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SRTC
Savannah River Technology Center

Available Decontamination and Decommissioning Capabilities at the Savannah River Technology Center

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Equipment Engineering Section
Environmental Science Section
Environmental Technology Section
Interim Waste Technology Section
Nuclear Processes Safety Research Section
Safety Technology Section
Scientific Computation Section

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LIST OF ACRONYMS

BRC	Below Regulatory Concern
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulation
D&D	Decontamination and Decommissioning
DCS	Distributed Control Systems
DOE	Department of Energy
DOE-EM	Department of Energy Office of Environmental Restoration and Waste Management
DWPF	Defense Waste Processing Facility
EPA	Environmental Protection Agency
ER	Environmental Restoration
ET	Eddy (Current) Test
FIA	Flow Injection Analysis
LANL	Los Alamos National Laboratory
PCB	Polychlorinated Biphenyl
RCRA	Resource Conservation and Recovery Act
RESRAD	RESidual RADioactivity
SAR	Safety Analysis Report
SARP	Safety Analysis Report for Packages
SED	Separation Engineering Development
SIMON	Semi-Intelligent Mobile Observing Navigator
SNM	Special Nuclear Material
SRS	Savannah River Site
SRTC	Savannah River Technology Center
TEWM	Tritium Effluent Water Monitor
TIC	Total Inorganic Carbon
TOC	Total Organic Carbon
TRU	Transuranic
TSR	Technical Safety Requirements
USQD	Unreviewed Safety Questions Determination
UT	Ultrasonic Test
VCR	Video Cassette Recorder
WIPP	Waste Isolation Pilot Plant
WSRC	Westinghouse Savannah River Company

1.0 EXECUTIVE SUMMARY

The Safety Analysis and Engineering Services Group has performed a survey of the Savannah River Technology Center (SRTC) technical capabilities, skills, and experience in Decontamination and Decommissioning (D&D) activities. The goal of this survey is to enhance the integration of the SRTC capabilities with the technical needs of the Environmental Restoration Department D&D program and the DOE Office of Technology Development through the Integrated Demonstration Program.

Within the Environmental Restoration mission of the SRTC is the development, demonstration, evaluation, and improvement of technologies for the D&D of the Savannah River Site (SRS) facilities in a proactive, environmentally sound, and cost effective manner.

The SRTC has applied a large number of technologies at SRS which can be useful to the DOE-EM D&D program at SRS and throughout the DOE Nuclear Complex. Many of these activities were performed as a part of SRTC mission to support production facilities under the Office of Defense Programs. These technologies have varied widely in content and in point of application. The purpose of this study was to identify the specific technologies which have application in D&D so maximum utilization of SRTC capabilities might be achieved in providing technical support to D&D activities in the most cost effective manner.

The SRTC has adapted technology from elsewhere to meet the SRS needs when appropriate. The SRTC staff has effectively employed existing technology in solving previous D&D problems, and has developed expertise in this regard. When existing technologies were not available, innovative and creative research and development programs were conducted to provide cost effective high-technology and state-of-the-art techniques. The result of SRTC's support of SRS during past decades has lead to a robust experience base. Examples of the applications of existing technology and development of new capabilities are found throughout this report.

The SRTC has added significant value to these technologies by developing multidisciplinary expertise in their application. This synergism provides technological excellence which would not otherwise be available.

This survey has identified technical capabilities, skills, and experience in the following D&D areas: Characterization, Decontamination, Dismantlement, Material Disposal, Remote Systems, and support on Safety Technology for D&D.

This review demonstrates the depth and wealth of technical capability resident in the

SRTC in relation to these activities, and the unique qualifications of the SRTC to supply technical support in the area of DOE facility D&D. Additional details on specific technologies and applications to D&D will be made available on request.

2.0 INTRODUCTION

The Safety Analysis and Engineering Services group has performed a survey of the D&D technology capabilities at the SRTC. The purpose of the survey is to enhance the integration of the SRTC capabilities with the technical needs of the Environmental Restoration and Waste Management Division D&D program, and the DOE Office of Technology Development.

Within the Environmental Restoration mission of the SRTC is the development, demonstration, evaluation, and improvement of technologies for the D&D of SRS facilities in a proactive, environmentally sound, and cost effective manner. Emphasis is on the research, development, demonstration, testing, and evaluation of new technologies to assure compliance with environmental, safety, and health regulations.

The SRTC has applied a large number of technologies at SRS which can be useful to the DOE-EM D&D program at SRS and throughout the DOE Nuclear Complex. These technologies have varied widely in content and in the point of application. Many of these activities were performed as a part of the SRTC mission to support SRS production facilities under the Office of Defense Programs. The purpose of this study was to identify the specific technologies which have application in D&D so maximum utilization of SRTC capabilities might be achieved in providing technical support to D&D activities in a cost effective manner.

The SRTC has adapted technology from elsewhere to meet the SRS needs when appropriate. The SRTC staff has effectively employed existing technology in solving previous D&D problems, and has developed expertise in this regard. When existing technologies were not available, innovative and creative research and development programs were conducted to provide cost effective high-technology and state-of-the-art techniques. Examples of existing technology and development of new capabilities are found throughout this report.

This survey reports the existing capabilities of the SRTC in various areas of D&D. It reports existing technical capabilities and examples of applications. The result of the survey is reported in major groups, each including a brief description of the available experience and capabilities:

- Characterization Technologies
- Decontamination Technologies
- Dismantlement Technologies

- Material Disposal Technologies
- Remote Systems Technologies
- Safety Technology for D&D

Although attempts have been made to assess comprehensively the technical capabilities and experience of the SRTC during this survey, due to the often unique nature of D&D activities, creative, one-of-a-kind solutions may be required which are not reflected in this survey. However, the depth of experience present in the SRTC indicates that it is qualified to provide technical support services to SRS D&D activities.

3.0 CHARACTERIZATION TECHNOLOGIES EXPERIENCE

Characterization of facilities and waste streams is essential to all phases of D&D.

Initial characterization of facilities for radioisotopes and hazardous constituents is essential to assess the requirements for personnel protection and planning of the decontamination process. Continuing characterization is essential to evaluate the effectiveness of the decontamination activities. Waste streams generated as a result of D&D must be characterized such that ultimate disposition can occur in an effective and efficient manner, and in total compliance with all applicable regulatory requirements. Finally, analytical methods and instrumentation must be available for performing close-out surveys of the post-decontamination facility to determine if target levels have been reached, and what final state of protection is appropriate for the facility.

The SRTC has characterization capabilities and experience in radiation mapping, sensor and detector development including advanced low-level radiation sensors, satellite linked survey and mapping systems, chemical and radiological analytical development and services, materials analysis, and pathway analysis.

3.1 Radiation Mapping

3.1.1 Semi-Intelligent Mobile Observing Navigator (SIMON)

The SRTC has developed a mobile robot capable of performing radiological survey of floors. The robot is radio dispatched, navigates by counting wheel revolutions, and uses a docking station to recharge its batteries and calibrate its position.

SIMON is equipped with gas-proportional detectors and a radiation counting monitor. These detectors are sensitive to α, β, and γ radiation. The robot scans floors and continuously collects and stores radiation and position data in its memory or alarms when high levels are encountered. At the end of a mission, data is downloaded onto a host computer to be processed to form 3-D or contour maps giving a precise characterization of specific areas.

3.1.2 Portable Radiation Mapping Equipment

The SRTC has a variety of portable and hand-held radiation detection equipment that can be used to map α, β, γ, and neutron radiation. These detectors were utilized in various projects such as neutron dose mapping, special nuclear materials holdup measurements, and holdup measurements in a shutdown SRS fuel fabrication facility.

3.2 Sensors and Detectors

3.2.1 Mission Modules

The SRTC developed a radiation detection mission module for the Emergency Response Program support hardware. This module is self-contained and is mounted onto a robot and operates independently of its host. Mission modules can be added to mobile teleoperators without requiring modifications to the host's software. They can also be placed in an environment to continuously monitor radiation leaks.

A mission module was also developed to measure temperature and humidity, and detect explosive gases. A portable operator console communicates over a radio frequency data-link to the module. The console allows real-time display, printing, and storing of data sent by the module.

3.2.2 Remote Sensing

The SRTC is investigating new characterization and monitoring technologies to support regulatory activities. The SRTC has capabilities in aerial photography and other remote sensing technologies applicable for the identification and characterization of waste sites.

The SRTC is developing fiber optic sensors for in-situ measurements of waste tanks, separation processes, and ER field work. Some example applications include measurement systems for: soil temperature, groundwater flows, uranium and nitrate concentration, and D_2O purity.

3.2.3 Tritium Forms Monitor

Tritium oxide is 25,000 times more biologically active than elemental tritium. The SRTC developed equipment capable of measuring total tritium and tritium oxide in air. The forms monitor is microprocessor controlled and can provide total daily values for total tritium and tritium oxide. This monitor incorporates alarm functions and outputs to meteorological modelling systems used at SRS.

3.2.4 Tritium Effluent Water Monitor

The SRTC is developing an improved Tritium Effluent Water Monitor (TEWM) system for the K-area utilizing new detection technologies. The new TEWM will provide improved time response and reliability in the detection of tritium.

3.2.5 Boxed Waste Monitor

The SRTC developed a Boxed Waste Monitor. It is a computer-controlled system to monitor the presence of uranium and transuranic elements in low-level boxed waste. The system detects the characteristic γ energy which identifies which isotopes are present. The quantity of each isotope is determined by the intensity of the γ radiation. The system provides printed output to the operator as needed.

3.3 Satellite Linked Survey and Mapping Systems

The SRTC developed a γ-radiation monitoring system that collects data from twelve SRS locations and transmits the data via satellite telemetry to a central receiver and display system. Detectors are linked to a United States Geological Survey transmission platform. The data is received by a central receiving station for subsequent analysis. The system can be expanded to as many stations as required for coverage of the areas of interest.

3.4 Analytical Services

The SRTC provides analytical support for SRS programs. It can also provide analytical support for non-routine material characterization and/or special chemical analyses. The SRTC is currently adding hazardous and mixed-waste analytical capabilities through the addition of three new laboratories. The numerous analytical capabilities are summarized in Tables 3.1 through 3.6.

3.4.1 Analytical Automation

The SRTC also integrates measurement systems with automated control systems. The general goal is to enhance SRS processes by providing faster analytical information, reducing sample handling and the subsequent chemical and radiation exposure, and improving process control. The services provided are summarized in Table 3.7. Table 3.8 contains a partial list of work performed or in progress.

3.4.2 Environmental Restoration Analytical Technology

The SRTC develops and deploys field and in-situ instrumentation to support the analytical measurement needs of WSRC Environmental Restoration (and associated organizations). Table 3.9 contains a partial list of work performed or in progress.

3.5 Materials Analysis

The SRTC provides fully documented metallurgical test and failure analyses for clean and contaminated samples, and consulting services on materials selection and compatibility.

3.6 Residual Radioactive Materials

The SRTC has the expertise to perform Pathway Analyses using RESRAD (RESidual RADioactivity) computer code. RESRAD is a computer program developed at Argonne National Laboratory to calculate site-specific residual radioactive material guidelines and radiation dose to on-site maximally exposed individuals.

The RESRAD analysis considers nine environmental pathways: direct exposure, dust inhalation, radon, and ingestion of plant foods, meat, milk, aquatic foods, water, and soil.

3.7 Nuclear Analysis

D&D requires close contact with and movement of components which potentially contain or are contaminated with varying levels of fissile or radioactive material. It is essential that nuclear criticality analyses and radiation dose assessments be conducted prior to and during D&D activities to ensure the safety of workers and preclude the potential of a nuclear criticality. The SRTC performs these assessments.

3.7.1 Nuclear Criticality Analysis

The SRTC performs criticality analyses and reviews using state-of-the-art numerical tools. The SRTC provides overview training for managers responsible for facilities containing fissionable materials.

3.7.2 Radiation Shielding Analysis

Having an understanding of the radiation fields of the facility decontaminated is vital for safety. The SRTC performs analyses of neutron and γ transport. Examples of work that can be performed are the establishment of shielding requirements for the transport of contaminated equipment through a facility, and the packaging and shielded cask requirements for the shipment of contaminated equipment.

4.0 DECONTAMINATION TECHNOLOGY EXPERIENCE

Decontamination of surplus DOE facilities is critical to do the following:

- To permit unrestricted reuse/recycle
- To permit reuse of the item in the DOE complex
- To reduce worker radiation exposure
- To avoid potential criticality accidents
- To permit or enhance disposal
- To separate the hazardous from the radioactive constituents during decontamination

The SRTC decontamination capabilities and experience involve the evaluation, testing and development of various technologies to the specific requirements of the SRS facility. Some examples of past and current development are high pressure water technology, chemical treatment, concrete scabbling, foam and gel techniques, Freon spray, abrasive blasting, electropolishing, strippable coatings, and CO_2 blasting.

4.1 Ultra High Pressure Water Jet Technology/Wet Vacuum System

The SRTC adapted an existing robot for the decontamination of the top of a large waste storage tank. A teleoperated vehicle, an ultra high pressure spray, and a vacuum system were used to decontaminate the concrete tank top. The robot removed the contaminated lead sheets and applied 36 kpsi water jet to the concrete surfaces. Radiation levels were reduced below 10 mR/hr.

4.2 Electrochemical Decontamination Technologies

Electrochemical decontamination using silver as the oxidant is used to oxidize organic contaminants. This process was performed previously in a two-compartment electrocell, and resulted in the generation of a hazardous secondary waste stream. The SRTC developed a new cell producing only one waste stream. This design, known as the *common-electrolyte cell*, is the subject of several invention disclosures. This new cell provides a user-friendly process with a simpler and safer design.

4.2.1 Surface Decontamination Usi' g Cerium

Cerium can be used as the oxidant to decontaminate large solid waste forms where the use of hazardous silver is not practical. Cerium dissolves plutonium oxide at a slow rate. However, the rate of dissolution is adequate for surface decontamination. Other electropolishing techniques comparable to electrochemical decontamination using cerium have been demonstrated to be successful.

4.3 Freon Spray Decontamination

This decontamination technique was evaluated in laboratory scalc tests and applied to the remotely operated bridge cranes in the Canyon buildings at SRS. High pressure Freon was found to be the most attractive process available. Decontamination of the crane using this technology was accomplished with 85% less personnel exposure than estimated.

4.4 Abrasive Blasting Decontamination

This technique removes both smearable and fixed contamination. The contaminated surface is mechanically removed by abrading it with a water slurry containing glass frit as the abrasive. All wastes from the process can be fed to a waste glass melter for disposal. This decontamination technique was developed to decontaminate the waste glass canisters in the DWPF. It resulted in a reduction of $79 million in the cost of the DWPF. Because the glass frit is needed to produce waste glass, this decontamination generates no additional radioactive waste.

4.5 Polyurethane Foams

The use of this material has two applications:

a. Fixing contamination: A device was developed that allows foam to be injected into pipes without breaking containment. The foam stabilizes any radioactive material inside the pipe. This minimizes the potential for airborne radioactive material when the pipe is cut during D&D operations.

b. Immobilization: Foam is used to stabilize equipment inside a glovebox to avoid shifting, which could cause a broken window and result in release of contaminated material during D&D operations.

4.6 CO_2 Blasting

The SRTC is currently investigating CO_2 blasting technology. This technique uses solid carbon dioxide pellets to remove contamination. No additional waste is generated and the surface finish is not degraded.

4.7 Additional Decontamination Experience

The SRTC has been active in the area of nuclear facility decontamination for over eleven years. This experience is briefly summarized in Table 4.1.

5.0 DISMANTLEMENT TECHNOLOGY EXPERIENCE

Removal of equipment and reduction of its size for packaging is often a part of a D&D operation. Dismantling activities require specific and unique methods depending on site requirements. A critical issue in the selection of dismantling techniques is the minimization of secondary waste streams and the introduction/spread of contaminants resulting from dismantling activities.

The SRTC dismantlement experience has been in the development and application of vessel cutting, pipe cutting, and excavation using remote instruments in hazardous environments.

5.1 Vessel Cutting

5.1.1 Pneumatic End-Grinder

A group of radioactive retired reactor ion exchanger and deionizer vessels had to be disposed at the site burial ground. To protect the environment, the lead counterweight on the vessel had to be removed before the burial. The vessels were removed from storage by a remotely operated crane. A remote controlled vehicle with a pneumatic end-grinder was used to successfully cut the counterweight box and remove lead shot.

5.1.2 Mobile Teleoperator

A leak of radioactive liquid in an equipment corridor at the Savannah River Site had contaminated the inside of a junction box. The box had to be removed to allow normal maintenance and repair of equipment in this section of the corridor. The SRTC developed a method to remotely remove this junction box. A control station consisting of teleoperator control, hydraulic cutter control, monitors, and camera controls was set up 150 ft away from the junction box and the contaminated junction box was successfully removed.

5.2 Pipe Cutting

5.2.1 Remote Jumper Cutter

Vessels and equipment used for processing radioactive liquids are connected with pipe sections which are remotely connected and disconnected. These pipe sections are called jumpers. The SRTC developed a remote cutting and handling system for contaminated jumper assemblies. The jumper cutting system consists of a hydraulic cutter that is mounted to a backhoe. The jumper assemblies are first placed into a jumper transport box, and the backhoe is then used to cut the jumpers into 4-ft sections inside the box. After the cutting operation is complete, the cutter is used as a grappler to place the jumper sections into burial boxes.

5.2.2 Elbow Cutting Pipe Crawler

The SRTC has developed a pipe crawler capable of removing an elbow in the FB-Line ventilation system to alter air flow paths for fire safety reasons. This device is capable of crawling through 90-degree elbows and up or down in vertical piping. The pipe crawler contains two main segments: a tractor for locomotion and a cutting attachment to hold and direct a plasma arc torch. Cameras and lights are mounted on the crawler for remote visual inspections prior to and during cutting operations. The crawler is remotely operable to reduce radiation exposure to field personnel. The pipe crawler provides an excellent working platform for many other applications that involve piping systems.

5.3 Excavation

SRS has developed a radio controlled Bobcat. In one application it was loaned to the Waste Isolation Pilot Plant (WIPP). The Bobcat was used in a remote retrieval demonstration. The purpose of the demonstration was to provide evidence of their ability to retrieve radioactive waste in the event of a ceiling collapse during some extended testing in one of the proposed repository rooms. The Bobcat was used in clearing debris which covered the waste boxes holding the simulated radioactive waste. A remote controlled camera system was also used in the demonstration and was vital in helping navigate the Bobcat to perform the excavation work.

6.0 MATERIAL DISPOSAL TECHNOLOGY EXPERIENCE

Material disposal includes recycle of valuable materials, disposal of materials which cannot be re-used, and management of waste streams. These operations must be done cost effectively and in a manner that protects health and the environment. Treatment methodologies needed to support material disposition are: chemical treatments, stabilization, packaging, refining, melting, shaping, machining and other processes. Issues arising from D&D activities include:

- Physical, thermal, and chemical processing to convert material into a form that will facilitate its management for recycle or disposal.
- Placing the material in a temporary or interim facility for later recycle or disposal.
- Finding potential new uses for contaminated and decontaminated materials inside the DOE complex or within commercial markets.
- Movement of material within or off DOE sites for treatment and/or to either a temporary or permanent disposal facility.
- Locating waste in a permanent facility.

The SRTC waste management capabilities and experience involves robotics, size reduction, and development of site specific technologies for low-level, liquid, solid transuranics, hazardous and mixed-waste handling, storage, and processing.

6.1 Size Reduction and Material Handling

The SRTC is currently evaluating a unique eight-degree-of-freedom telerobot manipulator to perform size-reduction and material handling operations of contaminated process equipment. A similar telerobot will be installed in the proposed Transuranic (TRU) Waste Processing Facility. All the telerobotic operations required in the TRU Waste Facility such as crate unpacking, equipment dismantling, material size-reduction, and selected maintenance operations are being tested. These operations require remote tool changing, thus a tool change system is included in the telerobot. Recent work with the telerobot has focused on force control applications, control of the standoff distance for a plasma cutting torch, and a real-time simulation of the telerobot using a workstation.

6.2 Waste Management Technology Development

The SRTC develops and evaluates technology for the handling, storage and processing of liquid wastes, solid TRU, and low-level mixed-wastes. The SRTC provides technical support for waste management operations through chemical research, engineering studies, and computer modeling of waste operations, handling and processing. Some of the programs which are a significant contribution to D&D are:

- Performance assessment modeling of low-level and mixed-waste disposal.
- Conceptual design of low-level and mixed-waste disposal via vaults.
- Treatability studies for stabilizing mixed and hazardous wastes such as CIF blowdown and M-area sludge.
- Development of lead macro-encapsulation as a RCRA disposal technology.
- Development of treatability variances for mixed-wastes.
- Studies on disposal options for long lived radionuclides such as ^{14}C and ^{129}I.
- Preparation of de-listing petitions for mixed-wastes (M-area sludge).
- TRU waste preparation including shredding and compacting.
- Packaging of TRU and low-level waste for WIPP and on-site disposal.

6.2.1 Permanganate Destructive Oxidation of Tetraphenylborate

The SRTC investigated means for the oxidative destruction of sample residues using permanganate in acidic solution. The samples investigated contained tetraphenylborate and traces of benzene. Both of these compounds must be destroyed before the solutions can be discarded to the waste tanks.

7.0 REMOTE SYSTEMS TECHNOLOGY EXPERIENCE

Remote systems technologies play a key role in all phases of D&D due to the presence of hazardous and radioactive contaminants. Activities in this area involve cleaning, cutting, volume reduction, contamination control, retrieval/transport, packaging, characterization, environmental monitoring, and removal of imbedded components.

The SRTC capabilities and experience in the testing, development and application of remote devices is extensive. The SRTC experience includes robotics development, remote video system development, and pipe crawlers, as well as numerous applications of decontamination in hazardous radiation environments.

7.1 Robotics

The SRTC is developing a wide array of teleoperated vehicles and support equipment. Applications performed include radiological surveys, video surveillance, decontamination, radioactive material handling, disassembly, excavation, and non-destructive evaluation. The equipment used in these activities range from small crawlers with cameras to construction-size skid steer loaders. Table 7.1 list some of the equipment available.

7.1.1 Narrow Aisle Robot

A robot is under development for the inspection of 55 gallon drums of stored waste. The robot needs to travel through a 36-inch wide aisle. The system consists of a narrow mobile robot, a navigation system, an α detection system, a bar-code reader, and a video inspection system. While the robot is traveling through the facility, the α detection system scans floor surfaces for contamination. High level α-contamination will cause the vehicle to halt and notify an operator of the condition. Simultaneously, the video inspection system captures images of the drums being passed and reads the bar-code label. These images, location, and drum monitor output reading are stored in memory and then downloaded to an off-board computer. The computer will then compare images of each drum to old images to determine whether there has been any change since the last survey. A database of images will be available to provide a history of damage and deterioration to the drums.

7.1.2 Alternative to Radiation Hardened Cameras

Miniature solid state sensor type cameras have found application in high level radiation areas. The low cost, high quality images, and miniature size of these cameras allow their use in cases where radiation-hardened video cameras would not be practical. These cameras are available at low cost, and their use has made possible many applications that could not justify the expense and complexity of radiation-hardened systems.

One application is the development of tripod-like video units. Each assembly consists of a platform, a specialized lifting hook for deployment with a crane, and video equipment with zoom lens, lights, and a pan/tilt. The use of these units has resulted in views which were not previously possible.

7.1.3 In-Tank Precipitation Video System

An explosion-proof video system has been developed for constant process monitoring within the In-Tank Precipitation waste tanks. The video equipment consists of a radiation-hardened video camera and zoom lens, high powered lights, a tilting mirror, and a mechanism for panning. The video equipment is contained within a pressurized, explosion-proof housing, and the entire assembly is inserted into the tank. The system is operated using a compact console which allows the operator to control the system, view the process on a built-in display, and record the video on a VCR for documentation.

7.1.4 Pipe Crawler

The SRTC developed a pipe crawler capable of visually and ultrasonically inspecting inaccessible welds in the reactor process water system piping. The pipe crawler is capable of crawling through the piping system and adjusting to various pipe diameters while in transit. The pipe crawler consists of two main sections; a tractor for locomotion, and an instrument carriage for supporting an arm capable of four degrees of freedom for performing inspections. The crawler's arm houses ET (Eddy Current Test) and UT (Ultrasonic Test) probes for weld location and inspection, and cameras for visual inspection.

7.2 Telerobotics

7.2.1 Telerobot for Process Room Decontamination

The SRTC developed a system for remotely decontaminating the floor of a process room in HB-line. A vehicle was outfitted with two vacuum heads mounted with a compliant lifting arm in the center and two video cameras. All functions for controlling the vehicle and video system are contained in rack mount equipment cabinet. The control console utilizes a two-axis joystick for driving the vehicle. The vehicle is cable controlled and has a 200 ft range.

7.2.2 Remote Decontamination Vehicle

A remote decontamination vehicle is currently being developed to decontaminate the 776-2A pipe gallery. The vehicle supports a 6-degree of freedom hydraulic manipulator to remove obstacles and scrub the floor surfaces with high pressure hot water. The unit is controlled from a remote console. The vehicle's arm has a miniature video camera and light to look at objects and to control the fine movements necessary to grasp them.

7.2.3 Remote Manipulators

The SRTC has two remote underwater manipulators. One was acquired to be adapted to a vehicle for emergency response, and the other for a program in the reactors. A third underwater manipulator has been budgeted. This new manipulator will include force feedback and accurate position feedback to enable precise operation as a robot or teleoperator. This manipulator is intended to be mounted on a remote controlled vehicle to assist in D&D activities.

7.2.4 Corridor Decontamination

A section of the hot gang valve corridor in F canyon building was contaminated so that routine maintenance and repair of equipment were not possible. A mobile teleoperator was outfitted with a super-heated water decontamination system. The system remotely decontaminated the walls and floor in this section of the corridor.

7.2.5 Concrete Scabbling

The top of a waste tank became contaminated. A mobile teleoperator was equipped with a high-pressure-water concrete scabbler. The system remotely scabbled the surface of the concrete tank top until returned to background levels.

7.3 Solid Modeling

The SRTC has a capability to generate computer based solid models of equipment and facilities. Modeling is supported by workstations running robotics simulation software. The software allows the user to build an environment in 3-D that closely resembles the workspace of interest. Mechanisms within the model can be easily assigned kinematic and dynamic characteristics that simulate the real devices. Robots and mechanisms can be programmed and the resulting motion viewed in real-time.

The 3-D simulation is useful for accumulating, integrating and displaying data relating to a workspace. The 3-D modeling was used to simulate the 776-2A facility and to assess methods for decontamination and obstacle removal. The model was generated using construction drawings of the facility, then a remote video inspection was performed. The information from the video tape was included into the solid model. The result is a simulation providing a user with any desired view of the facility, displaying all the obstacles that must be either removed and/or avoided during decontamination. Thus, an entire operation can be accurately planned without physically entering the facility.

8.0 SAFETY TECHNOLOGY FOR D&D

The SRTC has considerable experience in supporting SRS with facility safety analysis and documentation, development of technical specification and operational safety requirements, environmental assessments, packaging and transportation of radioactive and hazardous wastes environmental impact, regulatory interpretation, and facility shutdown preparation. D&D plans and activities must meet stringent requirements of regulatory authorities regarding protection of personnel and the general public. Issues arising from safety and regulatory compliance are numerous and complex. D&D activities must comply with federal, state, and local health and environmental regulations. Integration of regulatory requirements into a D&D plan is critical and must consider all D&D activities. These activities involve decision analysis, risk based safety criteria, regulatory compliance, CERCLA, RCRA, DOE orders, Below Regulatory Concern (BRC) and *de minimis* level determination, waste acceptance criteria, and mixed waste regulatory guidance.

The Environmental Restoration organization is responsible for planning and managing these activities in a way that ensures compliance. The SRTC has capabilities to provide technical support to ER as ER develops plans and manages implementation. SRTC can provide support in all the areas of technology mentioned below.

8.1 Safety Analysis and Documentation

The SRTC provides analysis of the safety of activities associated with D&D. The primary vehicle for documentation of the safety basis is the Safety Analysis Report (SAR). DOE orders require the SAR to address D&D activities. The SAR defines the safe operating envelope within which all facility D&D activities can be safely performed. This envelope presents a summary of the limiting conditions for safe facility D&D operations within the constraints established by the accident analyses. SRTC, as provider of safety analysis services to SRS, has a unique and comprehensive understanding of the operating histories of these facilities (see section 8.1.2). This database will be invaluable in the development of D&D plans and selection of appropriate characterization, decontamination, dismantling and waste management technologies. The SRTC is providing technical support to the ER/D&D groups of SRS. The development of generic safety documentation guidance requirements for all D&D activities is in final preparation. In addition, development of specific safety documentation, risk assessment, hazard classification, Unreviewed Safety Questions Determination (USQD), and project management for the characterization phase of decommissioning the Separations Engineering Development (SED) facility is in progress. The SRTC will continue to provide safety analysis support throughout the SED decommissioning project.

8.1.1 Human Factors Engineering

The SRTC can provide technical and engineering support in human factors required for safe and effective D&D of nuclear facilities. Human Factors Programs include areas related to human performance and interaction with system elements such as equipment, procedures, software, facilities, and management and organizational structures, including supervisory control. Specific capabilities can be applied to the supervisory control of telerobotics and automation associated with the D&D of nuclear facilities. The SRTC provides human factors engineering support to operations, engineering, and independent oversight organizations by conducting human factors studies related to operations, providing information concerning human capabilities and limitations, and offering design guidance pertaining to man-machine interfaces.

8.1.2 Incident History

The Savannah River Site has, for many years, maintained a system for recording, retrieving, and reviewing its incident history. This system is based on a series of databanks, which include D&D activities, developed primarily for risk assessment. Five such data banks, for reprocessing, fuel fabrication, tritium, laboratory, and naval fuels facilities, were developed and are maintained by SRTC. Data sources include published and unpublished information. Application of theses databanks include risk assessment, failure rate data, equipment breakdown histories, generic incident histories, trend analysis, training, audits, incident investigation, and reliability studies.

8.2 Technical Safety Requirements Development

The SRTC develops and supports Technical Specifications / Technical Safety Requirements (TSR). The Technical Specifications / TSRs provide the operational framework to preserve the safety envelope described in the SAR. This support function involves review and revision of the Technical Specifications in response to emerging issues and preparation of safety evaluations in support of required changes. As a result of D&D activities, system integrity and operability, as related to maintaining the safety envelope, need to be preserved.

8.3 Environmental Risk Assessment

The SRTC staff is preparing the Human Health and Ecological Baseline Risk assessment for the TNX Ground Water Operable Unit. This project involves the following activities: toxicological assessment, site modeling, identification of contaminants of concern, data searches, uncertainty analysis, and identification of transport mechanisms. The pilot project is a demonstration project to identify SRTC's capabilities in performing baseline risk assessments for projects for the Environmental Restoration Department.

8.4 Environmental Impact

The SRTC develops technical support documents for SRS Environmental Impact statements. The SRTC applies current technologies to gather and interpret hydrogeological data for site specific waste site closures and for site-wide application to provide a framework for regulatory activities. Technical support is provided in the fields of hydrogeology, geology, geophysics, geochemistry, groundwater modeling, biotechnology, and environmental engineering. Modeling studies are performed to evaluate the effectiveness of closure/remedial measures proposed for various waste management facilities.

8.5 Packaging and Transportation

The SRTC has expertise in activities associated with development of containers for radioactive and hazardous materials transportation. In addition the SRTC reviews existing shipping containers to ensure that they satisfy current regulations. The SRTC ensures safe, leak-tight, and reliable containers which meet 10CFR71 or 49CFR100-199 for shipping radioactive and hazardous materials from and within SRS. Specific experience is summarized in Table 8.1.

8.6 Regulatory Interpretation

Because of the complexity and evolving nature of D&D activities, it is required to interpret complex regulations with potentially conflicting goals. The SRTC is well versed at investigating regulatory issues and in providing interpretations based on sound technical and regulatory analysis. The SRTC has access to extensive libraries of federal regulations. The SRTC has extensive experience in the area of DOE and EPA regulatory interpretation and compliance. Included in this experience are numerous direct applications of regulatory interpretation of environmental pollution remediation,and facility D&D. In addition, SRTC has participated in EPA special studies on rules and compliance, and in DOE Compliance Team which are essential activities that continue to expand and enhance this area of expertise. Assistance in regulatory interpretation is available directly from SRTC or in conjunction with other WSRC organizations who may be assigned lead responsibility.

8.7 Facility Shutdown Preparation

Prior to D&D, various activities must occur which place the facility in a long term, safe-state ready for D&D. These activities known as deactivation and disposition, consist of baseline characterization of the facility contamination, development of the facility transition acceptance criteria, a plan for temporary storage prior to D&D, a plan for minimum operation and maintenance of the facility, and monitoring and inspection. The SRTC has provided technical support to the SRS operating facilities in each of the above areas, and is qualified to provide technical assistance. This assistance may be provided directly or in conjunction with other WSRC organizations who may be assigned lead responsibility.

TABLE 3.1

IONS IN SOLUTION TECHNIQUES	
TECHNIQUE	**DESCRIPTION**
Electrochemical Methods	Quantitative and qualitative elemental analysis on more than 90 percent of all elements in the periodic table in aqueous and organic solutions Separation and speciation of component mixtures Synthesis Development of on-line analysis methods and instrumentation which perform the above applications
Ion Chromatography Methods	Quantitative and qualitative elemental analysis on more than 90 percent of all the elements in the periodic table in aqueous and organic solutions Separation and speciation of component mixtures Development of on-line analysis methods and instrumentation which perform the above applications
Spectrophotometric Methods	Spectrometry is used to determine the concentration of a wide variety of substances in solution including, but not limited to: Pu, U, nitrate, and nitrite
Titration Methods	Quantitative and qualitative analysis of aqueous and organic solutions
Uranium Analysis Technique	This technique is applicable to the measurement of ultra trace levels of uranium in aqueous and organic solutions, including radioactive solutions

TABLE 3.2

MATERIAL CHARACTERIZATION TECHNIQUES	
TECHNIQUE	**DESCRIPTION**
Electron Microprobe Analysis	Qualitative and quantitative microscopic analyses of samples to determine elemental composition and distribution. Elements with atomic numbers greater than four can be analyzed
Mercury Intrusion Porosimetry	Determination of pore distribution, and pore surface area
Particle Size Analysis	Particle size and distribution of powders
Scanning Electron Microscopy / Contained Scanning Electron Microscope	Examination and analysis of the microstructural characteristics of solid objects
Transmission Electron Microscopy	Analysis of materials using microstructural information from images and crystallographic information using diffraction patterns. Elemental analyses of atomic numbers greater than 10 are obtained using Energy Dispersive X-rays
X-ray Fluorescence	Identification and quantification of major and trace elements, C through U in solids and liquids
X-ray Powder Diffraction	Identification of crystalline phases and measurement of average crystallite size

TABLE 3.3

ORGANIC TECHNIQUES	
TECHNIQUE	**DESCRIPTION**
Fourier Transform Infrared Spectroscopy	This technique is used to confirm the presence of water, alcohols, quantitatively measure an organic species, and monitor off-gases from a test setup
Gas Chromatography	This technique is used for quantification of organic in samples (polar and non-polar species)
Gas Chromatography/Mass Spectrometry	This technique is used to provide identification and quantification of organic compounds in samples

TABLE 3.4

RADIATION CHEMISTRY TECHNIQUES	
TECHNIQUE	**DESCRIPTION**
α-Pulse Height Analysis	This technique is used when it is necessary to distinguish among several α emitting isotopes. Examples are samples containing two or more isotopes such as: ^{235}U, ^{241}Am, ^{238}Pu, ^{239}Pu, ^{252}Cf
Californium Neutron Activation Analysis	This technique finds application in non-destructive multi-element assays of many solids and liquid samples. Typical types of samples include ion exchange resins, soils, cements, coal, fly ash, freeze dried vegetation, and biological samples, as well as aqueous samples. Solutions may contain most acids except HCl and HBr, which will strongly activate and interfere with some trace analyses. Elemental analyses are determined based on natural isotopic abundances. Samples generally should not be radioactive except for very long-lived or fissile elements such as ^{129}I, ^{235}U, ^{238}Pu
γ-Pulse Height Analysis	This is one of the most useful and flexible non-destructive analysis techniques available. It is rapid, accurate, and can be used for almost any type of γ-ray emitting sample. It is used to routinely measure fission or activation products, as well as many of the actinides
Gross α, β, γ Counting	Gross counting is primarily used to measure the activity of a single isotope in a sample. Gross α or gross β / γ counts are widely used for process control samples pulled in canyon operations. Gross counting is also useful for comparisons of total activities in sets of similar samples
Liquid Scintillation Counting	This technique is used for the determination of α and β activity in aqueous and organic liquid samples. It offers very high counting efficiency, and is the standard method for ^{3}H, ^{14}C, and other low-energy β emitters

TABLE 3.5

SPECTROSCOPY TECHNIQUES	
TECHNIQUE	**DESCRIPTION**
Dissolution Methods	Preparation of samples by conversion of solids into solutions. Solids filtered from solution and solids obtained by evaporation of the volatile liquid are converted into solutions
Atomic Absorption Spectroscopy	Quantitative determination of metal elements in aqueous solutions (Cu, Fe, Hg, K, Li, Mg, Mn, Mo, Na, Ni, Pb, Si, Sr, Zn, Ag)
Cold Vapor Atomic Absorption Spectroscopy (mercury)	Quantitative determination of mercury in aqueous solutions
Inductively Coupled Plasma Emission Spectroscopy	Quantitative determination of metal elements in aqueous solutions. All metals and some non-metals can be analyzed by this technique
Inductively Coupled Plasma/Mass Spectroscopy	Quantitative elemental analysis of solutions for most of all elements in the periodic table. Isotope ratio determinations can be performed for some elements depending on the matrix of the sample

TABLE 3.6

WET CHEMISTRY AND MISCELLANEOUS ANALYSIS TECHNIQUES	
TECHNIQUE	**DESCRIPTION**
Carbon/Sulfur Determination	Simultaneous determination of total carbon and sulfur in solids
Flow Injection Analysis (FIA)	FIA utilizes a wide variety of detection devices to analyze different chemical species. Typical detection instrumentation systems are: Spectrometric Method - Spectrophotometry, chemiluminescence, fluorimetry, and infrared spectroscopy. Electrochemical Methods - e.g., amperometry, conductance voltametry, and ion selective electrodes. Likewise an extensive array of analytical techniques are utilized with FIA technology to automated solution chemistry systems. Examples of techniques are: compleximetric, calorimetric, redox, standard addition, stopped flow, titration, extraction, gas diffusion, and ion exchange.
Flash Point Determination	The determination of flash point by Pensky-Martins closed cup method
Hydrogen Determination	Hydrogen determination in ferrous and non-ferrous metals by either gas fusion or hot extraction
Nitrogen/Oxygen Determination	Determination of total nitrogen and oxygen in both metal and inorganic materials by the inert gas fusion technique. Specific nitrides and oxides may also be separated and identified.
Total Carbon Analysis	The determination of Total Organic Carbon (TOC) and Total Inorganic Carbon (TIC) in aqueous solutions
Total Solids by Microwave Drying	To directly measure the percent total solids in nonflammable samples
Oil And Grease In Aqueous Solution	Determination of oil and grease in aqueous suspensions

TABLE 3.7

ANALYTICAL AUTOMATION SERVICES
• Investigation of the problem to validate what is requested is actually needed Identification of existing means to provide the need or development of a new system
• Laboratory testing
• Prototype assembly and field testing
• Turnover to the customer with documentation

TABLE 3.8

ANALYTICAL AUTOMATION WORK PERFORMED AND/OR IN PROGRESS
• Developed a modification to the Canyon air-lift samplers to allow installation of fiber-optic interfaces for remote on-line analysis by spectrophotometry.
• Automated Canyon samplers to allow operation from the control room and possible control by DCS.
• Developed chemometric models for determination of uranium and nitrate concentration from H-Canyon on-line spectrophotometer spectra; developed on-line model for on-line plutonium determination in SRTC resin test system; developed model to determine PCB concentration in oils.
• Developed and improved, low maintenance α detector for use in low activity on-line monitoring applications (liquid and off-gas).
• Installed NO_x, oxygen and acid analyzers on F-Canyon NO_x absorber column and developed a computer model to determine the optimum control scheme to maximize acid production while limiting emissions.
• Developed a system of γ monitors interfaced with process functions to interlock systems upon detection of plutonium accumulation.
• Improved the reliability of operation and testing of F-Canyon neutron monitors through the use of improved detectors and in situ pulse height analysis.
• Developed a method of in-situ measurement of plutonium content of TRU waste culverts in the burial ground.
• Working with LANL to develop chemical sensors with indicators trapped in polymer coating on fiber-optic cables.
• Developed quantitative on-line mercury analyzer for tritium process lines. Performed SNM holdup monitoring in shutdown SRS facilities.

TABLE 3.9

ENVIRONMENTAL RESTORATION ANALYTICAL TECHNOLOGY WORK PERFORMED AND/OR IN PROGRESS
• Real-time methane flux measurements at the Sanitary Landfill
• Development of both shallow-well and bore-hole radiological screening detector systems for rapid radioactivity screens
• Development of a soil gas analyzer for field use by ER
• Development and operation of a field sampling vehicle for protocol sampling at SRS waste sites
• Operation of an Ion-Trap Mass Spectrometer at the SRS Integrated Demonstration Site, providing extremely sensitive analyses of organic compounds in soil, water and air samples

TABLE 4.1

ADDITIONAL DECONTAMINATION EXPERIENCE	
EXPERIENCE	**DESCRIPTION**
Decontamination of ^{14}C Containing Resin	The SRTC is investigating means for decontaminating spent reactor deionizers which can no longer be disposed through burial due to the potential hazard possessed by the resin contained inside. The resin contains ^{14}C, a radioactive isotope with a half life of 5730 years and it can travel through soils very quickly. Currently, the spent deionizers are accumulating above ground in the H-area. The SRTC is working on demonstrating the feasibility of decontaminating the resin so that the deionizers can be buried without fear of contamination to the environment.
Oxidation of SRTC Organic Waste	The SRTC has examined the use of air oxidation system as a means for destroying organics sent to the SRTC waste tanks. If successful, the process will minimize or eliminate the shutdown of SRTC's high and low level drains due to contamination with organics.
Decontamination of Silver Berl Saddles	The SRTC has been investigating means for decontaminating silver berl saddles used to scrub dissolver off-gas for iodine in the separations processes. The iodine is collected on the saddles as AgI. When saturated, these saddles are normally transported to the Solid Waste Disposal facility.
Concrete Scabbling	In this operation the surface of contaminated concrete is removed. This is accomplished by both mechanical and super-high-pressure water techniques. Super-high-pressure water scabbling is more easily operated remotely.
Chemical Decontamination	Environmentally safe, effective decontamination solutions have been evaluated and recommended site wide. A nitric, oxalic acid solution for decontamination of lead was identified.

TABLE 4.1 Continued

ADDITIONAL DECONTAMINATION EXPERIENCE	
EXPERIENCE	**DESCRIPTION**
Foam and Gel Decontamination	By applying decontaminating solutions as a foam, the dwell time of the solution is increased, enhancing its effectiveness. Decontamination solution waste is reduced by up to 70%.
Water Jet Technology	Water at 60 kpsi removed fixed contamination from concrete and asphalt surfaces by removing the top layer of the material. Water/abrasive slurry systems can be used to cut and clean surfaces. At 60 kpsi, this technology can be used to cut virtually any material.
Decontamination of Lead (Chemical and Abrasive Blasting)	A nitric, oxalic solution was identified that is used by the French for this purpose. Coating technology was also investigated for preventing lead from becoming contaminated.
Electropolishing (Preparation)	This method is used to prepare a metal surface to minimize the sites where contamination can become entrapped. Metal that is prepolished prior to being placed in service in contaminated areas becomes less contaminated and is easier to clean.
Electropolishing (Decontamination)	This method removes fixed contamination. Electropolishing can be done by immersion or in-situ.
High Pressure Superheated Water Spray (Kelly machine)	Superheated water chemically and mechanically removes smearable contamination. This equipment has performed well in a wide variety of applications at SRS including cleanup of the 221-F Hot Gang Valve Corridor and the decontamination in tank farm operations.
Strippable Coatings	These coatings have been evaluated for both decontamination and surface protection applications.
General Decontamination assistance	The SRTC offers general decontamination assistance on any decontamination job required in a D&D plan. Based on over 30 man-year of decontamination experience and a wide range of tools as mentioned above, SRTC has the capability to technical support to increase the effectiveness of any decontamination task.

TABLE 7.1

ROBOTICS EQUIPMENT INVENTORY
• Radio and tether controlled Pedsco mobile teleoperators
• Tether controlled IMI TSR-700 Wasp mobile teleoperator
• Radio and tether controlled IMI TSR-150 Hornet mobile teleoperators
• Radio and tether controlled OAO Model MPR-150 mobile teleoperator
• Radio controlled OAO Model MPR-800 mobile teleoperator
• Radio controlled Bobcat loader with backhoe
• Tether controlled Schilling Titan-7F arm with mini-master
• Radio and tether controlled ACEC mobile teleoperator with modular arm
• Radio and tether controlled MERRV mobile teleoperator with arm
• Radiation and General Purpose Mission modules
• Commercial pipe crawlers, underwater crawler, and swimming teleoperators
• Tripod-mounted cameras, zoom lenses, lights, microphones, pan/tilt devices

TABLE 8.1

PACKAGING AND TRANSPORTATION EXPERTISE
• Development of new containers
• Modifications or upgrades to existing containers to meet current regulations and quality assurance requirements
• Preparation of Safety Analysis Reports for Packages (SARP)
• Development of quality assurance requirements for new packaging
• Development of auxiliary equipment for testing and evaluating containers
• Conduction of formal and preliminary tests on containers, models and/or component parts
• Coordination of containers procurement and development with other sites
• Assisting production with: Miscellaneous shipping problems; Receipt of non-routine off-plant radioactive shipments; Improving operating, maintenance and leak testing techniques; Design of auxiliary equipment; Monitoring of new containers received on plant; Preparation of appropriate documentation to meet DOE requirements.
• Review of applicable requirements for new uses and/or first time uses at SRS of all type B or fissile radioactive material shipping packages

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