary waste. Water is not recycled. The operator station has to be located within 500 ft of the robot. Ideal for flat surfaces but it is not functional on contaminated concrete floors, wall surfaces. Big Rock Point facility, FIU Test Facility</td>
<td>Remote system for decontamination of floor and wall surfaces.</td>
<td>Bartlett Nuclear, Inc. P.O. Box 1800 60 Plymouth Industrial Park Road Plymouth, Massachusetts, 02360</td>
<td><img src="http://www.bartlettnc.com" alt="Robotic Climber II-1 Model" /></td>
</tr>
</tbody>
</table>

**NuVision Engineering, Inc.**

Decontamination

Potential Application(s) at ORNL

Vendor/Website

Photograph
2.4 MOOSE OST No. 2099

The MOOSE is a remotely operated floor scabbler designed to scarify large concrete floor slabs in environments that require strict control of airborne contamination and debris. The MOOSE scabbler utilizes a highly effective, single-step floor scarification process with an integrated vacuum control. The scabbling head houses seven independent reciprocating tungsten carbide-tipped bits to remove protective coatings and concrete substrates. The bits pulverize the surface by delivering 1,200 hammer impacts per minute through pistons driven by compressed air. Dust and debris are captured by the on-board 23 gallon HEPA vacuum system. The six-wheel chassis is powered by dual DC motors. Applications include the safe, efficient removal and collection of radioactive materials, PCBs, chemical residues, heavy metals, and other hazardous materials from manufacturing and utility facilities, military bases, and environmental restoration sites. ANL: CP-5 Research Reactor removal of concrete from service floor of research reactor, FIU Test Facility

The MOOSE was operated from a control panel outside of the demonstration area connected by a 50-ft tether allowing the operator to work without wearing PPE. However, a second operator, wearing PPE, was required with the MOOSE to rearrange hoses. The MOOSE was very maneuverable. The cost analysis shows utilizing the MOOSE to decontaminate floor areas greater than 2,100 ft\(^2\) should result in cost savings over the baseline technology. Contamination was demonstrated to be reduced by a factor of 30.

Remote system for decontamination of floor surfaces. This can potentially be used in all three types of facilities where concrete floors are contaminated.

Pentek, Inc.
1026 Fourth Avenue
Coraopolis, PA 15108
Phone: +1 (412) 262-0725
Fax: +1 (412) 262-0731
http://www.pentekusa.com

2.5 En-Vac Robotic Wall Scabbler OST No. 2321

The En-Vac Blasting System is an abrasive blasting technology consisting of the En-Vac robot, a recycling unit, a filter, and a vacuum unit. The System uses abrasive steel grit or steel shot as the surface removal media and can scabble, via the robot, on both horizontal and vertical surfaces. The main components of the En-Vac robot are the blast housing, lip seal, four motor and wheel drive-steer assemblies, blast nozzle with oscillator motor, and vacuum control device. The robot attaches to the working surface by vacuum contained in the sealed blasting chamber. The vacuum unit creates the vacuum to prevent any fugitive dust or grit emissions from the working surface of the blasting operation. The recycling unit continuously provides abrasive grit to the robot through the blast hose. Spent blast grit and blast residue are returned from the robot to the recycling unit through the vacuum hose. The recycling unit processes the spent abrasives and separates the blast residue. Blast residues are collected and stored for later disposal. The En-Vac system is heavy, with the heaviest piece weighing 6,800 pounds. All of the equipment is capable of being lifted by industrial forklift or mobile carry crane

INEEL: Test Area North (TAN) removal of paint and concrete from Deco Shop walls. FIU Test Facility

The En-Vac Blasting System performed five times faster and produced less debris on the floor than the baseline technology. Workers received lower radiation exposure due to less time spent in contaminated areas. The En-Vac Blasting System also has the capability to scabble deeper than the baseline technology.

Cannot scabble close to obstructions; very expensive, therefore more cost-effective for large surface areas. System requires additional support and rigging.

Remote system for decontamination of floor and wall surfaces. This can potentially be used in all three types of facilities where concrete and/or metal surfaces are contaminated.

MAB-CON, Inc.
9970 N.REQUIRED ST.
Portland, Oregon
United States 97260
Phone: (503) 285-5871
Technology maybe available through Mitsubishi Heavy Industries in Japan.
## 3.1 Dual Arm Work Platform Teleoperated Robotics System

**OST No:** 1787  
**DOE/EM-0389**

<table>
<thead>
<tr>
<th>Description</th>
<th>Previous Applications and Results</th>
<th>Benefits</th>
<th>Limitations</th>
<th>Potential Application(s) at ORNL</th>
<th>Vendor/Website</th>
</tr>
</thead>
</table>
| The DAWP manipulator standard, commercially available tools (i.e., circular saws, Jackhammers, etc) using two Schilling Titan III hydraulic, teleoperated manipulator arms that were controlled from a remote location. At the CP-5 reactor facility, the two arms were mounted to a steel work platform (DAWP) designed to hold the associated tooling, utilities, and cameras supporting the operation of the manipulator arms and providing a sturdy base for lifting the assembly into the reactor assembly using the facility's polar crane. Once positioned the system segmented, dismantled and moved the radioactive material to a transfer canister. The Titan III manipulator arms are made from titanium and stainless steel. The arms provide six degrees-of-freedom and are powered by a 3000-psi hydraulic system. Each arm is capable of lifting 240 lbs. The grippers on the arms are capable of exerting a 1000 lb. crushing force and a rotational torque of 75 lb-ft. | Reduced personnel exposure to radiation. The system showed it could perform extremely delicate and intricate operation. DAWP is quite efficient in reducing the complexity down to a well-managed, concise operating structure. One operator working in an adjacent control room typically controlled the DAWP. In this way personnel could maintain a safe distance from the hazardous environment. | Although the DAWP is a viable tool, it is not a commercially available product at this time. The water-glycol used as hydraulic fluid is corrosive to electrical connections internal to the manipulator. | Demanlement of hot cell internal components may require the use of remote operated equipment. Crane mounted robotic manipulators can potentially be used for this operations. | National Laboratories and Industry Manufacturers  
http://www.dandd.org/TechnologyFactSheet.aspx?TechnologyID=69 | ![Photograph](Image) |

### Potential Application(s) at ORNL
- Reduced personnel exposure to radiation.  
- The system showed it could perform extremely delicate and intricate operation.  
- DAWP is quite efficient in reducing the complexity down to a well-managed, concise operating structure.  
- One operator working in an adjacent control room typically controlled the DAWP. In this way personnel could maintain a safe distance from the hazardous environment.

### Limitations
- Although the DAWP is a viable tool, it is not a commercially available product at this time.  
- The water-glycol used as hydraulic fluid is corrosive to electrical connections internal to the manipulator.

### Benefits
- Reduced personnel exposure to radiation.
- The system showed it could perform extremely delicate and intricate operation.
- DAWP is quite efficient in reducing the complexity down to a well-managed, concise operating structure.
- One operator working in an adjacent control room typically controlled the DAWP. In this way personnel could maintain a safe distance from the hazardous environment.

### Potential Application(s) at ORNL
- Dismantlement of hot cell internal components may require the use of remote operated equipment.  
- Crane mounted robotic manipulators can potentially be used for this operations.

### Vendor/Website
- National Laboratories and Industry Manufacturers  

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## 3.2 Cybernetix Robotic Work Platform

- A robotic work platform that is designed to provide remote access to hot cell floors, walls, ceilings, and below-grade pits.  
- The work platform and its 3-AXIS robotic arm can be deployed via an overhead crane, a 16-foot tall TOTEM mast, or a rectangular support structure.  
- Deactivation tools and end-effectors can include: grippers, impact wrenches, drills, saws, pipe cutters, decontamination equipment, grinders, and characterization sensors.

### Previous Applications and Results
- Hanford: Used to support Bldg 324’s Phase-I clean-out; specifically for the pipe trench. Used to cut and remove process piping, connectors, drip pans and condensers; removing contaminated items; scraping and scooping within the trench. Legacy crane and manipulators found ineffective in supporting the demands of D&D activities. Plans were made for this system to continue to be used in 324 Bldg clean-out.

### Benefits
- Higher payload capacity than available MSMs; able to reach locations MSM and crane cannot reach.
- Onboard lighting and video provide visual access to operator.
- Maximum payload capacity is 200 lbs. Expensive.

### Limitations
- Several cells (Cells 11E and 11W, Cell 12, Cell 13, Cell 14E, Cell 18) in Building 3517 are highly contaminated and remote technologies would apply for removing equipment, size reduction, sorting/segregating, and initial decontamination efforts for metal and concrete surfaces. Stainless steel liners are present in Cells 1-15, the liner surfaces would need to be remotely inspected for contamination and decontaminated accordingly.

### Potential Application(s) at ORNL
- Fuel pool clean out and inspection.

### Vendor/Website
- Cybernetix  
36 Boulevard des Oceans  
Marseille, France 13275  
Phone: (+33) 91 29 75 53  
Fax: (+33) 91 29 75 90  
www.cybernetix.fr  

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## 3.3 PERCHE: Underwater pool manipulator

- The pool manipulator Perche Romain is designed to pick up and move objects up to 5 daN and carry out remote underwater inspection up to a depth of 20 m. It is easily installed on all overhanging footbridge pools. Degrees of movement are obtained by a combination of the crane and the footbridge on which it is installed (x, y, z) and the electrical movements of the manipulator arm (elbow, azimuth, long elevation, long rotation).
- Can be used as a carrier for special tools.

### Previous Applications and Results
- France

### Benefits
- N/A

### Limitations
- N/A

### Potential Application(s) at ORNL
- Fuel pool clean out and inspection.

### Vendor/Website
- Cybernetix  
36 Boulevard des Oceans  
Marseille, France 13275  
Phone: (+33) 91 29 75 53  
Fax: (+33) 91 29 75 90  
www.cybernetix.fr  

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<table>
<thead>
<tr>
<th>Index</th>
<th>Technology</th>
<th>Description</th>
<th>Previous Applications and Results</th>
<th>Benefits</th>
<th>Limitations</th>
<th>Potential Application(s) at ORNL</th>
<th>Vendor/Website</th>
<th>Photograph</th>
</tr>
</thead>
<tbody>
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<td>3.4</td>
<td>RODDIN: Crane-deployed work platform</td>
<td>RODDIN is a modular work platform deployed with a crane. It can be equipped with one or two hydraulic manipulators (SAMM or AESTRO), and one or two hydraulic or pneumatic winches. This configuration allows a great deal of flexibility.</td>
<td>N/A</td>
<td>Made of stainless steel. Resistance to radiation (depending on configuration) up to 10^7 rad cumulated dose. Decorable with both high pressure and chemical solutions decontamination methods. Equipped with safety inter-locking devices. Floor mounted support structure.</td>
<td>N/A</td>
<td>Hot cell D&amp;D and debris removal and remote operations for removal of piping networks in both process facilities and reactor facilities.</td>
<td>Cybernetix 36 Boulevard des Oceans Marseille, France 13275 Phone: (+334) 91 29 75 53 Fax: (+334) 91 29 75 90 <a href="http://www.cybernetix.fr">www.cybernetix.fr</a></td>
<td><img src="image1" alt="RODDIN Crane-deployed work platform" /></td>
</tr>
<tr>
<td>3.5</td>
<td>MAESTRO Advanced Hydraulic Manipulator</td>
<td>The MAESTRO hydraulic manipulator is a 120 kg Titan arm with six degrees of freedom. The oil is supplied through the arm at a 210 bars pressure and a rate of 15l/min. It is able to carry a 70 daN payload at a 2.3m distance from the axis of the first joint. The actuators technology is based on rotary hydraulic joints. Oil is sent in one of the two chambers of the actuator’s cylinder and pushed on a paddle mounted on the rotor part of the joint. Monitoring the pressure difference in the two chambers of the actuators makes it possible to drive the arm in a force control mode. It also ensures reversibility of all the actuators for their use in a force reflective master-slave system. The MAESTRO was designed to be radiation tolerant up to 10^6 Rad.</td>
<td>Maintenance tasks and decontamination activities require use of powerful force-reflective remote handling devices. CEA in collaboration with CYBERNETIX and IFREMER has developed the MAESTRO hydraulic manipulator (Modular Arm and Efficient System for TeleRObotics). For tele-operated tasks inside the ITER vacuum vessel, model-based monitoring of the robot can be used to warn the operator of possible failures, without additional sensors. The use of this model to detect abnormal situations has been investigated. Even if fine monitoring is limited to the case of moving axes, due to friction preponderance at low velocities, results help drawing up a detection strategy for unpermitted behaviors, such as collision of the robot with its environment.</td>
<td>The MAESTRO arm actuating technology is based on an intensive use of “flow” control servo-valves. It means that the response of the servo-valve to an electrical current step is a precise flow of oil in the joint. For force monitoring of the arm, pressure sensors are used in the control loop to set equivalence between the pressure in the joint’s chambers and the flow provided by the valve. Using pressure control servo-valve instead of flow control servo-valve is a real simplification of the control loop. In that case the response to a current step is a pressure step and no more extra sensors are needed for monitoring the hydraulic joint in force control mode. Using this kind of valve results in big safety improvements, for the environment and for the arm itself.</td>
<td>N/A</td>
<td>Hot cell D&amp;D and debris removal and remote operations for removal of piping networks in both process facilities and reactor facilities.</td>
<td>Cybernetix 36 Boulevard des Oceans Marseille, France 13275 Phone: (+334) 91 29 75 53 Fax: (+334) 91 29 75 90 <a href="http://www.cybernetix.fr">www.cybernetix.fr</a></td>
<td><img src="image2" alt="MAESTRO Advanced Hydraulic Manipulator" /></td>
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<td>Potential Application(s) at ORNL</td>
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<td>3.6</td>
<td>ROMAIN 50/125: Master/Slave Telemanipulator</td>
<td>ROMAIN 50 &amp; 125 are two master/slave manipulators dedicated to intervention in nuclear environments for maintenance and work for which high a level of resolution and dexterity are required. ROMAIN can be driven in position control mode using a mini master arm or in speed control mode using joysticks. Robotic functions are also available to provide the operator assistance when automatic replay trajectory is performed with specific arm controller. Technical description: • Payload: 5 kg (Romain 50) or 12.5 kg (Romain 125)* • Built in aluminum • All joints are protected against overload using torque limitation • 6 degrees of freedom • Minimum speed: 0.4 m/s • Weight: 50 kg* • Waterproof and pressure resistant for intervention in 20 m deep nuclear pool. Motion range control system: • Master/Slave control mode with Mini Master Arm. • Sped control mode with joystick. • Includes all usual added functions such as degrees of freedom, • Locking, change of master-slave ratios, etc... • Automatic trajectory generation. • Teach and team functions.</td>
<td>France</td>
<td>N/A</td>
<td>N/A</td>
<td>Several cells (Cells 11E and 11W, Cell 12, Cell 13, Cell 14E, Cell 18) in Building 317 are highly contaminated and remote technologies would apply for removing equipment, size reduction, sorting/segregating, and initial decontamination efforts for metal and concrete surfaces. Stainless steel liners are present in Cells 1-15, the liner surfaces would need to be remotely inspected for contamination and decontaminated accordingly. Concrete surfaces underneath the stainless steel liners would have to be remotely characterized and decontaminated once liners are removed.</td>
<td>Cybernetix 36 Boulevard des Oceans Marseille, France 13275 Phone: (+334) 91 29 75 53 Fax: (+334) 91 29 75 90 <a href="http://www.cybernetix.fr">www.cybernetix.fr</a></td>
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<td>3.7</td>
<td>TMTC: Electrical Manipulator arm</td>
<td>TMTC ARM is a heavy duty bridge mounted electric manipulator arm dedicated to intervention in irradiated and contaminated hot cells. Power, reliability and dexterity are its major assets. General Characteristics: • Dimensions, torque &amp; speed • Total length: *1600/1300 mm. • Weight: <em>430/210 Kg. • Telescope • Standard stroke: 6m. • Axis load: 500 kg. Functional Highlights • Stainless steel structure – Decontamination friendly. • All electric motors are remotely changeable • Resistance to radiation: 105 rad cumulated dose. • Degrees of freedom</em>: 6 or 7 + 1 optional. (6 axes + grip tool exchanger).</td>
<td>France</td>
<td>N/A</td>
<td>N/A</td>
<td>Several cells (Cells 11E and 11W, Cell 12, Cell 13, Cell 14E, Cell 18) in Building 317 are highly contaminated and remote technologies would apply for removing equipment, size reduction, sorting/segregating, and initial decontamination efforts for metal and concrete surfaces. Stainless steel liners are present in Cells 1-15, the liner surfaces would need to be remotely inspected for contamination and decontaminated accordingly.</td>
<td>Cybernetix 36 Boulevard des Oceans Marseille, France 13275 Phone: (+334) 91 29 75 53 Fax: (+334) 91 29 75 90 <a href="http://www.cybernetix.fr">www.cybernetix.fr</a></td>
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<td>3.8</td>
<td>NuVision Engineering: RAPTOR® hydraulic manipulator systems</td>
<td>NuVision Engineering’s RAPTOR® hydraulic manipulator systems have been specially designed for hazardous duty operations. The RAPTOR® is designed for deployment on all-terrain, unmanned ground vehicles (UGV), robotic combat support systems (RCSS), and all purpose robotic transport systems (ARTS) as well as other heavy-duty equipment such as excavators or in fixed mount applications. Raptor’s are rugged, reliable and robust and provide the capability to operate in extremely hazardous environments from a safe distance thereby minimizing risk to the operator. Military applications include: • Explosives and Ordnance Handling • Handing / Positioning Tooling • Supporting / Firing Weapons • Remote Hazardous Decontamination • Soldier &amp; Patient Recovery • HazMat Response • Remote Fire Fighting • Video Surveillance Key Features of the RAPTOR® • Open system and modular design for heavy duty lifting and dragging power • Commonality of components – easy to maintain and cost effective and to minimal life cycle costs • Standard System Configurations • RAPTOR® 300 – 300 lb. Payload at 7’ (Full Extension) • RAPTOR® 300 – 300 lb. Payload at 9.5’ (Full Extension) • Operating Temperature - 32°F to 140°F • Relative Humidity - 5% to 95%</td>
<td>N/A</td>
<td>N/A</td>
<td>Several cells (Cells 11E and 11W, Cell 12, Cell 13, Cell 14E, Cell 18) in Building 317 are highly contaminated and remote technologies would apply for removing equipment, size reduction, sorting/segregating, and initial decontamination efforts for metal and concrete surfaces. Stainless steel liners are present in Cells 1-15, the liner surfaces would need to be remotely inspected for contamination and decontaminated accordingly.</td>
<td>NuVision Engineering, Inc. 2801 Sidney Street Suite 700 Pittsburgh, PA 15203 Phone: 412-586-1810 Fax: 412-586-1811 <a href="http://www.nuvisioneng.com">http://www.nuvisioneng.com</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td>Technology</td>
<td>Description</td>
<td>Previous Applications and Results</td>
<td>Benefits</td>
<td>Limitations</td>
<td>Potential Application(s) at ORNL</td>
<td>Vendor/Website</td>
<td></td>
</tr>
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<td>-------</td>
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<td>3.9</td>
<td>NuVision Engineering</td>
<td>ARTISAN Manipulator</td>
<td>NuVision Engineering’s ARTISAN™ telerobotic heavy-duty hydraulic manipulators and control systems are designed specifically for hazardous environment/material handling applications. It has six degrees of freedom and a payload limit of 220 pounds (nearly 10 times more than the facilities existing manipulators) when horizontally extended (over 15 feet). It is regularly used for tasks such as: hot cell decontamination, volume reduction of facilities and waste retrieval. The ARTISAN™ is a robust, reliable, modular workhorse that can be easily maintained and operated. It has achieved very high levels of availability, even in the most demanding of applications with over 100,000 operating hours of service at 97% reliability in harsh and radioactive environments.</td>
<td>Supported by a specially-designed structure, the 1,100-pound robotic arm can be removed and reinserted in different ports in a straightforward manner. The overall reach capability with the hot cells can range from 11 feet to more than 15 feet by installing various extension tubes between joints. Key features of the ARTISAN Manipulator: • Heavy duty payload • Radiation hardened • Modular component design • Variable mounting configurations • Harsh environment/nuclear applications • Joystick controlled control system • Teach/repeat functionality • Joint / world / tool modes of operation • Standard industrial tooling interface</td>
<td>N/A</td>
<td>Several cells (Cells 11E and 11W, Cell 12, Cell 13, Cell 14E, Cell 18) in Building 3517 are highly contaminated and remote technologies would apply for removing equipment, size reduction, sorting/segregating, and initial decontamination efforts for metal and concrete surfaces. Stainless steel liners are present in Cells 1-15, the liner surfaces would need to be remotely inspected for contamination and decontaminated accordingly.</td>
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<td>3.10</td>
<td>PaR Systems</td>
<td>Manipulators</td>
<td>PaR Systems’ manipulator systems have served the nuclear industry hot cell operators worldwide since the early 1960s. With several hundred systems in the field, the PaR Systems M3000 and M6000 are simple rugged manipulator arms with payloads up to 400 pounds (181 kg.). Applications range from hot cell utility and process operation to retrieval and waste packaging. Deployment is mainly by overhead mounting or wall mounting of transporters. Other options are vehicle and pedestal mounting. The M3000 has a payload of up to 150 pounds and the M6000 payload is up to 400 pounds in any hand position. They are inherently radiation resistant and can be washed down for decontamination. The TR® Telerobotic Manipulator System provides operators with intuitive remote control of motion and payload in hazardous environments. Advanced controls and payload capability up to 400 pounds (181 kg), provide adaptability to deploy processes ranging from traditional hot cell remote handling to automated adaptive control. Radiation resistant and ready for explosive, corrosive and other difficult operational environments. Deployable by overhead or wall mounted transporters with vertical telescoping and fixed masts, cranes, pedestals or by vehicle. Through wall docking station that enables installation of TR® manipulators through existing Master Slave Manipulator ports without facility modification or additional shielding.</td>
<td>The TR® provides programmability and repeatable operation. The TR® is maintained with simple toolbox tools. Its remote maintenance features and modularity allows users to perform all routine maintenance and simplifies complex maintenance tasks. A simple gripper or a range of wrist mounted tooling including torque and impact tools, hook hands, grinders, saws and other devices. Control options include finger switches or joystick type controls.</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>PaR Systems, Inc. 899 Highway 96 West, Shoreview, MN 55126 USA (800) 464-1320 or (651) 444-7261 <a href="http://www.paran.com/">http://www.paran.com/</a></td>
</tr>
</tbody>
</table>
## Manipulator Systems

### Index | Technology | Description | Previous Applications and Results | Benefits | Limitations | Potential Application(s) | Vendor/Website | Photograph
--- | --- | --- | --- | --- | --- | --- | --- | ---
### 3.11 | Schilling Robotics TITAN 4 Manipulator | The TITAN 4 manipulator from Schilling Robotics is a seven-function servo-hydraulic system that features titanium construction and offers exceptional dexterity. With slave electronics now located inside the slave arm, the TITAN 4 is designed for reliability and performance. | Since the introduction of the TITAN 7F in 1987, TITAN systems have been used in underwater applications, and are extensively used on remotely operated vehicles (ROVs). Benefits of the TITAN 4 Manipulator include: • Only slave electronics • Titanium construction • Standard 4km depth rating: 7m optional • Maximum nominal lift: 454 kg (1000 lb) • Maximum reach of 191.6 cm (75.4 in) • Quick, easy diagnostics • Miniature replica master arm • Large operating envelope • High lift-to-weight ratio • Dexterous and accurate • Rugged and reliable | N/A | Several cells (Cells 11E and 11W, Cell 12, Cell 13, Cell 14E, Cell 19) in Building 317 are highly contaminated and remote technologies would apply for removing equipment, size reduction, sorting/segregating, and initial decontamination efforts for metal and concrete surfaces. Stainless-steel liners are present in Cells 1-15, the liner surfaces would need to be remotely inspected for contamination and decontaminated accordingly. | Schilling Robotics Headquarters 201 Constarins Place Davis, California 95618-5412 U.S.A. Tel: +1 530 753 6718 Fax: +1 530 753 8092 24-hour Tel: +1 530 755 6718 www.ssaalliance.com
### 3.12 | Schilling Robotics CONAN Manipulator | A manipulator system for medium-to-large work-class ROV systems. The CONAN from Schilling Robotics is a rugged, high-capacity, seven-function remote manipulator system that is available in position-controlled and rate-controlled models. The CONAN is designed to perform demanding tasks and yet be economical to install, operate, and maintain. | Benefits in the CONAN Manipulator include: • Interchangeable actuator modules • High degree of component commonality • Rugged aluminum structural components • Large internal conduit • Hard-anodized surfaces resist corrosion • Over-sized joint pivot bearings • Zinc sacrificial anodes minimize corrosion • Through-base bolting simplifies installation • Rate or position-controlled versions | N/A | Several cells (Cells 11E and 11W, Cell 12, Cell 13, Cell 14E, Cell 19) in Building 317 are highly contaminated and remote technologies would apply for removing equipment, size reduction, sorting/segregating, and initial decontamination efforts for metal and concrete surfaces. Stainless-steel liners are present in Cells 1-15, the liner surfaces would need to be remotely inspected for contamination and decontaminated accordingly. | Schilling Robotics Headquarters 201 Constarins Place Davis, California 95618-5412 U.S.A. Tel: +1 530 753 6718 Fax: +1 530 753 8092 24-hour Tel: +1 530 755 6718 www.ssaalliance.com
### 3.13 | Schilling Robotics ORION Manipulator | An economical, lightweight manipulator system designed for use on systems with limited stowage room. Used widely on light-to-medium work-class ROVs and tenders. The ORION from Schilling Robotics is a compact, dexterous, seven-function remote manipulator system that is available in position-controlled and rate-controlled models and in standard and extended lengths. The ORION’s light weight and kinematics configuration make it the perfect choice for submarin applications that require a small stow envelope. | Benefits in the ORION Manipulator include • Nominal maximum lift capacity of 273 kg (600 lb) • Lightweight aluminum construction • Compact stow envelope • Choice of standard or extended reach • Rotary forearm joint • Hard-anodized surface resists corrosion • Maintains position in power-off condition • High degree of component commonality • Through-base bolting simplifies installation • Blind ports on each actuator • Rate or position-controlled versions | N/A | Several cells (Cells 11E and 11W, Cell 12, Cell 13, Cell 14E, Cell 19) in Building 317 are highly contaminated and remote technologies would apply for removing equipment, size reduction, sorting/segregating, and initial decontamination efforts for metal and concrete surfaces. Stainless-steel liners are present in Cells 1-15, the liner surfaces would need to be remotely inspected for contamination and decontaminated accordingly. | Schilling Robotics Headquarters 201 Constarins Place Davis, California 95618-5412 U.S.A. Tel: +1 530 753 6718 Fax: +1 530 753 8092 24-hour Tel: +1 530 755 6718 www.ssaalliance.com
### 3.14 | Schilling Robotics Rig Master Grabber | An industry-standard, five-function grabber. Operated by proportional, servo, or solenoid valves. Titanium and aluminum construction. Typically used in conjunction with the TITAN 4 or CONAN manipulator systems. The Rig Master is a heavy-lift grabber arm that can be mounted on a wide range of ROVs. The grabber arm can be used to grasp and lift heavy objects or to anchor the ROV by clamping the gripper around a structural member at the work site. The Rig Master's boom function extends or retracts the gripper by 305 mm (12 inches) for a maximum reach of 1,300 mm (51.2 inches). The system's standard four-finger intertwining gripper can handle bulky objects by opening to 284 mm (11.2 inches). | Benefits in the Rig Master Grabber include • Arm length: 3.05 m (10 ft) • High-strength, high-tensile manganese steel • Strong, rugged, and reliable • High lift-to-weight ratio • Modular jaw configurations • Interchangeable jaw configurations • Extends by 305 mm (12 in.) | N/A | Several cells (Cells 11E and 11W, Cell 12, Cell 13, Cell 14E, Cell 19) in Building 317 are highly contaminated and remote technologies would apply for removing equipment, size reduction, sorting/segregating, and initial decontamination efforts for metal and concrete surfaces. Stainless-steel liners are present in Cells 1-15, the liner surfaces would need to be remotely inspected for contamination and decontaminated accordingly. | Schilling Robotics Headquarters 201 Constarins Place Davis, California 95618-5412 U.S.A. Tel: +1 530 753 6718 Fax: +1 530 753 8092 24-hour Tel: +1 530 755 6718 www.ssaalliance.com
<table>
<thead>
<tr>
<th>Index</th>
<th>Technology</th>
<th>Description</th>
<th>Previous Applications and Results</th>
<th>Benefits</th>
<th>Limitations</th>
<th>Potential Application(s) at ORNL</th>
<th>Vendor/Website</th>
<th>Photograph</th>
</tr>
</thead>
</table>
| 3.15  | Schilling Robotics ORION 4R Manipulator | The ORION 4R's compact size, light weight, and excellent payload capacity for small work-class ROVs. The arm’s shoulder segment is fabricated from hard-anodized extruded aluminum for strength and corrosion resistance. It is typically paired with a dexterous manipulator. | N/A | • Four functions (including grip)  
• Weight 21 kg (46 lb) in seawater  
• Depth rating of 6,500 m (21,327 ft)  
• High wrist torque (greater than 170 Nm/125 lb-ft)  
• All standard and optional grippers can accommodate 13-mm (0.50-inch) and 19-mm (0.75-inch) T-bars  
• Rugged, extruded aluminum structural components maximize service life  
• Hard-anodized surface resists corrosion  
• Through-base bolting simplifies installation  
• Bleed ports on each actuator facilitate purging air from hydraulic lines | N/A | Several cells (Cells 11E and 11W, Cell 12, Cell 13, Cell 14E, Cell 18) in Building 317 are highly contaminated and remote technologies would apply for removing equipment, size reduction, sorting/segregating, and initial decontamination efforts for metal and concrete surfaces. Stainless steel liners are present in Cells 1-15, the liner surfaces would need to be remotely inspected for contamination and decontaminated accordingly. | Schilling Robotics Headquarters  
201 Cousteau Place  
Davis, California. 95618-5412  
U.S.A.  
Tel: +1 530 753 6718  
Fax: +1 530 753 8092  
24-hour Tel: +1 530 755 6718  
www.ssaalliance.com |
| 3.16  | Schilling Robotics TITAN T and TITAN T-Gamma Manipulators | A powerful, rugged, dexterous seven-function manipulator system for terrestrial (land-based) applications. The radiation-hardened TITAN T-Gamma model can be used in radioactive environments ranging from nuclear environmental restoration and waste management to routine reactor maintenance and inspection. | N/A | • Seven functions (including grip)  
• Radiation hardened up to 10⁷ Rad gamma  
• Easy decontamination  
• Titanium construction  
• Dexterity and accuracy  
• Large operating envelope  
• High lift-to-weight ratio  
• Rugged and reliable  
• Miniature replica master arm for intuitive operation | N/A | Several cells (Cells 11E and 11W, Cell 12, Cell 13, Cell 14E, Cell 18) in Building 317 are highly contaminated and remote technologies would apply for removing equipment, size reduction, sorting/segregating, and initial decontamination efforts for metal and concrete surfaces. Stainless steel liners are present in Cells 1-15, the liner surfaces would need to be remotely inspected for contamination and decontaminated accordingly. | Schilling Robotics Headquarters  
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www.ssaalliance.com |
<table>
<thead>
<tr>
<th>Index</th>
<th>Technology</th>
<th>Description</th>
<th>Previous Applications and Results</th>
<th>Benefits</th>
<th>Limitations</th>
<th>Potential Application(s) at ORNL</th>
<th>Vendor/Website</th>
<th>Photograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Mobile Work Platform</td>
<td>The Mobile Work Platform (MWP) supplied by Eagle Tech has a four wheel chassis, a multi-articulating, folding main boom attached to the chassis by means of a 360-degree rotating tower assembly. Attached to the telescoping jib and end of the main boom are two independently operable arms that are mounted on a common articulating and rotating support platform base called Rotec. The Rotec allows both arms to work at a 90-degree angle off either side of the main boom arm. Both end-effectors have the ability to grab, hold in place, clamp, and shear pipe/conduit and lower the segmented section to the floor, waste containers or a predefined staging area.</td>
<td>Fernald LSIBS, OST No. 2243 - DOE/EM 0450</td>
<td>• Improved health and safety for D&amp;D workers</td>
<td>MWP has a lower production rate than the baseline technology (manual removal methods), 20 linear feet/h versus 50 linear feet/h respectively. MWP has higher operational costs than the baseline technology (manual removal methods), $4.94/linear feet versus $4.80/linear feet respectively.</td>
<td>Dismantlement/demolition of structures, piping removal.</td>
<td>RedZone Robotics 484 West Seventh Avenue Homestead, Pa. 15120 Phone (412) 476-8980 Fax (412) 476-8981</td>
<td><a href="http://www.redzone.com/index.php?dualarm">http://www.redzone.com/index.php?dualarm</a></td>
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<td>4.2</td>
<td>Houdini</td>
<td>Houdini, a bulldozer-like mobile robot, is part of an integrated solution for tank-waste retrieval. The vehicle folds to fit through a 24” (60-cm) opening, providing substantial work capability inside tanks and other limited access areas. Houdini’s hydraulic power, track drives, submergeability, radiation tolerance, and low center of gravity enable it to perform a wide variety of tasks in very challenging environments. The Houdini is only available in a non folding frame version. It can be outfitted or handle different types of tools including a High-pressure water (HPW) cutting tool. This tool system is a 20000 psi, 35mpm water cutting technology. Also been successfully used in numerous tanks at the Oak Ridge National Laboratories (e.g. Gunite Tanks) for the dismantlement of the Hot Cell #4 process system at the Oquossoc Hot Cell Facility for Pennsylvania Department of Environmental Protection in Harrisburg, PA.</td>
<td></td>
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<td>RedZone Robotics 484 West Seventh Avenue Homestead, Pa. 15120 Phone (412) 476-8980 Fax (412) 476-8981</td>
<td><a href="http://www.redzone.com">http://www.redzone.com</a></td>
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<td>4.3</td>
<td>Houdini II (Pioneer)</td>
<td>Houdini II is a remotely controlled, folding, work platform that can pass through 24-in. openings and then expand to become a 4 x 5.5 ft mini bulldozer, complete with a plow blade, a dexterous, high payload manipulator, and remote camera systems. A single-operator control console can be located up to a few hundred feet away. Though training is straightforward and with no special qualifications needed, inexperienced operators can easily damage the system; therefore, the need for operators to practice in cold tests is critical to mission success. Houdini can deploy a variety of tools fitted with appropriate grasp points and can manipulate objects up to 250 lb. It can shovel waste or deploy localized sluicing systems for heel removal, cut and remove-in-tank debris, deploy tools to obtain core samples, and perform characterization and inspection missions. It has successfully and extensively manipulated a localized sluicer that uses high-pressure water to dislodge and then pump a variety of physical waste forms.</td>
<td>ONSL Gunite Tank waste retrieval</td>
<td>Ability to perform waste retrieval activities in areas were it would be too dangerous to have workers present.</td>
<td>Prototype system, encountered several instrumentation issues during operation in tank; also requires thorough training. Expenses, reliability and maintainability need improvement. Inexperienced operators can easily damage the system.</td>
<td>RedZone Robotics 484 West Seventh Avenue Homestead, Pa. 15120 Phone (412) 476-8980 Fax (412) 476-8981</td>
<td><a href="http://www.redzone.com">http://www.redzone.com</a></td>
<td><a href="http://www.redzone.com/index.php?houdini">http://www.redzone.com/index.php?houdini</a></td>
</tr>
<tr>
<td>Index</td>
<td>Technology</td>
<td>Description</td>
<td>Previous Applications and Results</td>
<td>Benefits</td>
<td>Limitations</td>
<td>Potential Application(s) at ORNL</td>
<td>Vendor/Website</td>
<td>Photograph</td>
</tr>
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<td>-------</td>
<td>------------</td>
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<td>4.4</td>
<td>Mobile Robot Worksysterm &quot;ROSIE&quot;</td>
<td>ROSIE is a tethered 50-m (165-ft) long, robotic system controlled via teleoperation from a control console that is located outside of the radiological containment area. ROSIE performs mechanical dismantlement of radiologically contaminated structures by remotely deploying others tools or systems. ROSIE is a mobile platform used to support reactor assembly demolition through its long reach, heavy lift capability and its deployment and positioning of Kraft Predator dexterous manipulator arm.</td>
<td>Reduced personnel exposure to radiation. The system showed it could perform extremely delicate and intricate operation. Deployed a wide variety of tools for multitask D&amp;D activities. Remote operation removes workers from high-radiation environments supporting ALARA principles. Radiation hardened for easy maintenance and decontamination. ROSIE-C broke up a high-density concrete plug in an hour compared to several days for workers using jackhammers.</td>
<td>Rosie has limited maneuverability in confined areas and areas with low ceilings. The telescoping boom was not long enough to reach inside the reactor, yet the platform was bulky and difficult to maneuver on the reactor floor.</td>
<td>Dismantlement/demolition of structures, piping removal and safety removal.</td>
<td>RedZone Robotics 444 West Seventh Avenue Homestead, Pa. 15120 Phone (412) 476-8980 Fax (412) 476-8981 <a href="http://www.redzone.com/rosie">http://www.redzone.com/rosie</a></td>
<td>![Image]</td>
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<td>4.5</td>
<td>Modified Brokk Demolition Machine with Remote Operator Console</td>
<td>The Modified BROKK Demolition Machine with Remote Console combines a commercially available BROKK demolition system with the Compact Remote Operator Console (TMS ID 2180) to extend the applicability of the BROKK system to projects that require removal of the operator from the work area due to exposure to radiological, chemical, or industrial hazards. The Robotics Crosscutting Program has developed modifications to a BROKK to provide remote viewing and tool control capabilities. The modified BROKK has been integrated with the Compact Remote Operator Console to provide a true remotely operated low-cost D&amp;D system applicable to a wide range of small D&amp;D demolition tasks across the DOE complex.</td>
<td>The Modified Brokk Demolition Machine with Remote Console allows the operator to be at a safe distance from areas with high radiation, falling debris, or other environmental concerns. Remote video provides the capability to do work out of the operator’s line of sight. Working time using the Brokk is less than half that of most operations performed using manual tools, significantly reducing cost and schedule.</td>
<td>Operation from a remote trailer is preferred due to improved safety conditions, comfort, operator isolation, and so forth. The INEEL purchased a Brokk and hammer for $118,372 ($104,750 robot and hammer + $7500 radio control + $3722 spares + $1500 shipping). The overall purchase cost (P) is $ (118,372 + 3722) * 1.27 * 1.053 * 1.045 = $190,578. The Brokk 250 is not longer available.</td>
<td>Dismantlement/demolition of structures, piping, debris, and utility removal.</td>
<td>This system was developed by the Department of Energy Robotics Technology Development Program (RTDP) primarily at PNNL with support from the Idaho National Engineering and Environmental Laboratory and the Oak Ridge National Laboratory. Brokk <a href="http://www.brokk.com">http://www.brokk.com</a></td>
<td>![Image]</td>
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</tr>
</tbody>
</table>
### Table: Remote Control Concrete Demolition System

<table>
<thead>
<tr>
<th>Index</th>
<th>Technology Description</th>
<th>Previous Applications and Results</th>
<th>Benefits</th>
<th>Limitations</th>
<th>Potential Application(s) at ORNL</th>
<th>Vendor/Website</th>
<th>Photograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.6</td>
<td><strong>Brokk BM 150</strong>&lt;br&gt;OST No 2100 DOE/EM-0410&lt;br&gt;&quot;Modified Brokk Demolition Machine with Remote Operator Console,&quot; September 2001 ANL-CP-5&lt;br&gt;OST No. 2100 - DOE/EM-0410&lt;br&gt;&quot;Modified Brokk Demolition Machine with Remote Operator Console.&quot;</td>
<td>• Operator is removed from the dangers of falling debris&lt;br&gt;• Worker radiation exposure and heat stress are reduced&lt;br&gt;• The Brokk, with the hydraulic hammer, is able to break concrete much faster and safer than a manually operated jackhammer&lt;br&gt;• Equipment is easy to operate and can be operated with a reasonable amount of control&lt;br&gt;• Equipment is also able to segregate waste&lt;br&gt;• The equipment is versatile and can accommodate various other attachments&lt;br&gt;• Equipment is small enough to be operated indoors.</td>
<td>The Brokk Remote-controlled demolition system demonstrated at CP-5 does not have any implementation issues.</td>
<td>Dismantlement/demolition of structures, piping removal and utility removal.</td>
<td>Brokk&lt;br&gt;<a href="http://www.brokk.com/pdf/trycksaker%20pdf/Brokk%20180_0GB.pdf">http://www.brokk.com/pdf/trycksaker%20pdf/Brokk%20180_0GB.pdf</a></td>
<td><img src="http://www.brokk.com/images/BrokkBM150.jpg" alt="Brokk BM 150" /></td>
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</tbody>
</table>

#### Brokk BM 150

The Brokk BM 150 uses a remotely operated articulating hydraulic boom with various tools attachments to perform the work. The machine is designed primarily to drive a hammer and has a reach of 15 feet. The machine can also rotate a continuous 360 degrees. The Brokk can be operated by someone 400 feet away or in a different room using a TV monitor. The equipment can be operated up to a 30-degree gradient. The unit requires a 480-volt, 50-amp circuit for its power source. The hammer operates at 600 foot-pounds and has outputs of 1000 to 1500 beats per minute. The bucket has a capacity of one cubic yard. Other attachments available include a concrete crusher, a La Bounty shear, and a one yard clamshell bucket. Brokk website currently lists models 40, 90, 180, and 330.

#### Brokk website currently lists models 40, 90, 180, and 330.

<table>
<thead>
<tr>
<th>Index</th>
<th>Technology Description</th>
<th>Previous Applications and Results</th>
<th>Benefits</th>
<th>Limitations</th>
<th>Potential Application(s) at ORNL</th>
<th>Vendor/Website</th>
<th>Photograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.7</td>
<td><strong>KT-15 &amp; KT-30</strong>&lt;br&gt;FIU-ARC Technology Demonstration Program&lt;br&gt;&quot;Powerful and well-protected hydraulics.&lt;br&gt;• The ability to handle an attachment in excess of 3,000 lbs and still remain mobile working on track, making it a robust, versatile, and reliable machine.&lt;br&gt;• Remote control system protects worker safety.&lt;br&gt;• Generates no secondary waste.&lt;br&gt;• KT-30's unique, double pivot design keeps the overall profile height low (7'11&quot;) but unfolds for maximum reach when needed.&lt;br&gt;• The equipment has been tested and used extensively in industrial sector.&lt;br&gt;• The vendor is able to design, manufacture and ship customized attachments in approximately 3 weeks.&lt;br&gt;Use of magnesium oxygen lance generates a considerable amount of potentially hazardous smoke. Respirators need to be used, especially when operation is conducted in a confined space area. The size of the equipment does not allow its use in a confined space area.</td>
<td>Dismantlement/demolition of structures, piping removal and utility removal.</td>
<td>The New Keibler Thompson Company&lt;br&gt;3073 Route 66&lt;br&gt;Export PA. 15632&lt;br&gt;<a href="http://www.rgrantinc.com/keibler-thompson_products.html">http://www.rgrantinc.com/keibler-thompson_products.html</a></td>
<td><img src="http://www.rgrantinc.com/images/keibler_thompson_products.html" alt="The New Keibler Thompson Company" /></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td>Technology Name</td>
<td>Description</td>
<td>Previous Applications and Results</td>
<td>Benefits</td>
<td>Limitations</td>
<td>Potential Application(s) at ORNL</td>
<td>Vendor/Website</td>
</tr>
<tr>
<td>-------</td>
<td>-----------------</td>
<td>-------------</td>
<td>----------------------------------</td>
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<td>4.8</td>
<td>Swing-Reduced Crane Control</td>
<td>During movements of an overhead crane, a pendulum-like swing is naturally induced in a suspended load. DOE's Robotics Technology Development Program (RTDP) funded the installation of a swing-reducing crane control system and other upgrades to the polar crane at the Argonne National Laboratory CP-5 facility.</td>
<td>Swing measurements for different bridge and trolley motions. Crane hook heights indicate a reduction in the induced swing of 61% to 86% Increased productivity and safety compared to standard baseline crane configurations. Allows for the remote lifting and positioning of heavy components and deployment of equipment systems in highly radioactive areas.</td>
<td>If load is swinging because it was picked up off center or it bumped something this system cannot be used to stop the swinging. The way the system is currently configured, the operator would have to turn off the swing reducing controller or manually bump the control button or paddle to stop the oscillations. The controller could be turned back on and the load moved. The technology is not well suited for work in the exact center of a pole crane.</td>
<td>N/A</td>
<td>The Department of Energy (DOE), Office of Technology Development (OTD), Robotics Technology Development Program (RTDP) through the Oak Ridge National Laboratory (ORNL) and the Savannah River Technology Center (SRTC) has provided this technology. <a href="http://apps.em.doe.gov/ost/pubs/DOE/EM-0475.pdf">http://apps.em.doe.gov/ost/pubs/DOE/EM-0475</a></td>
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<td>4.9</td>
<td>Dispersible Removal System</td>
<td>The DRS is a small crawler (about 24 inches wide by 24 inches long, weighing approximately 159 pounds) equipped with stainless steel tracks, lighting, a light-duty telescoping boom and two-jaw gripper, a wrist-tilt mechanism, and suite of end-effectors that can be remotely changed using a motor-driven coupler. A joy-stick and push-button console controls the crawler via a 75-foot-long electrical connection.</td>
<td>System has limited payload capabilities; controls only provide 75 ft connection cable to system.</td>
<td>N/A</td>
<td>Debris removal; source term removal; chemical inventory removal.</td>
<td>ROV Technologies Inc. 484 West Seventh Avenue Homestead, Pa. 15120 Phone (412) 476-8980 Fax (412) 476-8981 <a href="http://www.rovtech.com/index.php?p=ripple">http://www.rovtech.com/index.php?p=ripple</a></td>
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<td>4.10</td>
<td>Ripple</td>
<td>Ripple is used to traverse the interior of pipe networks. It can be equipped with a variety of inspection sensors and tools including UT Sensors, Flux leakage sensors, manipulators, machinery, equipment or welders. The robot uses extendable feet to brace itself against the pipe and an inch worm like motion to move along the pipe length. A prototype of the concept was built and tested in mock up to prove the viability of the concept. A conceptual design of a variation of Ripple was developed for NASA for inspection of ductwork inside the space shuttle orbiter. This version used inflatable shackles instead of feet, in order to operate inside the Kevlar ductwork in the shuttle.</td>
<td>N/A</td>
<td>N/A</td>
<td>Pipe/duct inspection vehicle</td>
<td>RedZone Robotics 484 West Seventh Avenue Homestead, Pa. 15120 Phone (412) 476-8980 Fax (412) 476-8981 <a href="http://www.redzone.com/index.php?p=ripple">http://www.redzone.com/index.php?p=ripple</a></td>
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<td>4.11</td>
<td>KT 30 GOM</td>
<td>The GOM 360BDRE features an elevated boom capable of reaching elevations above thirty feet. Both the deck and boom rotate 360 degrees. Attachments: GRH 125 Hydraulic Hammer GRH 470 Hydraulic Hammer Kneit 999 Pneumatic hammer Buckets, bins, scrapers, reamers Refractory Profile Refractory Spray Nozzles Skull Hooks. KT-30 is a track mounted mobile telescopic boom type machine that can be equipped with a variety of head attachments to perform dismantlement or demolition work. Both equipment can be powered by electricity or diesel fuel.</td>
<td>Designed for tough demolition projects, the equipment has powerful and well protected hydraulics. It has the ability to handle an attachment in excess of 3,000 lbs and still remain mobile working on track, making it a robust, versatile, and reliable machine. Remote control system protects worker safety. Generates no secondary waste. KT-30’s unique, double pivot design keeps the overall profile height low (7’11”) but unfolds excess of 3,000 lbs and still remain mobile working on track, making it a robust, versatile, and reliable machine. Remote control system protects worker safety. Generates no secondary waste. KT-30’s unique, double pivot design keeps the overall profile height low (7’11”) but unfolds. Use of magnesium oxygen lance generates a considerable amount of potentially hazardous smoke. Respirators need to be used, especially when operation is conducted in a confined space area. The size of the equipment does not allow its use in an extremely confined space area. Dismantlement/demolition of structures, piping removal and utility removal.</td>
<td>N/A</td>
<td>N/A</td>
<td>ROV Technologies Inc. 484 West Seventh Avenue Homestead, Pa. 15120 Phone (412) 476-8980 Fax (412) 476-8981 <a href="http://www.rovtech.com/index.php?p=ripple">http://www.rovtech.com/index.php?p=ripple</a></td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td>Technology</td>
<td>Description</td>
<td>Previous Applications and Results</td>
<td>Benefits</td>
<td>Limitations</td>
<td>Potential Application(s) at ORNL</td>
<td>Vendor/Website</td>
</tr>
<tr>
<td>-------</td>
<td>------------</td>
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<td>4.12</td>
<td>GOM 380 LG-JR</td>
<td>The GOM 380 LG-JR is the smallest unit manufactured by New Keibler. The LG-JR can work in areas that would normally be done by hand labor. Attachment: GRH 125 Hydraulic Hammer</td>
<td>N/A</td>
<td>N/A</td>
<td>Dismantlement/demolition of structures, piping removal and utility removal.</td>
<td>The New Keibler Thompson Company 3073 Route 66 Export PA. 15632 <a href="http://www.rgrantinc.com/380lg-jr.html">http://www.rgrantinc.com/380lg-jr.html</a></td>
<td>N/A</td>
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<td>4.14</td>
<td>UPC</td>
<td>The UPC is a radio controlled loader built specifically for clean-out areas with low overhead clearance. The UPC is small and compact but has power to move hundreds of pounds of heavy debris with each bucket load.</td>
<td>N/A</td>
<td>N/A</td>
<td>Debris removal</td>
<td>The New Keibler Thompson Company 3073 Route 66 Export PA. 15632 <a href="http://www.rgrantinc.com/upc.html">http://www.rgrantinc.com/upc.html</a></td>
<td>N/A</td>
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<td>4.15</td>
<td>Cybernetix BROKK &amp; SAMM Remote Intervention Vehicle</td>
<td>BROKK &amp; SAMM - Remote intervention vehicle for dismantling operation by Cybernetix consists of a BROOK 150 which is an intervention vehicle for nuclear dismantling specialized in trench digging, pull down and shovel, using a SAMM manipulator arm by CYBERNETIX. The platform supports two tools racks and a sight system. This equipment can be tele-operated at a distance of 50m maximum and works in lightly contaminated hot cells or nuclear process facilities. General characteristics: • Vehicle : 150E-BROKK • Speed : 1m/s • Weight : 3000 kg • Length : 2340 mm • Width : 780/1200 mm • Height : &lt; 1,80 m (tucked arm) • Energy : hydraulic power (mineral oil) 16,5 MPa - 6l/mn Manipulator arm: • It is a 7 functions manipulator • Maximum load : 80 kg (extended arm) • Energy : hydraulic provided by the vehicle, Tool exchanger: fully equipped</td>
<td>N/A</td>
<td>N/A</td>
<td>Hot cell D&amp;D and debris removal and remote operations for removal of piping networks in both process facilities and reactor facilities.</td>
<td>Cybernetix 36 Boulevard des Oceans Marseille, France 13275 Phone: (+33) 91 29 75 53 Fax: (+33) 91 29 75 90 <a href="http://www.cybernetix.fr">www.cybernetix.fr</a></td>
<td>N/A</td>
</tr>
<tr>
<td>Index</td>
<td>Technology</td>
<td>Description</td>
<td>Previous Applications and Results</td>
<td>Benefits</td>
<td>Limitations</td>
<td>Potential Application(s) at ORNL</td>
<td>Vendor/Website</td>
</tr>
<tr>
<td>-------</td>
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<td>4.16</td>
<td>CASTOTEL: Intervention in Nuclear Environment</td>
<td>The CASTOTEL is a light remote-controlled vehicle designed to carry out radioactivity measurements in nuclear atmospheres. It’s a light weight and extremely mobile device. Its small size allows it to operate easily in the most difficult access areas.</td>
<td>France (La Hague)</td>
<td>N/A</td>
<td>N/A</td>
<td>Various uses: inspection, characterization, small debris removal, decontamination.</td>
<td>Cybernetix 36 Boulevard des Oceans Marseille, France 13275</td>
</tr>
<tr>
<td>4.17</td>
<td>EROS: Post Accidental Intervention</td>
<td>EROS is a robot dedicated to post-accidental inspection and maintenance operations in nuclear indoor environments. It is a tracked robot formed by 2 articulated structures which allow high performance in narrow areas and high obstacle clearance.</td>
<td>France (La Hague)</td>
<td>N/A</td>
<td>N/A</td>
<td>Various uses: inspection, characterization, small debris removal, decontamination.</td>
<td>Cybernetix 36 Boulevard des Oceans Marseille, France 13275</td>
</tr>
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<td>4.18</td>
<td>LMF/MENHIR</td>
<td>The LMF robot is a modular vehicle for remote-controlled intervention in dangerous environments, indoors &amp; outdoors, including surveillance, inspection, maintenance and decommissioning in nuclear facilities. The mobile base can cross obstacles like stairs, ditches and steps. It is equipped with a heavy-duty hydraulic telemanipulator or alternatively with a dexterous telemanipulator for master-slave control with force feedback combined with a hydraulic telemanipulator. Control/data and video images are transmitted by an umbilical cable, or by a radio system using spread-spectrum technology.</td>
<td>France (La Hague)</td>
<td>N/A</td>
<td>N/A</td>
<td>Various uses: inspection, characterization, small debris removal, decontamination.</td>
<td>Cybernetix 36 Boulevard des Oceans Marseille, France 13275</td>
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<td>4.19</td>
<td>ROV Technologies Scarab I</td>
<td>The remote operated Scarab I system is a user friendly tri-camera / light multi use vehicle designed to perform visual inspections, video measurement, retrieval, vacuuming, high pressure jet-spraying and radiation surveying (both dose rate and smears). The vehicle operates via a state of the art control console utilizing proportional joystick control for forward / reverse and right / left movements. Speed of the vehicle is from 0 to 30 f.p.m. The vehicle can turn on its center axis. There are three miniature cameras with constant focus lensing. A 6X zoom lens is optional for the turret camera. Turret movement includes 180 degrees of pan and ninety degrees of tilt. The turret light is a high intensity semi-spot light (interchangeable wet or dry lights are supplied.) The vehicle is four wheel drive with track drive optional.</td>
<td>Various applications in the commercial nuclear markets; ROV has been very active in the commercial and the DOE networks. Various crawler units have been successfully deployed in ungrounded nuclear waste tanks at ORNL and other DOE sites along with various stages at numerous commercial Nuclear Power Plants across the country.</td>
<td>In this configuration the system is particularly well suited for visual inspections, video measurements, FME retrievals, vacuuming, high pressure jet-spraying and radiation surveying in either wet or dry environments.</td>
<td>N/A</td>
<td>ROV Technologies Inc. Franklin Rd Vernon, VT 05354 Phone (802) 254-9353 Fax (802) 254-9354 <a href="http://www.rovtech.com">http://www.rovtech.com</a></td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td>Technology</td>
<td>Description</td>
<td>Previous Applications and Results</td>
<td>Benefits</td>
<td>Limitations</td>
<td>Potential Application(s) at ORNL</td>
<td>Vendor/Website</td>
</tr>
<tr>
<td>-------</td>
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<td>4.20</td>
<td>ROV Technologies Scarab II</td>
<td>The remote operated crawling/climbing Scarab II system is a user friendly tri-camera/light multi use vehicle. This unit is designed to negotiate obstacles up to seven inches in height with its independent front and rear drive tracks. It is capable of visual inspections, video measurement, retrieval, vacuuming, high pressure jet-spraying and radiation surveying (both dose rate and smear). The vehicle operation is via a state of the art control console utilizing a proportional joystick for forward/reverse and right/left movements. Speed of the vehicle is from zero to fifty f.p.m. The turning radius is all inclusive from a zero degree pivot point. The track system is operated right/left for drive operation and independently forward and rear for obstacle operations. The upper turret camera is a constant focus (optional 6X zoom), high resolution, radiation tolerant camera with audio feedback. The turret movement includes 270 degrees of pan and ninety degrees of tilt. The turret camera light is a high intensity semi-spot light, and interchangeable wet or dry lights are supplied.</td>
<td>Various applications in the commercial nuclear markets. ROV has been very active in the commercial and the DOE networks. Various crawler units have been successfully deployed in ungrounded nuclear waste tanks at ORNL and other DOE sites along with various outages at numerous commercial nuclear power plants across the country.</td>
<td>N/A</td>
<td>N/A</td>
<td>FSM retrievals, vacuuming, high-pressure jet-spraying and radiation surveying in either wet or dry environments.</td>
<td>ROV Technologies Inc. Franklin Rd Vernon, VT 05354 Phone (802) 254-9353 Fax (802) 254-9354 <a href="http://www.rovtech.com">http://www.rovtech.com</a></td>
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<td>4.21</td>
<td>ROV Technologies Scarab III H</td>
<td>The remote operated crawling/climbing Scarab III H vehicle is designed for multipurpose use in either wet or dry environments. The system is user friendly, with three cameras and lights for monitoring travel and process control as well as a state-of-the-art Vehicle Operators Control Console (VOCC) which features a sturdy proportional joystick for finite control of travel movements at all speeds (0 to 30 f.p.m.). The vehicle, with tilting front and rear drive extensions, is designed to negotiate obstacles up to seven inches in height and to turn within its own length by pivoting on its center axis. The drive system features eight stainless steel sprocket style wheels with laminated fabric/rubber traction pads on the extremities. The drive chains have been enclosed within the extension arms and body for protection when operating in “gritty” environments. These drive wheels operate compositely for all travel movement, however the front and rear drive extensions operate independently to enhance obstacle negotiation and certain process control activities.</td>
<td>Various applications in the commercial nuclear markets. ROV has been very active in the commercial and the DOE networks. Various crawler units have been successfully deployed in ungrounded nuclear waste tanks at ORNL and other DOE sites along with various outages at numerous commercial Nuclear Power Plants across the country.</td>
<td>N/A</td>
<td>N/A</td>
<td>Visual inspections, video measurements, FSM retrievals, vacuuming, high-pressure jet-spraying and radiation surveying in either wet or dry environments.</td>
<td>ROV Technologies Inc. Franklin Rd Vernon, VT 05354 Phone (802) 254-9353 Fax (802) 254-9354 <a href="http://www.rovtech.com">http://www.rovtech.com</a></td>
</tr>
</tbody>
</table>
### Vehicle Systems

**Technology**

**Remotec F6A Andros**

#### Description

The ANDROS F6A features a unique, articulated track chassis which allows it to operate over rough terrain, cross obstacles and ditches, climb stairs and operate in sand, gravel, mud and grass. The most unique feature of the ANDROS F6A is its narrow width which allows for operation in very constrained areas without sacrificing the all-terrain capabilities. The ANDROS F6A is equipped with multiple television cameras for remote viewing and a dexterous manipulator for hazardous tasks. The ANDROS F6A can be optionally equipped with a variety of tools and accessories to meet the specific application. Features color surveillance camera with light, zoom, pan/tilt surveillance camera with image stabilization - 216:1 total zoom (26x optical/12x digital), stationary arm camera - 40:1 total zoom (10x optical/4x digital) with 24-inch camera extender, multiple-mission tool/sensor mounts with plug-and-play capabilities, gripper with continuous rotate with Manipulator arm's seven degrees of freedom ensure optimum dexterity, quick-release pneumatic wheels for rapid width-reduction, no tools required and Patented articulating tracks allow for traversing ditches, obstacles and the roughest terrain, vehicle data / communication links. The three data links available for operator control of the ANDROS vehicle are: • Fiber-optic cable - deployed from the vehicle • Radio control (wireless) • Hand-held cable

#### Previous Applications and Results

- Used in the airline industry for examination and retrieval of suspicious bags.
- Used in the airline industry for examination and retrieval of suspicious bags.

#### Benefits

- Multiple cameras for visual inspection
- Vertical reach capability
- Multiple control options

#### Limitations

- N/A

#### Potential Application(s) at ORNL

- Visual inspections, FME retrievals and radiation surveying
- Visual inspections, FME retrievals and radiation surveying

#### Vendor/Website

- REMOTEC, Inc.
  - 114 Union Valley Road
  - Oak Ridge, TN 37830 USA
  - Tel: (865) 483 0228
  - Fax: (865) 483 1426
  - http://www.remotec-andros.com

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**Telerobotic Manipulation System (OST Tech ID 2181)**

No good description available. The website provides the following description: The Telerobotic Manipulation System was established as a project within the Rbx D&D product line as a new start in FY 1999. From Rbx interactions with the Tanks Focus Area, there is a similar near-term need for a remote system to perform decontamination of pits associated with underground storage tanks at Hanford. The Rbx D&D activity was merged with the Rbx Tank Waste Retrieval (TWR) project for development of a prototype system. The Rbx D&D product line will assist in concept development and may provide operator console and telerobotic controls technologies for use in the prototype. The long-term target for D&D deployment of a system is within the Canyon Disposition Initiative for D&D of the canyon process cells.

#### Previous Applications and Results

- N/A

#### Benefits

- N/A

#### Limitations

- N/A

#### Potential Application(s) at ORNL

- N/A

#### Vendor/Website

- This system was developed by the Department of Energy Robotics Technology Development Program (RTDP) primarily at PNNL with support from the Idaho National Engineering and Environmental Laboratory and the Oak Ridge National Laboratory.
  - http://www.robotics.ost.doe.gov/techid-2181-dd.htm
<table>
<thead>
<tr>
<th>Index</th>
<th>Technology</th>
<th>Description</th>
<th>Previous Applications and Results</th>
<th>Benefits</th>
<th>Limitations</th>
<th>Potential Application(s) at ORNL</th>
<th>Vendor/Website</th>
<th>Photograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.24</td>
<td>Remotec Wolverine</td>
<td>This heavy-duty, all-terrain robot includes strength and manipulator dexterity. The ANDROS Wolverine is the largest, strongest wheeled robot manufactured by REMOTEC. The Wolverine is environmentally sealed to operate in any weather condition and in areas of high temperature/humidity and can operate on virtually any surface including sand, mud, gravel, grass, and snow. The ANDROS Wolverine is equipped with multiple television cameras for remote viewing and a dexterous manipulator for hazardous tasks. The 6X6 can be optionally equipped with a variety of tools and accessories to meet the specific applications. Features include: Color surveillance camera with light, zoom, pan/tilt, 216:1 total zoom (26x optical/12x digital) Manipulator arm with seven degrees of freedom ensures optional dexterity Single-module electronics for quick field replacement Switchbox for walk-along control Four, 12-volt batteries for extended run-time Optional track system Six individually powered wheels with lock-out hubs for free-wheeling Vehicle Data / Communication Links The three data links available for operator control of the ANDROS vehicle are: • Fiber-Optic Cable - deployed from the vehicle • Radio Control (wireless) • Hard tether cable</td>
<td>More than 1,400 REMOTEC® robots are in use worldwide by the military, law enforcement agencies, nuclear facilities, chemical plants and industrial service providers. This user list includes the British Ministry of Defense, US Department of Defense, US Federal Bureau of Investigation and other international agencies and organizations.</td>
<td>N/A</td>
<td>N/A</td>
<td>Visual inspections, video measurements, FME retrievals, vacuuming, high-pressure jet-spraying and radiation surveying in either wet or dry environments.</td>
<td>REMOTEC, Inc. 114 Union Valley Road Oak Ridge, TN 37830 USA Tel: (865) 483 0228 Fax: (865) 483 1426 <a href="http://www.remotec-andros.com">http://www.remotec-andros.com</a></td>
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</tr>
</tbody>
</table>

<p>| 4.25  | MURV-100 | This man-portable system can be operated remotely using the standard radio control, or with an optional fiber optic control system. Modular design allows the operator to quickly configure this system for current needs. A wide range of accessories greatly increase this system's utility. The system is powered by quick change battery packs: one in the vehicle and one in the control console. Two extra vehicle battery packs are supplied with each system. One extra console battery pack is standard. The battery packs provide up to 4 hours of operation and are exchanged using the supplied battery charger. The manipulator assembly can be quickly attached and detached from the platform without the use of tools. The arm reaches from 6 inches to over 5 feet. It includes 180 degree wrist pitch, 360 degree wrist rotation, arm elevation from below horizontal to beyond vertical, and 9 inch gripper opening with 4 different gripper sets and adjustable gripper force limit. A new elbow function enhances the utility of this arm. The manipulator can lift up to 50 pounds and drag over 130 pounds. The wrist camera is a high resolution, full color camera and positioned to always have a clear view of the gripper. The platform without the manipulator is only 4 1/2&quot; high using the small wheels. It can easily inspect under vehicles and in other confined areas. Also available are a set of 6 1/2&quot; large wheels. This platform can operate in a wide variety of terrain, including mud, sand, grass, and gravel. It can easily climb curbs and some stairs. A black and white camera with pan and tilt capability is located on the front of the platform. A black and white back-up camera is also standard on the platform. Optional camera configurations are also available. | N/A | N/A | Deployment of Characterization sensors, or possible deployment vehicle for manipulators or other decontamination technologies. | HDE Manufacturing, Inc. 2732 Weisenberger Street Fort Worth, TX 76107 Telephone (817) 336 5449 FAX (817) 336 3166 <a href="http://www.hdemfg.com">http://www.hdemfg.com</a> |</p>
<table>
<thead>
<tr>
<th>Index</th>
<th>Technology</th>
<th>Description</th>
<th>Previous Applications and Results</th>
<th>Benefits</th>
<th>Limitations</th>
<th>Potential Application(s) at ORNL</th>
<th>Vendor/Website</th>
<th>Photograph</th>
</tr>
</thead>
</table>
| 5.1   | Exchanger: Handling Tool | Teleoperation tool connection / disconnection (tools set on specialized support):  
By view operator  
Automatically after training position where tools are stored. | N/A | N/A | N/A | Cybernetix 36 Boulevard des Oceans Marseille, France 13275  
Phone: (+334) 91 29 75 53  
Fax: (+334) 91 29 75 90  
www.cybernetix.fr | N/A |
| 5.2   | Gripper: Handling Tool | Gripping by means of 2 parallel jaws. | N/A | N/A | N/A | Removal of inventory waste and tools, debris, small objects.  
Cybernetix 36 Boulevard des Oceans Marseille, France 13275  
Phone: (+334) 91 29 75 53  
Fax: (+334) 91 29 75 90  
www.cybernetix.fr | N/A |
| 5.3   | TPE: Inspection Tool | The function of this tool is to drive the manipulator via a laser beam controlled through a video camera. This allows positioning with great degree of accuracy. The coordinates are stored in the supervisor. The positions can also be stored for future operations. | N/A | N/A | N/A | N/A |
| 5.4   | UHPT-C Tool: Clean up & decontamination tool | Concrete and steel wall decontamination by superficial removal. Process using UHP water projection in teleoperation. UHPT-C tool is the necessary interface for maintenance of water projection need with sweeping rotating nozzle. UHP projection “FLOW Inc” system is excluded from the supply. | N/A | N/A | N/A | Decontamination of metal and concrete surfaces.  
Cybernetix 36 Boulevard des Oceans Marseille, France 13275  
Phone: (+334) 91 29 75 53  
Fax: (+334) 91 29 75 90  
www.cybernetix.fr | N/A |
| 5.5   | UHPT-L Tool: Clean up & decontamination tool | This tool is designed to perform remote decontamination of stainless steel liners with ultra high-pressure water jet method. It is dedicated to wide surface treatment. | N/A | N/A | N/A | Decontamination of metal and concrete surfaces.  
Cybernetix 36 Boulevard des Oceans Marseille, France 13275  
Phone: (+334) 91 29 75 53  
Fax: (+334) 91 29 75 90  
www.cybernetix.fr | N/A |
| 5.6   | UHPT-S Tool: Clean up & decontamination tool | This tool is designed to perform remote decontamination of stainless steel liners with ultra high-pressure water jet method. It is dedicated to narrow surface treatment. | N/A | N/A | N/A | Decontamination of metal and concrete surfaces.  
Cybernetix 36 Boulevard des Oceans Marseille, France 13275  
Phone: (+334) 91 29 75 53  
Fax: (+334) 91 29 75 90  
www.cybernetix.fr | N/A |
| 5.7   | WU & PC Tools: Water jet and plasma cutting tools | Gripping by means of 2 parallel jaws. | N/A | N/A | N/A | Removal of inventory waste and tools, debris, small objects.  
Cybernetix 36 Boulevard des Oceans Marseille, France 13275  
Phone: (+334) 91 29 75 53  
Fax: (+334) 91 29 75 90  
www.cybernetix.fr | N/A |
<table>
<thead>
<tr>
<th>Index</th>
<th>Technology</th>
<th>Description</th>
<th>Previous Applications and Results</th>
<th>Benefits</th>
<th>Limitations</th>
<th>Potential Application(s) at ORNL</th>
<th>Vendor/Website</th>
<th>Photograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.8</td>
<td>Concrete Grinder</td>
<td>The Flex concrete grinder is a lightweight, hand-held concrete and coating removal system that uses a diamond grinding wheel for decontamination or stripping of concrete surfaces. The grinder is an electric powered tool with a vacuum port for dust extraction and a diamond-grinding wheel. The grinder is suitable for flat or slightly curved surfaces and results in a smooth surface, which makes release surveys more reliable. The grinder is lightweight and produces little vibration. The technology provides an attractive alternative to traditional methods that can be used to remove coatings from concrete floors, walls or slabs. It can be used for radiological decontamination of general areas or hot spots on floors and walls or release radiological surveys. Dimensions of Tech Model (LxWxH): Grinding wheel: - 5 in. diameter, Weight of Tech Model (lb.): Grinding Wheel: - 6, Shaver: - 6.5.</td>
<td>The concrete grinder technology costs are significantly lower than the baseline technology (mechanical scabbling and pneumatic scabbling), $2.92/sq.ft for the grinder versus $10.45/sq.ft for the scabbling technology. • Unit is adaptable with existing vacuum filtration systems • Leaves a smooth surface finish • Tool is very lightweight, decreasing worker fatigue • Good maneuverability around/over wall protrusions • Simple to deploy • Better production rate and less vibration than the baseline technology</td>
<td>Not appropriate for very large, wide-open concrete floors and slabs where push-type and wheel powered diamond shavers are more efficient. • Not able to remove concrete at wall corners or wall/floor junctions • Unlike the baseline, there is a potential for a motor burnout problem • Requires adaptation for remote deployment</td>
<td>Decontamination of metal and concrete surfaces.</td>
<td>Andrews Machinery Construction, Suppliers. 1757 1st Ave S Seattle, Washington United States 98122 Phone : (206) 622-1121 <a href="http://www.dandd.org/TechnologyFactSheet.aspx?TechnologyID=41">http://www.dandd.org/TechnologyFactSheet.aspx?TechnologyID=41</a></td>
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<td>5.9</td>
<td>Air angle grinder</td>
<td>The Framatome 77A Air Angle Grinder is a pneumatically operated “hand-held” portable abrasive tool designed for use in “close-quarters” or areas of tight spaces. The grinder uses a 7-inch depressed center wheel. The abrasive wheel is made of aluminum oxide. An air angle grinder with a 9-inch wheel is also available. The grinder is designed to operate at the free speed specified on the nameplate, if the air supply is maintained at 90 psig air pressure at the tool. The free speed for the grinder is 6000 rpm.</td>
<td>Technology is mobile, easy to operate, and relatively simple to set up and tear down. Production rate is relatively high. Cutting activities can be conducted under safe conditions for operators, evaluators and the environment. This tool vibrates during use. Sparking, and hot metal debris are generated during cutting operation, which are harmful for operator if not protected properly. Requires adaptation for remote deployment</td>
<td>Decontamination of metal and concrete surfaces.</td>
<td>Framatome Technologies, Inc. 3315 Old Forest Rd., Lynchburg, Virginia United States 24502 Phone : (804) 832-2649 Fax : (804) 832-2873 Email: <a href="mailto:kleidoux@framatech.com">kleidoux@framatech.com</a> Website : <a href="http://www.framatech.com">http://www.framatech.com</a></td>
<td><a href="http://www.dandd.org/TechnologyFactSheet.aspx?TechnologyID=45">http://www.dandd.org/TechnologyFactSheet.aspx?TechnologyID=45</a> OR <a href="http://www.btinternet.com/~ken/gilham/hands/SampleRA-AirAngleGrinder_TSDS.pdf">http://www.btinternet.com/~ken/gilham/hands/SampleRA-AirAngleGrinder_TSDS.pdf</a></td>
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<td>5.10</td>
<td>Squirrel-1</td>
<td>It is a single piston, air driven scabbler with localized exhaust that safely removes PCBs, radioactivity, lead based paints, chromium and other hazardous materials from flat concrete surfaces. This manually operated scabbler scrapes concrete floors and slabs in the environmentally safe manner with a unique vacuum flow design that provides high efficiency control over dust, debris and airborne contamination.</td>
<td>Based on the testing performed by FIU-HCET, the floor technologies Squirrel I meets the required end point average depth of removal of one quarter of an inch of concrete floor. Requires adaptation for remote deployment.</td>
<td>Decontamination of concrete surfaces.</td>
<td>Pentek, Inc. Address : 1026 Fourth Avenue, Coraopolis, Pennsylvania, United States 15108 Phone : (412) 262-0725 Fax : (412) 262-0731 Email: <a href="mailto:pentekusa@aol.com">pentekusa@aol.com</a> Website : <a href="http://www.pentek.com">http://www.pentek.com</a></td>
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<td></td>
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<tr>
<td>Index</td>
<td>Technology</td>
<td>Description</td>
<td></td>
<td></td>
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<td>5.11</td>
<td>ROTO-PEEN Scaler</td>
<td>Pentek's ROTO-PEEN Scaler with localized exhaust is designed to remove hazardous protective coatings (including lead-based paints) from steel, concrete, brick and wood in an environmentally safe manner. The ROTO-PEEN Scaler is designed to operate independently or in conjunction with Pentek's voll suite of integrated decontamination equipment, including CORNER-CUTTER® needle guns and the VAC-PAC® high performance, self-drumming waste collection system. The ROTO-PEEN Scaler and the VAC-PAC waste collection system, is a fully developed and commercialized technology used to remove hazardous coatings from concrete and steel floors, walls, ceilings, and structural components. The ROTO-PEEN Scaler, the basic hand-held tool, weighs 6.5 lb, has a cutting width of 2 in, is pneumatically driven, and works with a variety of interchangeable cutting media such as cutting wheels and SM TM Heavy-Duty Roto Pan Flaps. It was designed to remove lead-based paints and radioactive and other hazardous contaminants from flat areas and large vertical surfaces, including the interface near walls and within confined spaces. The ROTO-PEEN Scaler operates independently or in conjunction with the Pentek VAC-PAC® waste collection system. The VAC-PAC® high-efficacy particulate air (HEPA) filter and vacuum system is a portable unit offering two-stage positive filtration of hazardous particulates, including radioactive particles and lead-based paint. The VAC-PAC® also has a patented controllable-seal drum fill system, which allows the operator to fill, seal, remove, and replace the waste drum under controlled vacuum conditions. Pentek, Inc 1026 Fourth Avenue, Coraopolis, Pennsylvania, United States 15108 Phone: (412) 262-0725 Fax: (412)-262-0731 Email: <a href="mailto:pentekinfo@aol.com">pentekinfo@aol.com</a> Website: <a href="http://www.pentek.com">http://www.pentek.com</a> <a href="http://www.dandd.org/AdvanceS">http://www.dandd.org/AdvanceS</a></td>
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<td>5.12</td>
<td>Plama Arc Cutter</td>
<td>In the torch, a single torch lead provides compressed air or nitrogen (N2) from a single source to be used as both the plasma and secondary gas. The air flow is divided inside the torch head. Single-gas operation provides a smaller sized torch and inexpensive operation. Plama torches are similar in design to the common automotive spark plug. They consist of negative and positive sections which are separated by a center insulator. Inside the torch, the pilot arc is initiated in the gap between the negatively charged electrode and the positively charged tip. Once the pilot arc has ionized the plasma gas, the unheathed column of gas flows through the small orifice in the torch tip, which is focused on the metal to be cut. FIU's Technology Demonstration site, Miami, FL, USA. Technology is mobile, easy to operate, and relatively simple to set up and use. The cutting head produces a highly ionized plasma arc, which is used to cut through a material. The plasma arc is an electric arc that is generated by passing a high voltage electric current through a gas. The gas is usually a mixture of argon and nitrogen, and is typically fed into the plasma arc through a nozzle. The plasma arc is then directed onto the material to be cut, and the energy generated by the plasma arc is used to melt and remove the material. The plasma arc is a highly ionized gas, which means that it contains a large number of ions and electrons. This high level of ionization allows the plasma arc to cut through a variety of materials, including metals and non-metals. The cutting speed and quality of the cut can be controlled by adjusting the power level and the type of gas used. The plasma arc is a very versatile and efficient cutting method, and is used in a variety of industries, including the metalworking, construction, and manufacturing industries. Framatone Technologies, Inc. 3315 Old Forest Rd., Lynchburg, Virginia United States 24502 Phone: (804) 832-2649 Fax: (804) 832-2873 Email: <a href="mailto:klesdon@framatech.com">klesdon@framatech.com</a> Website: <a href="http://www.framtech.com">http://www.framtech.com</a> <a href="http://www.dandd.org/AdvanceS">http://www.dandd.org/AdvanceS</a></td>
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<td>5.13</td>
<td>Pneumatic Cut-off Tool</td>
<td>The pneumatic cutoff tool is a air-powered, hand-held, abrasive cutoff wheel. The tool comes in a variety of sizes and can be adapted to cut most materials with the selection of the appropriate grinding disk. The cutoff wheel is a standard tool designed for close quarter work in the metal working industry. They are particularly good where conduits, pipes, ducts, etc. pass through bulkheads or frames. The grinders are very efficient at grinding weld bead and leaving a fine finish. This can be achieved by choosing the appropriate set of grinders, sanders, and polishers for smoothing, trimming, or removing metal. Technology Demonstration site, Miami, FL, USA. Low capital and operating cost, portable, quick set up, low maintenance. Cuts are limited to the blade’s radius and access to desired cut line. Requires adaptation for remote deployment. Equipment size reduction Framatone Technologies, Inc. 3315 Old Forest Rd., Lynchburg, Virginia United States 24502 Phone: (804) 832-2649 Fax: (804) 832-2873 Email: <a href="mailto:klesdon@framatech.com">klesdon@framatech.com</a> Website: <a href="http://www.framtech.com">http://www.framtech.com</a> <a href="http://www.dandd.org/AdvanceS">http://www.dandd.org/AdvanceS</a></td>
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<td></td>
</tr>
</tbody>
</table>
### Tooling

<table>
<thead>
<tr>
<th>Index</th>
<th>Technology</th>
<th>Description</th>
<th>Previous Applications and Results</th>
<th>Benefits</th>
<th>Limitations</th>
<th>Potential Application(s) at ORNL</th>
<th>Vendor/Website</th>
<th>Photograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.14</td>
<td>CORNER-CUTTER®</td>
<td>The CORNER-CUTTER® is designed to remove lead-based paints, radioactivity and other hazardous contaminants from both steel and concrete surfaces in an environmentally safe manner. Pentek developed the CORNER-CUTTER® to scurry walls, joints, ceilings, stairs, grinders, pipes, and other areas which are inaccessible to other technologies. CORNER-CUTTER: 14&quot; x 1.75 x N/A Weight of Tech Model. CORNER-CUTTER: 9 lbs.</td>
<td>THU's Technology Demonstration site, Miami, FL, USA</td>
<td>The Pentek Decontamination System is fully integrated with a vacuum and dust collection system. Fully contained system; no airborne dust escapes during operation. There are many commercial units available. System requires minimal time to set up and operate. System can be adjusted to remove a selected amount of surface. The CORNER CUTTER can reach edges and corners.</td>
<td>The surface of the concrete must be dry for the equipment to operate. If wet, the debris becomes wet and may clog the machine. Steel reinforcing will damage the tungsten-carbide bits. In some cases the vacuum may not be able to collect all the debris left on the surface. A second vacuuming operation may be necessary. A clean, compressed air supply is required to minimize damage to equipment. A poor compressed air supply creates vibrations and of air connections. The CORNER CUTTER models generate substantial vibrations, which is transferred to the operator. Requires adaptation for remote deployment.</td>
<td>Decontamination of metal and concrete surfaces. Pentek, Inc 1820 Fourth Avenue, Coraopolis, Pennsylvania, United States 15108 Phone: (412) 262-0725 Fax: (412)-262-0731 Email: <a href="mailto:pentekusa@aol.com">pentekusa@aol.com</a> Website: <a href="http://www.pentek.com">http://www.pentek.com</a> <a href="http://www.pentekusa.com/CCs">http://www.pentekusa.com/CCs</a></td>
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<td>5.15</td>
<td>Oxyacetylene Torch</td>
<td>The oxyacetylene torch is a basic thermal cutting technique that can be used on carbon steel up to 4&quot; thick. Cutting speeds up to about 10 inches per minute can be obtained; the speed is a function of the material thickness and geometry. The torch burns the metal and coatings, producing smoke and fumes that may require control using portable HEPA filters, especially in radiologically contaminated environments. The torch can be manipulated by hand or can be placed on a motorized track for use in inaccessible or high radiation areas and long and uniform surfaces. Dimensions of Tech Model (LxWxH): 20 inches Weight of Technology Model (lb): 3 lbs.</td>
<td>THU's Technology Demonstration site, Miami, FL, USA.</td>
<td>Low capital and operating cost, fast cutting and portable. Quick set up and low maintenance. Easily adapted for remote operation.</td>
<td>Will cut only metal that oxidizes readily. Requires adaptation for remote deployment.</td>
<td>Equipment size reduction. Framatome Technologies, Inc. 3315 Oak Forest Rd., Lynchburg, Virginia United States 24502 Phone: (804) 832-2649 Fax: (804) 832-2873 Email: <a href="mailto:kledoux@framatone.com">kledoux@framatone.com</a> Website: <a href="http://www.framatone.com">http://www.framatone.com</a> <a href="http://www.dandd.org/AdvanceSearch.aspx?SearchVendorID=29">http://www.dandd.org/AdvanceSearch.aspx?SearchVendorID=29</a></td>
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<td>5.16</td>
<td>Spectrum 90™ Camera</td>
<td>The amphibious Spectrum 90™ is a Pan, tilt and zoom camera for toxic environment, confined space or underwater inspection. This robust 40 x zoom, 1/4 &quot; CCD color camera, with a diameter of 90mm and 1.5 lux sensitivity to build out of aluminum or stainless steel and depth rating to 30 meters. In addition the Spectrum 90™ zoom camera offers both flood and spot lighting with variable brightness to maximize your penetration and visibility with the opportunity for zoom when required.</td>
<td>N/A</td>
<td>Robust reliable and light weight construction. Can be used to supplement other crawler systems.</td>
<td>Visual Inspection. Inuktun Services Ltd. 2569 Kenworth Road, Suite C Nanaimo, BC, Canada V9T 3M4 Phone: (250) 729-8080 Toll Free: 1 (877) 468-5886 Fax: (250) 729-8077 <a href="http://www.inuktun.com">www.inuktun.com</a></td>
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<td>5.17</td>
<td>Spectrum 60™ PT Camera</td>
<td>The Spectrum 60™ PT is a small and robust remotely operated submersible pan and tilt camera manufactured from lightweight corrosion resistant materials. This high performance camera has high resolution and good sensitivity. Intuitive controls for ease of operation and the following key features: Diameter: 45 mm / 1.75 in Length: 125 mm / 4.92 in Pne connector Depth Rating: 30 m / 100 ft Resolution: 380 TV lines Sensitivity: 3 lux Light: Variable intensity.</td>
<td>N/A</td>
<td>:::Robust reliable and light weight construction.:::</td>
<td>Visual Inspection. Inuktun Services Ltd. 2569 Kenworth Road, Suite C Nanaimo, BC, Canada V9T 3M4 Phone: (250) 729-8080 Toll Free: 1 (877) 468-5886 Fax: (250) 729-8077 <a href="http://www.inuktun.com">www.inuktun.com</a></td>
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<td></td>
</tr>
<tr>
<td>Index</td>
<td>Technology</td>
<td>Description</td>
<td>Benefits</td>
<td>Limitations</td>
<td>Potential Application(s) at ORNL</td>
<td>Vendor/Website</td>
<td>Photograph</td>
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<td>5.18</td>
<td>Spectrum 45™ PT Camera</td>
<td>The Spectrum 45™ PT Camera is compact and powerful. Diameter: 45 mm / 1.75 in Length: 123 mm / 4.82 in Plus connector Depth Rating: 30 m / 100 ft Resolution: 380 TV lines Sensitivity: 3 lux Lights: Variable intensity • Toxic environment inspection • Underwater inspection • Small diameter pipe inspection • Foreign object search and assessment • Dam and lock inspection • Robotics and remote tooling • ROV integration Miniature size for 45 mm inspections that is light weight robust and reliable. This unit is waterproof to 30 m / 100 ft and has sensitive controls for precise operation. It can be used to supplement other crawler systems.</td>
<td>N/A</td>
<td>Visual Inspection</td>
<td>Inuktun Services Ltd. 2569 Kenworth Road, Suite C Nanaimo, BC, Canada V9T 3M4 Phone: (250) 729-8080 Toll Free: 1 (877) 468-5886 Fax: (250) 729-8077 <a href="http://www.inuktun.com">www.inuktun.com</a></td>
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<td>5.19</td>
<td>Crystal Cam® Push Camera</td>
<td>The low-cost Crystal Cam® Push Camera is a high-performance color video camera system that is designed for lateral and mainline pipe push inspections. This compact, lightweight readily affordable camera system with built-in LED lighting and a high resolution, low lux camera is effective in low light environments. The camera head is completely encased in transparent epoxy making it robust with a lightweight portable tether reel for key pipe inspection applications. Shock proof resin encased camera system with portable cable reel and self-contained control system. High resolution color camera with internal LED lighting with monitor in controller lid and has optional digital recording module with on-screen display for distance, time and date. Modular design is easy to operate and has the following key features: Diameter: 44.5 mm / 1.75 in Camera Length: 50 mm / 2 in Depth Rating: 300 m / 1000 ft Min. Pipe Diameter: 50 mm / 2 in Resolution: 380 TV lines Sensitivity: 0.5 lux Lights: 12 LEDs with Variable intensity Applications: • Lateral pipe inspections • Mainline pipe inspections up to 300 ft • Manhole safety inspections • Drop camera N/A</td>
<td>N/A</td>
<td>Visual Inspection of Pipes</td>
<td>Inuktun Services Ltd. 2569 Kenworth Road, Suite C Nanaimo, BC, Canada V9T 3M4 Phone: (250) 729-8080 Toll Free: 1 (877) 468-5886 Fax: (250) 729-8077 <a href="http://www.inuktun.com">www.inuktun.com</a></td>
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<td>5.20</td>
<td>Everest Co-Zoom 6.2 - PTZ100 Head</td>
<td>The Everest Co-Zoom® 6.2 system is the world’s most advanced industrial pan-tilt-zoom camera system. The system features still image or full-motion video capture, CompactFlash® removable storage media, an available laser measurement system, and PC remote control and re-measurement software. The PTZ100 camera head can be deployed through 100 mm (4.00 inch) diameter openings, and features a high-performance 10x-optical and 4x-digital zoom capability, high-powered LED lighting, and advanced camera setup features with our exclusive VIEW™ image management platform. Cumulative Dose: 220 Gy (~22,000 rads), Dose Rate: 30 Gy/hr (~1,000 R/hr) N/A Rad-hardened camera N/A</td>
<td>N/A</td>
<td>Inspection of hot cell and other facilities</td>
<td>GE Inspection Technologies Charlotte, NC Tel: (704) 882-4598 Mobile: (704) 905-3518 Fax: (704) 882-4081 Email: <a href="mailto:sean.alexander@ge.com">sean.alexander@ge.com</a> <a href="http://www.everestvit.com/en/products/rvi/ptz/ptz100/overview.html">http://www.everestvit.com/en/products/rvi/ptz/ptz100/overview.html</a></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td>Technology</td>
<td>Description</td>
<td>Previous Applications and Results</td>
<td>Benefits</td>
<td>Limitations</td>
<td>Potential Application(s) at ORNL</td>
<td>Vendor/Website</td>
<td>Photograph</td>
</tr>
<tr>
<td>-------</td>
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<td>6.1</td>
<td>CARTOGAM</td>
<td>The CARTOGAM is a relatively small (3.2 inches diameter by 16 inches long and relatively lightweight (approximately 15 pounds), real-time, gamma camera that provides two-dimensional mapping of gamma emitting sources. The characterization data is depicted as concentric and colored iso-contours that are overlain on a two-dimensional photographic image of the waste object or surface area in order to identify the location of gamma emitting hot-spots. Dose rates associated with each of uniquely colored iso-contours are also indicated on each image by a color-coded scale. Specialized software (Flannan/Gamma, which operates under Windows NT) is used to analyze the data. Using a thin connecting cable, the system is capable of operating with a PC-to-camera distance of up to 275 yards.</td>
<td>Hanford: deployed at Bldg 327 Hot cells. Also, deployed at East Tennessee Technology Park (ETTP) as part of DOE’s Portsmouth Alternatives for Characterization and Remediation Technology Survey (Concurrent Technologies Inc./FIU project)</td>
<td>Can be deployed through hot cell ports; can provide visual overlay of dose information, ensuring high-dose items can be handled properly (or shielded).</td>
<td>No deployment mechanism provided; no automatic pan-and-tilt capability</td>
<td>Hot cell, process cell and research reactor gamma emitting source identification</td>
<td>Canberra Industries: <a href="http://www.canberra.com/products/1099.asp">http://www.canberra.com/products/1099.asp</a></td>
<td>![CARTOGAM Diagram](Image 150x1004 to 312x1134)</td>
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<td>6.2</td>
<td>ISOCS</td>
<td>The ISOCS is a field portable unit that is capable of collecting data from very large surfaces in-situ, and can average any non-homogeneity of the contamination over the entire object or surface area of interest. Use of an ISOCS shield and/or selected collimators (allowing for 30-, 90-, or 180-degree fields of view) is also available to ensure that other nearby sources do not influence the data received for the specific area or objects of interest.</td>
<td>Hanford: deployed at Bldg 327 Hot cells</td>
<td>Allows for in-situ gamma spectrometry analysis, capable of collecting information from very large surfaces in-situ.</td>
<td>Deployment medium consists of cart where all components (including N-downs) are housed. Somewhat bulky configuration.</td>
<td>Process or hot cell characterization</td>
<td>Canberra Industries: <a href="http://www.canberra.com/products/1099.asp">http://www.canberra.com/products/1099.asp</a></td>
<td>![ISOCS Diagram](Image 389x1004 to 527x1130)</td>
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<td>6.3</td>
<td>Neutron Instrument Pod</td>
<td>The portable Neutron Instrument Pod incorporates fission chamber detectors for neutron detection, a Cadmium/Tellurium detector for gamma spectroscopy, and an Eberline R07 ion chamber for measuring gamma dose rates. The fission chamber neutron detector chosen for the Instrument Pod is a proportional counter containing a thin coating of highly-enriched uranium on the inside surface of its cylindrical wall. Fission chambers are less sensitive to neutrons than commonly-used neutron detectors such as beryllium tubes, but they were chosen for this application because they are insensitive to gamma radiation. The Neutron Instrument Pod hardware and deployment support was provided by PNNL.</td>
<td>Hanford: deployed at Bldg 327 Hot cells (G &amp; H) - 10/2002: Scherpelz RI, GM Mapili, and DS Dutt. 2003. Characterization of Tru Inventories in G and H Cells, 327 Building using a Neutron Instrument Pod. PNNL-14178, Pacific Northwest National Laboratory, Richland, WA</td>
<td>6-survey measurement of TRU items. Inductive method if facility contains other non-TRU sources with neutron emission technology is not remotely operated or mounted on an automated deployment mechanism.</td>
<td>TRU waste characterization</td>
<td>PNNL: <a href="http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14178.pdf">http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14178.pdf</a></td>
<td>![Neutron Instrument Pod Diagram](Image 565x1004 to 640x1152)</td>
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</tr>
</tbody>
</table>
Other Technologies

<table>
<thead>
<tr>
<th>Index</th>
<th>Technology</th>
<th>Description</th>
<th>Previous Applications and Results</th>
<th>Benefits</th>
<th>Limitations</th>
<th>Potential Application(s) at ORNL</th>
<th>Vendor/Website</th>
<th>Photograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.4</td>
<td>Gamma Locating Device (GLD)</td>
<td>The GLD detects gamma-emitting nuclides using a collimated detector. The system was designed to measure emissions from specific nuclides in high-background radiation environments. A built-in rangefinder determines the distance to the source being measured so that source intensities can be determined. The GLD detector is positioned in the area to be measured, remotely from the control and analysis equipment, and communication for control and data are transmitted by wireless means. The system uses a multi-channel analyzer to capture and identify radionuclides. Spectral lines of target isotopes are stored in the MCA and compared against the data. The system includes a television camera to provide visual images, and a graphic representation of the radiation intensity distribution is superimposed on the visual image. The combination of visual image, isotopic radiation intensity, and distance to source (and thus a real extent) may eliminate the need for sampling of the contamination.</td>
<td>Remote characterization</td>
<td>Prototype built; no commercialization thus far.</td>
<td>Hot cell, process cell and research reactor gamma emitting source identification.</td>
<td>As part of the FY 2000 and 2001 LSDDP, the Idaho National Engineering and Environmental Laboratory (INEEL) collaborated with the Russian Research and Development Institute of Construction Technology (NIKIMT). This collaboration resulted in the development of the Gamma Locating Device.</td>
<td><a href="http://www.emea.org/abstract2004/100465.pdf">http://www.emea.org/abstract2004/100465.pdf</a></td>
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<td>6.5</td>
<td>Niton Analyzer 700</td>
<td>The Niton 700 series analyzer uses X-ray fluorescence (XRF) spectrum analysis to identify and quantify elements in metal and then compares the readings to a built-in library to determine the alloy. The library contains 300 elements and alloys, and can be customized to fit user needs. Batteries power provide power for eight hours and charge in less than two hours. The analyzer stores up to 3,000 data sets, including sample locations. Data from the Niton analyzer is easily downloadable to a conventional personal computer. The Niton 700 series analyzer is a hand-held unit. The analyzer uses two radioactive sources, Americium-241 to test for antimony, bismuth, cadmium, indium, lead, palladium, silver, and tin, and Cadmium-109 to test for arsenic, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, nickel, selenium, strontium, titanium, zinc, and zirconium. The unit can be carried, shipped, and transported without exterior labeling conforming to 49 CFR 173.421. Placing the analyzer against a surface opens the shutter window. Within seconds the unit finishes the reading and displays the data.</td>
<td>Identifies and quantifies elements in metal and provides data that is more accurate and repeatable than laboratory analysis.</td>
<td>There are no significant technology limitations. This technology is currently not approved by the regulators as an alternative to laboratory analysis. Until approval by the regulators as an alternative to laboratory analysis, the potential benefit of this technology will be screening activities that will in some cases require confirmatory sample analysis.</td>
<td>Identification and characterization of surfaces containing lead paint.</td>
<td>NITON Corporation 900 Middlesex Turnpike Building 8 Billerica, Massachusetts United States 01821 Ph: (978) 670-7460 (800) 675-1578 Fax: (978) 670-7430 <a href="http://www.niton.com/XLiXLti700.asp">http://www.niton.com/XLiXLti700.asp</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td>Technology</td>
<td>Description</td>
<td>Previous Applications and Results</td>
<td>Benefits</td>
<td>Limitations</td>
<td>Potential Application(s) at ORNL</td>
<td>Vendor/Website</td>
<td>Photograph</td>
</tr>
<tr>
<td>-------</td>
<td>------------</td>
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<td>6.6</td>
<td>The SPCETRO XEPOS - XRF Analysis of PCBs and Inorganics</td>
<td>The SPCETRO XEPOS is an X-ray fluorescence spectrometer which uses polarized radiation to detect elements ranging from sodium to uranium. X-ray fluorescence spectrometers generally only measure the top surface of the sample, so it is important to grind and mix the sample into the powder so that a uniform reading that is representative of the entire sample will be achieved. A binding agent SPECTROBlend was added to the powder. The equipment was also used to detect the possible presence PCBs in various media (soil, paint, PPE, liquid, and oils) by measuring the total chlorine concentration. The SPECTRO XEPOS can measure the concentration of total chlorine (organic chlorine and chloride salts) in a sample, since chlorine is an elemental component of PCB. The XEPOS provides simultaneous determination of the elements present in a single measurement that varies from 100 to 500 seconds in length depending upon quality objectives. The results can be printed or saved as an electronic file for later use. The system can be set up with multiple internal standards that are matrix matched for various media such as soils, water, coatings, biological materials etc.</td>
<td>Deployed at The Idaho National Engineering and Environmental Laboratory (INEL) DOE-EP-0056, “XRF Analysis of PCBs and Inorganics,” September 2000</td>
<td>It is much faster turnaround on the sample results than the baseline. The SPCETRO XEPOS does not require samples to be digested or otherwise prepared before analysis. The new technology may eventually eliminate the need to ship samples offshore. Faster turn-around times result in D&amp;D schedules being reduced, resulting in cost savings.</td>
<td>For PCB analysis, the SPCETRO XEPOS can be used to reduce the number of samples that must be sent to the laboratory for analysis but, because it does not actually detect PCB, laboratory verification is still needed. If, however, the instrument does show a chlorine free reading, laboratory verification should not be required to conclude that the sample is free of PCBs.</td>
<td>SPECTRO Analytical Instruments Inc 160 Authority Drive Fitchburg, Massachusetts United States 01420 Ph : (978) 342-3400 Fax : (978) 342-8695</td>
<td><a href="http://www.spectro-usa.com">http://www.spectro-usa.com</a></td>
<td><img src="Image" alt="Photograph" /></td>
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<td>6.7</td>
<td>The EPOCH 4/EPOCH 4PLUS - Ultrasonic liquid level measurement</td>
<td>Ultrasonic liquid level measurement is often a good solution for situations that require fast, automatic measurement of level in a large number of containers that are going through a filling process. Ultrasonic liquid level measurement is also useful for the following specific areas: Measuring levels of caustic or reactive fluids in chemical processing applications where containers cannot be opened for safety reasons and the nature of the chemical or the process prevents installation of an internal float gage. Detecting the presence of standing fluids in pipe, particularly to investigate pipes that are being opened or cut during maintenance procedures. These high voltage pulser offer the operator extensive application versatility and ease of use. The Tunable Square Wave Pulser along with Narrowband filtering produce class-leading material penetration and signal-to-noise ratio in difficult materials such as cast metals, large forgings, composites, and plastics. Both pulsers are standard equipment on the EPOCH 4PLUS, EPOCH 4, and EPOCH 4B</td>
<td>N/A</td>
<td>Measuring liquid levels in a container or pipe using a noninvasive method (direct level measurement) or detecting the presence or absence of liquid in a sealed container (presence/absence test).</td>
<td>N/A</td>
<td>N/A</td>
<td>High Tech Supply Inc.</td>
<td><a href="http://www.clynd%E6%A2%86es.com/en/">http://www.clynd梆es.com/en/</a> minigapulation/22- pl307123246.html OR <a href="http://www.olympusndt.com/en/">http://www.olympusndt.com/en/</a> ePOCH-4/</td>
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<td>6.8</td>
<td>The EX-F70/F60 Series of Sunx Leak Detection Sensors</td>
<td>The EX-F70/F60 Series of Sunx Leak Detection Sensors is a unique and reliable method of protecting your equipment against leaks. Using a capillary effect, the sensor utilizes the change in refractive index to detect small leaks and viscous liquids. The built-in amplifier offers a compact design, and is available in general purpose (water detection) and chemical-resistant types. A convenient LED indicator allows for simple verification of fault conditions.</td>
<td>N/A</td>
<td>There is no need for sensitivity adjustments, and two simple mounting bracket styles facilitate simple installation.</td>
<td>N/A</td>
<td>N/A</td>
<td>Clearwater Technologies Inc.</td>
<td><a href="http://www.clrwtr.com/Sunx-">http://www.clrwtr.com/Sunx-</a> F70-Photoelectric- Sensors.pdf</td>
</tr>
<tr>
<td>Index</td>
<td>Technology Description</td>
<td>Previous Applications and Results</td>
<td>Benefits</td>
<td>Limitations</td>
<td>Potential Application(s) at ORNL</td>
<td>Vendor/Website</td>
<td>Photograph</td>
<td></td>
</tr>
<tr>
<td>-------</td>
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<td>6.9</td>
<td>The Ultrasonic Liquid Level Detection System</td>
<td>The technology uses ultrasonic transducer (UT) pulse-echo based instruments with custom electronics designed for the manual detection of free-standing liquid in drums, tanks, and pipes. The Ultrasonic Liquid Level Detection System provides the capability for real-time, simple &quot;yes/no&quot; electronic detection/determination of standing liquid. A gel is used to couple the acoustic wave from the piezoelectric-based sensor into the wall of the vessel to be tested. The metal wall has acoustic impedance similar to that of the gel. This acoustic impedance combined with low attenuation conducts the acoustic wave to the other side of the wall.</td>
<td>The Ultrasonic Liquid Level Detection System was deployed in the 221-U Facility at the Hanford Site during fiscal year 2000. The results of the ultrasound examinations were identical to the results obtained using traditional methods and/or an infrared liquid level detection method. Deployment of the Ultrasonic Liquid Level Detection System was accomplished through the support of the Deactivation and Decommissioning Focus Area, which is managed by the National Energy Technology Laboratory.</td>
<td>Requirement for application of gel between the sensor and the vessel wall.</td>
<td>Liquid detection in non-transparent containers.</td>
<td>Pacific Northwest National Laboratory.</td>
<td><img src="Ultrasonic_LCD_Cost.pdf" alt="Image" /></td>
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<td>6.10</td>
<td>LVUD101 Micro Size Liquid Sensing Switch</td>
<td>The LVUD101 offers a micro-sized sensing body for the detection of liquids. The LVUD101 liquid level switch can be used in many different applications including: containment sump sensor, dispensing pan sensor, containment tank sensor, high level/full/low level alarm sensor and hydrostatic leak detection. The LVUD101 operates on the ultrasonic principle. A signal transmitted by the sensor is affected by the attenuation and dielectric properties of air versus liquid. The electronics determines which product is present and provides a corresponding output to the alarm/control system. Digital sampling techniques employed by the electronics, ensure high reliability and no false indications. Controlling environmental pollution due to leakage and overfill of hazardous chemicals is a primary concern to anyone with either underground or above ground storage tanks.</td>
<td></td>
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<td><a href="http://www.omega.com">www.omega.com</a> 1-800-TC-OMEGA Stamford, CT.</td>
<td><img src="LVUD-101.pdf" alt="Image" /></td>
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<td>6.11</td>
<td>FSL 500C5Y00 - fiber optics for pipe / tube-mounted liquid level detection</td>
<td>Pipe-mount liquid level sensors from Flomer electric were designed specifically to function with clean, highly transparent pipes of diameters up to 13 mm. The sensor's infrared light beam refracts when liquid is present, rendering the beam unrecognizable by the receiver. This allows non-contact detection of liquids through the piping, eliminating the need for drilling. This family is available in both PNP and NPN outputs. The fiber optic array unit offers enhanced chemical resistance and will suppress bubbles up to 3 mm, ensuring true liquid level measurements in foamy targets.</td>
<td></td>
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<td>Flomer Electric AB</td>
<td><img src="Honeywell-ProductInfo.aspx?C7232A1008" alt="Image" /></td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td>Technology</td>
<td>Description</td>
<td>Previous Applications and Results</td>
<td>Benefits</td>
<td>Limitations</td>
<td>Potential Application(s) at ORNL</td>
<td>Vendor/Website</td>
<td>Photograph</td>
</tr>
<tr>
<td>-------</td>
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<td>6.12</td>
<td>C7232A1008</td>
<td>The sensor measures the CO2 concentration in the ventilated space or duct. The sensors are used in ventilation and air conditioning systems to control the amount of fresh outdoor air supplied to maintain acceptable levels of CO2 in the space. • Models available with LCD that provides sensor readings and status information. • Non-Dispersion-Infrared (NDIR) technology used to measure carbon dioxide gas. • C7232 provides voltage or current output based on CO2 levels. • SPST relay output. • Used for CO2 based ventilation control (Demand Control Ventilation (DCV)).</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Honeywell International Inc <a href="http://customer.honeywell.com/honeywell/ProductInfo.aspx?C7232A1008">http://customer.honeywell.com/honeywell/ProductInfo.aspx?C7232A1008</a></td>
<td>N/A</td>
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<td>6.13</td>
<td>SBG-200 Wall Mounted Gas Monitor</td>
<td>The SBG-200 is an affordable solid-state completely self-contained monitor capable of detecting a variety of toxic and flammable gases and vapors. Several sensors are available which allow it to be calibrated to alarm at gas concentrations well below their lower explosive limit or OSHA ceiling. The SBG-200 uses a solid state high reliability sensor which is located either on the bottom portion of the unit enclosed in the black housing or at the end of the optional sensor extension. Under most conditions your sensor is sufficiently protected from dust and other contaminants. Several sensors are available. When monitoring particularly hazardous or corrosive environments or locate the sensor at an alternate point, the SBG-200 is available on an optional basis with the sensor mounted on a cable which can be extended from the monitor up to a distance of 100 feet depending upon the application. The sensor operates by diffusion. It is very stable over time. Carbon Monoxide (CO) 50-200 ppm.</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A American Gas &amp; Chemical Co. ltd <a href="http://www.amgas.com/sbgpage.htm">http://www.amgas.com/sbgpage.htm</a></td>
<td>N/A</td>
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<td>6.14</td>
<td>LIBS</td>
<td>The Spark I.D. (often referred to as LIBS) produced by Science and Engineering Associates Inc. is a commercial application from earlier research done principally by Dr. David Creames of Los Alamos National Laboratory (LANL) in the late 1980s and early 1990s. The principal of the analysis is commonly referred to as laser-induced breakdown spectrosopy (LIBS). LIBS is rather simple in concept as a pulsed Nd:YAG laser provides the necessary energy to electronically excite electrons in the target elements, and once the energy is removed, the electrons move from the excited state to a lower more stable energy level and emit energy in the form of photons. These photons are discrete energy, and in the case of beryllium the most predominant wavelength is the 313 nanometer and less predominant is the 334-nanometer wavelength. Of course, other metals can be similarly analyzed using different emission lines.</td>
<td>The demonstration at Golden was in the Hill Hall of the Colorado School of Mines, Reactive Metals Laboratory - August 2003</td>
<td>The LIBS appears to be quite mature in development.</td>
<td>The LIBS results appear to be biased low as compared to a laboratory result. The results may be low due to particle diffraction from the photon emission. A possibility for the apparent low results may also be that during a traverse across the filter surface, a significant amount of analyte does not get impingement by the laser and consequently does not undergo excitation with resulting emission.</td>
<td>Beryllium Detection Science and Engineering Associates Inc</td>
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### 6.15 BAM

**Description:** The beryllium air monitor (BAM) is a field-transportable air monitor that uses an atmospheric pressure microwave generation to provide 5,000 degree Celsius plasma that is sufficient to excite beryllium to an atomic excited electronic state. The emission from the excited state is energy in the ultraviolet region. By using a spectrometer that has the capability to differentiate discrete wavelengths in the ultraviolet and to quantify the spectral energy using photometer and electronic amplification, the instrument is capable of distinguishing and quantifying beryllium in air. The BAM technology requires 208V, 3-phase power with a 5-connector plug. The BAM also requires compressed air at approximately 50 psi and 10 CFM. The exhaust from the plasma is unfiltered, and when analyzing or calibrating with beryllium standards, the operator must provide for an external HEPA filtration of the plasma torch. The BAM is housed in a cabinet that is approximately 4 feet in height, 3½ feet in depth, and 3½ feet in length. The wheeled cabinet requires considerable cooling ventilation; it has several fans and exhaust ports.

**Potential Application(s) at ORNL:** N/A

**Benefit:** The BAM in the present configuration will not adequately perform as a transportable beryllium air monitor.

**Limitation:**

**Vendor/Website:** Beryllium Detection

**Photograph:**

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### 6.16 VecLoader

**Description:** The VecLoader High-Efficiency Particulate Air (HEPA) Vacuum is a self-contained, trailer-mounted vacuum unit used commercially to evacuate asbestos insulation. The HEPA VAC transports the insulation through a flexible suction hose up to 500 ft. Asbestos insulation and fiber are vacuumed and captured in a fully enclosed negative-pressure system and sent into diesel engine-powered vacuum cyclone separator where it is sprayed with water to promote clumping. The VecLoader HEPA VAC can pull insulation right off the wall and send it directly into appropriate disposal containers. It is an extremely high-powered vacuum system capable of suctioning 1,700 cubic feet of air per minute at a vacuum of 15 inches of mercury and is equipped with automatic shutoff safety valves. All components of the VecLoader are mounted on a readily transportable trailer. The VecLoader is designed to vacuum any material-liquid, slurry, or solid-that can be drawn through its 5-inch diameter smooth bore vacuum hose. The integrated engine/vacuum generates high noise levels, and in a typical configuration, the VecLoader is located outside the work area. Dimensions of Tech Model (LxWxH): Width of HEPA VAC 7 ft 10 in, Traveling Height of HEPA VAC 11 ft 4 in, Operating Height of HEPA VAC 18 ft 0 in, Traveling Length of HEPA VAC 17 ft 8 in, Operating Length of HEPA VAC 24 ft 2 in, Maximum Operating Height of HEPA VAC 8 ft 6 in. Weight of Tech Model (lb.): 9,800.

**Potential Application(s) at ORNL:** Removal of asbestos from all three types of facilities.

**Benefit:** The VecLoader insulation removal process is more than three times as fast as manual removal. Other benefits include: reduced airborne contamination and worker exposure to contaminants and radionuclides, reduced personal protective equipment, this due to its higher production rate that reduced the time required for insulation removal. Reduced waste disposal because achieved 58.5% compaction of the insulation versus 7.7% for manual removal.

**Limitation:** The 5-inch diameter hose was difficult and cumbersome to maneuver and the 2.5-inch diameter hose was not effective due to repeated plugging. There were no handle or nozzle at the end of the hose and the workers simply held the hose directly with their hands. The power suction caused the vacuum hose to stick to the wall. Communication between the vacuum hose operator and the VecLoader operator was difficult due to noise levels generated by the equipment. Locating clogs in the vacuum line was difficult. The VecLoader operator had no way of knowing how much insulation was being suctioned into the cyclone separator or when the waste needed to be discharged into the waste collection bags. The moistened insulation discharged into the waste disposal bags sometimes made them heavy and difficult to handle.

**Vendor/Website:** Vector Technologies Ltd.

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*Fernald LSDDP - OSI No 1374, DOE/EM-0469*

*Removal of asbestos from all three types of facilities.*

*http://www.vector-vacuums.com*
### VAC-PAC® HEPA vacuum & waste collection system

The standard VAC-PAC® design offers two-stage positive filtration of hazardous particulates, including radionuclides, toxic chemicals and lead-based paint. First stage efficiency is 95% at 1 micron; second stage HEPA efficiency is 99.97% at 0.3 microns. First stage design offers automatic self-cleaning by reverse-flow pulses of high-pressure air. This feature substantially reduces the need for routine filter maintenance; recommended replacement is at annual intervals. Even extremely fine powders such as Portland cement can be vacuumed on a continuous basis without interruption. VAC-PAC® reliability is high, as the system is designed with virtually no moving parts.

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### COMPACT-VAC™ man-portable HEPA vacuum

The COMPACT-VAC is designed to support one shrouded power tool anywhere up to ten feet away from the vacuum system. The COMPACT-VAC utilizes an air venturi design to eliminate moving parts and motors which may burn out. The COMPACT-VAC offers two-stage positive filtration of hazardous particulates. First stage micro filtration captures the bulk of the collected debris with an efficiency of 99.9% for particulates greater than two microns. Second stage HEPA filtration prevents passage of lead-containing paint dust with an efficiency of 99.97% for all particulates greater than 0.3 microns. Waste is transported via the vacuum hose into disposable bags located within the vacuum container. The COMPACT-VAC holds one gallon or approximately 50 square feet of removed material. The waste container is constructed of stainless steel, allowing for ease of cleaning and decontamination. The COMPACT-VAC supports Pentek’s shrouded power tools, including the CORNER-CUTTER needle gun, which comes equipped with multi-geometric nozzles for corners, edges and bolts. The COMPACT-VAC collects all dust and debris as the ROTO-PEEN Scaler prepares steel, concrete, brick and wood surfaces at a nominal rate of 45 sq. ft./hr. The COMPACT-VAC offers two-stage positive filtration of hazardous particulates. First stage efficiency is 95% at 1 micron; second stage HEPA efficiency is 99.97% for all particulates greater than 0.3 microns.

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### Compact Remote Operator Console

The compact remote operator console provides an economical solution to remote systems control in a portable and modular fashion. It is based on a single box to be wheeled in through a standard size personnel entry door, opened up, and folded out rapidly into a working system. Weight, power consumption, and ease and speed of setup are emphasized. Remote viewing and graphical user interface are provided via flat panel screens arranged as a video cylinder in front of the operator. A control chair is the central focal point, using side consoles for remote viewing and peripheral control inputs. High-level control provided for the remote system is supplied via a separate control box.

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### Photographs

1. [Photograph of VAC-PAC® HEPA Filtration Systems](http://www.pentekusa.com)
2. [Photograph of COMPACT-VAC™ Man-Portable HEPA Vacuum](http://www.pentekusa.com)
3. [Photograph of Compact Remote Operator Console](http://www.pentekusa.com)
<table>
<thead>
<tr>
<th>Index</th>
<th>Technology</th>
<th>Description</th>
<th>Previous Applications and Results</th>
<th>Benefits</th>
<th>Limitations</th>
<th>Potential Application(s) at ORNL</th>
<th>Vendor/Website</th>
<th>Photograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.20</td>
<td>SQUIRREL-III Floor Scabbler</td>
<td>The Squirrel-III was developed to scarify concrete floors and slabs in an environmentally safe manner. The Squirrel-III is designed to tackle small jobs and to get into tight places near corners, wall/floor joints, floor penetrations, steps and under protruding equipment. It is also designed to remove protective coatings, laitance, and concrete substrate in a single step-process. Surfaces are left clean with a uniform texture, and ready to receive new coatings. The Squirrel-III is a pneumatic operated scabbler that operates in conjunction with an ultra-high performance HEPA-filtered vacuum system. The Squirrel-III incorporates unique vacuum flow designs which provide high efficiency performance in contaminated or clean-room environments which require stringent control of dust, debris, and airborne contamination. The Squirrel-III minimizes the need for respiratory protection of operating personnel from airborne radiological and toxic particulate hazards. The need to protect nearby equipment from flying dust and debris is also minimized. The Squirrel-III also incorporates Pentek’s exclusive scabbling head vibration isolation technology. The Squirrel-III is equipped with carrier wheels and a handle for easy transport around the job site. Dimensions of Tech Model (LxWxH): 12” X 6” X 12” Weight of Tech Model (lb.): 50</td>
<td>Easy to operate, requires little training. Leaves surface smooth and even for repainting or reuse. Vacuum unit minimizes dust. Unit is very manuverable and reaches tight spots.</td>
<td>Equipment is designed to be used on small or confined areas such as wall/floor joints instead of large floor surfaces. The operator’s hand that depresses the trigger is subjected to some fatigue. At the demonstration, one operator taped the trigger down for continual operation. Requires adaptation for remote deployment.</td>
<td>Decontamination of concrete surfaces.</td>
<td>Pentek, Inc 1026 Fourth Avenue Coraopolis, Pennsylvania United States 15108 Phone: (412) 262-0725 Fax: (412)-262-0731 Email: <a href="mailto:pentekusa@aol.com">pentekusa@aol.com</a> Website: <a href="http://www.pentek.com">http://www.pentek.com</a> <a href="http://www.dandd.org/TechnologyFactSheet.aspx?TechnologyID=64">http://www.dandd.org/TechnologyFactSheet.aspx?TechnologyID=64</a></td>
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</tr>
</tbody>
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Appendix 2 Universities with Robotics Programs

Listed below are internet links to currently active university robotics programs. This list is neither comprehensive nor an endorsement of any program. However, the programs listed here may be a source of support for filling some of the identified technology gaps.

**Boston University** .......................................................... http://robotics.bu.edu/

**Brown University** ............................................................ http://www.cs.brown.edu/research/robotics/

**California Institute of Technology** ..................................... http://robotics.caltech.edu/

**Carnegie Mellon University**

  - *Robotics Institute* ..................................................... http://www.ri.cmu.edu/
  - *Field Robotics Center* ................................................ http://www.frc.ri.cmu.edu/
  - *Software Engineering Institute* ..................................... http://www.sei.cmu.edu/
  - *Vision/Autonomous Systems Center* ............................... http://www.ius.cs.cmu.edu/
  - *Advanced Manipulators Laboratory* ............................... http://www.cs.cmu.edu/afs/cs.cmu.edu/project/chimera/www/aml.html

**Case Western Reserve University**

  - *Dynamics of Adaptive Behavior Research Group* ... http://vorlon.cwru.edu/~beer/group.html
  - *Biologically Inspired Robotics Lab* ............................... http://biorobots.cwru.edu/

**Columbia University** ........................................................ http://www1.cs.columbia.edu/robotics/

**Cornell University** .......................................................... http://ccsl.mae.cornell.edu/research/selfrep/
Florida International University .................................
http://www.eng.fiu.edu/mme/robotics/

Georgia Institute of Technology

Mobile Robot Laboratory ................................. http://www-static.cc.gatech.edu/ai/robot-lab/

Harvard University ............................................. http://hrl.harvard.edu/

Iowa State University

Artificial Intelligence Research Group .............. http://www.cs.iastate.edu/~honavar/aigroup.html

Johns Hopkins University ................................. http://robotics.jhu.edu/

Massachusetts Institute of Technology

Field and Space Robotics Laboratory .............. http://robots.mit.edu/

Mobile Robotics Laboratory ..............................
http://www.ai.mit.edu/projects/mobile-robots/

McGill University

Intelligent Machines ................................. http://cim3.cs.mcgill.ca/

Ryerson University

Network-Centric Applied Research Team ............ http://ncart.scs.ryerson.ca/

Simon Fraser University

Intelligent Robotics and Manufacturing Systems ....
http://www.ensc.sfu.ca/research/irms/

Stanford University

Dextrous Manipulation Lab .............................. http://www-cdr.stanford.edu/Touch/touchpage.html

University of British Columbia

Laboratory for Computational Intelligence ......... http://www.cs.ubc.ca/nest/lci/
University of California Berkeley

Robotics and Intelligent Machines Lab .................. http://robotics.eecs.berkeley.edu/

Human Engineering Laboratory .............................. http://bleex.me.berkeley.edu/

University of Cincinnati

Center for Robotics Research .......................... http://www.robotics.uc.edu/

University of Delaware

Rehabilitation Robotics Lab ......................... http://www.asel.udel.edu/robotics/research.html

University of Florida

Machine Intelligence Laboratory ...................... http://www.mil.ufl.edu/

University of Hawaii

Autonomous Systems Laboratory ................. http://www.eng.hawaii.edu/~asl/

University of Illinois at Urbana-Champaign

Robotics and Computer Vision Laboratory .......... http://www-cvr.ai.uiuc.edu/

University of Maryland

Intelligent Servo systems Laboratory ............ http://www.isr.umd.edu/Labs/ISL/isl.html

Mechanical Engineering Robotics Laboratory ...... http://www.cfar.umd.edu/robotics/

Space Systems Laboratory ............................ http://www.ssl.umd.edu/

University of Michigan

MEAM Mobile Robotics Lab ....................... http://www.personal.engin.umich.edu/~johannb/moroblab.htm

University of New Hampshire

Robotics Laboratory ................................. http://www.ece.unh.edu/robots/robotics.htm
University of Rochester

Robotics Lab...........................................
http://www.cs.rochester.edu/u/brown/lab.html

University of Southern California

Institute for Robotics and Intelligent Systems ........ http://iris.usc.edu/iris.html

Modular Robotics Laboratory ....................... http://www.usc.edu/users/goldberg/mrl.html

University of Toronto

Virtual and Augmented Reality ......................
http://vered.rose.utoronto.ca/index.html

Robotics and Automation Laboratory ............... http://www.mie.utoronto.ca/labs/ral/

Utah State University

Center for Intelligent Systems........................
http://www.csois.usu.edu/index.php?PID=SaIZ0NrSAZ

Vanderbilt University

Intelligent Robotics Laboratory..................... http://eecs.vanderbilt.edu/cis/
Appendix 3 Website Links Related to D&D

Listed below is a set of internet links to sites related to D&D. This list is a subset of a more comprehensive list provided at the Argonne Decommissioning Training Course. The list is neither comprehensive nor an endorsement of any of the companies or technologies listed. Many of the links are not directly related to remote operations but may be useful resources as planning to fill technology gaps progresses.

**Dismantlement Tools**
- American Dismantlement (Explosives) [http://www.adc-il.com]
- Aquamazing Design Inc (Dismantlement) [http://www.plantdecommissioning.com]
- Barnhart Crane & Rigging Co (rigging & lifting) [http://www.barnhartcrane.com]
- Bigge Crane & Rigging Co (rigging & lifting) [http://www.bigge.com/crane/index.htm]
- Bluegrass Concrete Cutting Inc [http://www.concretecutters.com/]
- Boart Longyear (concrete saws) [http://www.boartlongyear.com/cushioncut]
- Bosch Tools (hand tools) [http://www.boschtools.com]
- Bristar (fracturing compound) [http://www.demolitiontechnologies.com]
- Brokk (concrete) [http://www.nasgolz.com/hmbody.htm]
- Concrete Shaver (concrete) [http://www.concreteshaver.com/]
- Controlled Demolition Inc (CDI) (explosives) [http://www.controlled-demolition.com]
- cr/x Environmental Services Inc (concrete demo) [http://www.crxeenvironmental.com]
- CS Unitec (tools) [http://www.csunitec.com]
- Cutting Edge Services (concrete cutting) [http://www.cuttingedgeservices.com/]
- DEMCO (D&D services) [http://www.demcodemolition.com]
- F2 Associates Inc (lasers) [http://www.f2laser.com]
- ENZ USA Inc (pipe cleaning tools) [http://www.enz.com]
- ESAB (plasma arc tools) [http://www.esab.com]
- Esco Tools (conc tools) [http://www.escotool.com]
- Fein Tools (hand tools) [http://www.fein.com]
- Golz [http://www.nasgolz.com/ghmbody.htm]
- Grey Pilgrim (robotics) [http://www.greypilgrim.com]
- Hamwic Projects Ltd [http://www.btinternet.com/~hamwic/projects/]
- Hennigan Engineering [http://www.henniganengineering.com]
- Hilti Tools (various) [http://www.us.hilti.com/]
- HTP America Inc (plasma arc equipment) [http://www.usaweld.com]
- Hypertherm (plasma arc) [http://www.hypertherm.com]
- Impact Technologies Inc (conc demolition tools) [http://powersledge.com]
- InstaCote (fixatives - RFETS) [http://www.instacote.com]
- Lampson International (cranes) [http://www.lampsoncrane.com]
- Laser Institute of America (lasers) [http://www.laserinstitute.org/member_directory/]
- Lukas Hydralik [http://www.lukas.de]
- Marcrist (air & surface prep tools) [http://www.marcrist.com]
- Mathey Dearman (pipe milling) [http://www.mathey.com]
Mega-Tech Services
Milwaukee Tools (hand tools)
Millerwelds (plasma)
NuCut (dismantling tools)
PCI Energy Services
Rigging International (rigging and lifting)
SSI Shredding Systems Inc (shredders)
Stihl (hand tools)
Stone Construction Equipment
Tri-Tool (milling)
Trumpf (nibblers/shears)
Universal Ice Blast (carbon dioxide cleaning)
Wachs Company (saws)
Waterjet Technology Inc
Welding Services
W F Wells (saws)

Decontamination Services/Tools
Adv Environmental Systems (scabblers, blasters)
Alpheus (CO2 blasters)
American Technologies Inc (mobile unit)
Atlas Copco Compressors
Butterworth Jetting Systems (high pressure water)
Cold Jet Inc
Contam-Away (Soda Blasting)
CORPEX Technologies (decon)
Cryogenesis International (CO2 blasting)
D&L Thomas Equipment Corporation
Desco Tools (decon tools)
Encapsulation Technologies (fogging)
Euro Aqua Drill Inc (HP water)
Framatome Technologies
Georg Fischer Disa Goff Inc (abras & hydro wash)
Hotsy System (high pressure water)
INTEK Technology (decont solutions)
Knight Armour Environmental Services
Lasertronics (laser decontamination)
MacDonald Tools (scabblers)
Master-Lee
Mega-Tech Services
Nilfisk (ind vacs)
NitroCision (Nitrogen decon tool)
Novatek (decont tools)

http://www.mega-tech.com
http://www.mymtoolstore.com
http://www.MillerWelds.com
http://www.elecdraulicsolutions.com
http://www_pci-energy.com
http://www.rigginginternational.com
http://www.ssiworld.com
http://www.stihlusa.com
http://www.stone-equip.com
http://www.trelawnyonline.com
http://www.us.trumpf.com
http://www.iceblast.net
http://www.wachsc.com
http://www.waterjet-tech.com
http://www.weldingservices.com
http://www.wfwells.com
http://www.aesinc.net
http://www.dryiceblasting.com
http://www.atechinc.com
http://www.atlascoipco.compressors-usa.com
http://www.coldjet.com
http://www.obg.com
http://www.corpextech.com
http://www.driller.com
http://www.DescoMfg.com
http://www.fogging.com
http://www.euroaquadrill.com
http://www.framatech.com
http://www.goff.thomasregister.com
http://www.hotsyalbertaab.com
http://www.INTEKtechnology.com
http://www.knightarmour.com
http://www.lasertronics.com
http://www.macdonaldtools.com
http://www.masterlee.com
http://www.mega-tech.org/
http://www.pa.nilfisk-advance.com
http://www.nitrocision.com
http://www.novatekco.com
Pentek (scabblers & vacs)  http://www.pentekusa.com
PN Services  http://www.pnservices.com
Sioux Steam Cleaner  http://www.siouxsteam.com
SpongeJet  http://www.spongejet.com
P W Stephens Environmental  http://www.pwstephens.com
Surface Technology Systems  http://www.stsus.com
Syntech Products  http://www.syntechproducts.com
TechniClean (CO2 blasting)  http://www.techniclean.com/nuclear.html
Tomco Equipment (CO2 blasters)  http://www.netheaven.com/~tncorp/index.html
Ultrasonic Power Corporation (ultrasonic decon)  http://www.upcorp.com
USF Surface Preparation (shotblasting )  http://www.surfacepreparation.com
Universal Ice Blasting Inc (decontamination)  http://www.iceblast.net
Vac-Trax (hydrolaser equipment)  http://www.tmrassociates.org
Vector (vacuums)  http://www.vector-vacuums.com

Health Physics/Instrumentation
AIL (Gamma Cam)  http://www.ail.com
The Alpha Group & Associates LLC (characteriz.)  http://www.alphagroup.us
Antech  http://www.antech-inc.com
Aptec-NRC  http://www.aptec-nrc.com
Berkeley Nucleonics  http://www.berkeleynucleonics.com/
Bicron  http://www.bicron.com/
Bioscan (direct radioisotope cting)  http://www.bioscan.com
Blade Werx (rad instruments)  http://www.bladewerx.com/
Blue Ridge Metrology (site modeling & Photogram)  http://www.blueridgemet.com
BNFL Instruments  http://www.bnfl-instruments.com
Cabrera Services (D&D Services)  http://www.cabreraservices.com/
Calibration Metrology Group (Instr Calib)  http://www.calshack.com
Canberra  http://www.canberra.com
ChemRad  http://www.chemrad.com/
Chesapeake Nuclear Services (HPs)  http://www.chesnuc.com
CHP Consultants (CHP services)  http://www.chpconsultants.com
Clamshell Buildings (temp dome structures)  http://www.clamshell.com
Co-Physics Corporation  http://www.co.physics.com
Cole & Associates (HP, IH services)  http://www.ctctbear.com
C S Engineering (nucl crit / trg / AB)  http://www.cseng.org
Eberline  http://www.eberline.com
ERS Solutions (Rad consulting – final surveys)  http://www.erssolutionsinc.com
Exploranium Radiation Detection Systems  http://www.exploranium.com
Hi-Q Environmental Products Co (air sampling)  http://www.hi-q.net
Intelligent Detection Systems Inc  http://www.idsdetection.com
Johnson & Associates  http://johnsonnuclear.com/
LND Inc  http://www.lndinc.com
Ludlum  http://www.ludlums.com
MGP Instruments  http://www.mgpi.com
Mound Technical Solutions (Instrumentation) http://www.moundtech.com
NFS-Radiation Protection Systems http://www.nfsrps.com
Niton Corp (hand held characterization eq) http://www.niton.com
Nuclear Lead Co. (lead shielding) http://www.nuclearlead.com
Nuclear Safety Associates (crit services / nucl serv) http://www.nuclearassociates.com
Nuclear Technology Services http://www.ntsincorg.com
Overhoff http://www.Overhoff.com
Perkin Elmer Instruments (formerly ORTEC) http://www.ortec-online.com
Princeton Gamma-Tech Inc http://www.pgt.com
Protean Instrument Corporation http://www.proteaninstrument.com/
Qal-Tek Associates (HP services/Rad Sources) http://www.qaltek.com
Quantrad Corporation http://www.quantrad.com
RadSurvey Systems LLC (Rad Survey solutions) http://www.radsurvey.com
Radiation Safety Information Computational Center (RSICC) (computational software codes) http://www.epics.cped.ornl.gov
RMD Inc LLC (gamma camera) http://www.rmdinc.com
RadElec (EPERM – Ra & Th Measurements) http://www.radelec.com
Radiation Monitoring Devices, Inc (Radcam) http://www.rmdinc.com
Radiological Instrumentation Calibration & Rental http://www.ricarinc.com
Radiological Services Inc (Pipe Crawler) http://www.radiologicalservices.com
Reuter Stokes Inc (env monitoring) http://www.gepower.com/reuterstokes/
Science & Engineering Associates (Pipe Explorer) http://www.seabase.com
Thermo-Hanford Inc (Laser Assisted Ranging & Data System) http://www.thermohanford.com/larads.html
Thermo-Electron http://www.eberline.com
Victoreen Nuclear Associates http://www.nucl.com
XRF Corp (gamma & x-ray fluor Spectrometers) http://www.xrfcorp.com

**Imaging Systems**
Bio-Imaging Research Inc http://www.bio-imaging.com
EverestVIT http://www.everestvit.com
Fast Track Projects Inc (photogrammetry) http://www.fast-track-projects.com
IST Rees http://www.istimaging.com/VisNuclearApp.htm
Meier Engineering (photogrammetry) http://www.meierinc.com
VJ Technologies http://www.vjt.com

**Robotics**
Brooks Automation http://www.brooks.com
Carnegie-Mellon http://www.frc.ri.cmu.edu/
Cybermotion http://www.cybermotion.com
Fanuc http://www.fanuc.com
Framatome Technologies http://www.framatech.com
HDE Manufacturing http://www.hdemfg.com
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