WSRC-MS-91-365

The Use and Development of Teleoperators for Hostile Environment Applications at the Savannah River Site (U)

R. F. Fogle

A paper proposed for presentation and publication at the
1991 IEEE International Conference on Robotics and Automation
Nice, France
May 10-15, 1991

WSRC-MS--91-365

DE92 015890

The Use and Development of Teleoperators for Hostile Environment Applications at the Savannah River Site (U)

R. F. Fogle
Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

Abstract

The Robotics Development Group (RDG) of the Westinghouse Savannah River Company (WSRC) has used a variety of teleoperated vehicles, arms, and support equipment in hostile environment applications at the U.S. Department of Energy's (DOE) Savannah River Site (SRS). WSRC primarily uses teleoperated hardware to eliminate or significantly reduce personnel exposure in radioactive activities or other hazardous tasks. Teleoperators at SRS handle radioactive material, decontaminate areas contaminated with radioactive isotopes, perform radiological surveys, and provide video surveillance in radiologically controlled areas (RCAs). Proposed future applications of teleoperators include decontamination, filter inspection, contaminated soil removal and dropped reactor target assembly retrieval. This paper discusses past, present, and future applications and current development work on several mobile teleoperators and remote-controlled devices at SRS.

Introduction

SRS is an isotope production facility operated by WSRC for DOE and was established in 1950 to produce nuclear materials for defense and peacetime applications. The 777 km^2 (300 mi^2) complex is composed of many separate site operations including fuel and target fabrication, nuclear reactors, chemical separations, waste management, and a research and development laboratory—the Savannah River Laboratory (SRL).

SRL supports all site operations through research, development, and demonstration studies. RDG is part of SRL and its mission is to apply, develop, and support robotics and remote technology to improve safety, reduce personnel radiation exposure and contamination potential, and reduce manpower, material, and disposal costs. RDG uses teleoperators in hostile environment applications such as radioactive material handling, decontamination, radiological surveys and mapping, and video surveillance. RDG proposes to use teleoperators for inspecting filters, removing contaminated soil, retrieving dropped reactor target assemblies, and other applications.

Because of the increasing reliance on technology to protect workers, RDG initiated a Robotics Emergency Response Program. This program helped develop several teleoperated devices and purchase a variety of teleoperators for quick response in emergency response applications. This paper highlights past and present applications that use teleoperators and details recent teleoperator development activities in the emergency response program.

Past Teleoperator Applications

Radioactive Material Handling

The mobile teleoperator shown in Figure 1 is an OAO–150 made by the OAO Corporation. RDG recently used it to remove a 55–curie cesium source located in a well that is used to calibrate radiation detection equipment.[1] The device for moving the source up and down in the well began to fail, and operators had to remove the source before they could perform maintenance work. RDG selected the OAO, a vehicle in the emergency response fleet, to retrieve the cesium source from the well.

The OAO–150 is a small, tracked, skid–steered mobile vehicle that can be operated by either radio–control or tether cable. The vehicle has a five–degree–of–freedom, joint–controlled manipulator arm with a parallel jaw gripper. RDG modified the gripper to perform both tweezer–like gripping for the 1.27 cm (0.5 in) diameter by 2.54 cm (1.0 in) long source and heavy lifting of a 11.4 kg (25 lb) shielding plug.

All operations were controlled from a remote, shielded room using camera video information supplied by two cameras on the vehicle and tripod–mounted cameras that were strategically placed in the room containing the cesium well. Because of the strength of the cesium source, the vehicle temporarily placed it behind 15.25 cm (6 in) of lead shielding, which required the OAO–150 to make two moves. No appreciable radiation exposure to the operators resulted during the operation.

Work in RCAs

The TSR–700 mobile teleoperator, manufactured by 21st Century/Sivan, is shown in Figure 2. This type of vehicle has been used in several applications at SRS including the removal of a lead counterweight from a reactor ion exchange process vessel, commonly referred to as a deionizer vessel.[2]

Lead counterweights (lead shot sealed in stainless steel containers) have historically been used with deionizer vessels and other equipment to facilitate their handling by remotely operated cranes. When the deionizer vessel is retired from

NFNA

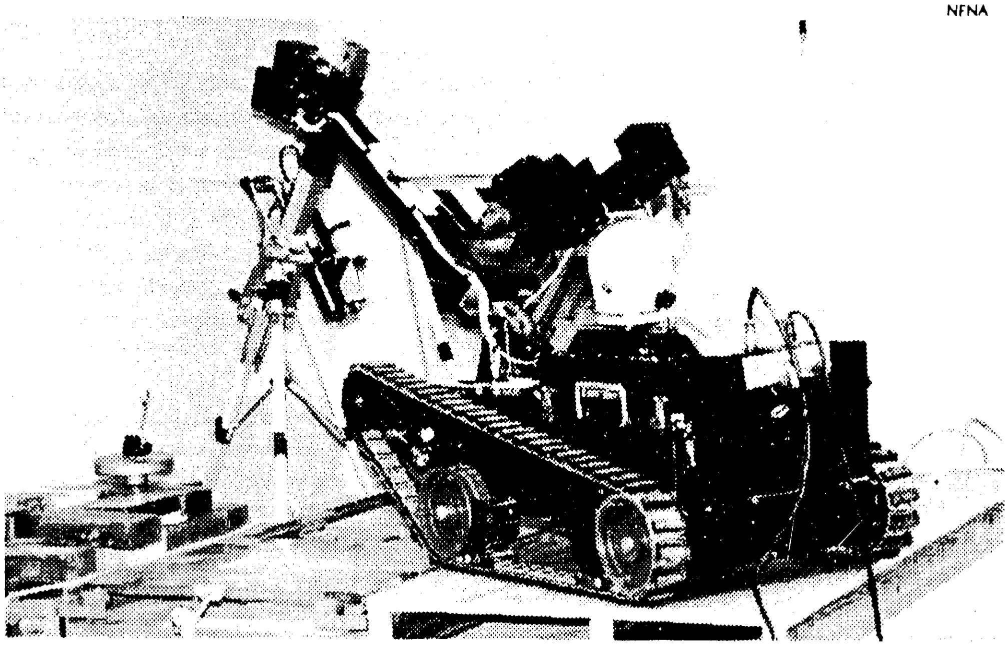

Figure 1. OAO Vehicle Positioned near Cesium Well

service, it is shipped to the burial ground for disposal; however, recent changes in environmental regulations require that no lead be buried in the burial grounds, which requires the retrieval of the lead from the counterweight.

Deionizer vessels are 1.83 m (6 ft) high by 1.52 m (5 ft) in diameter and weigh nearly 454 kg (1000 lb). Radiation levels measure as much as 5 R/hr on the vessel surface and 10–20 mR/hr for background radiation where the deionizers

NFNA

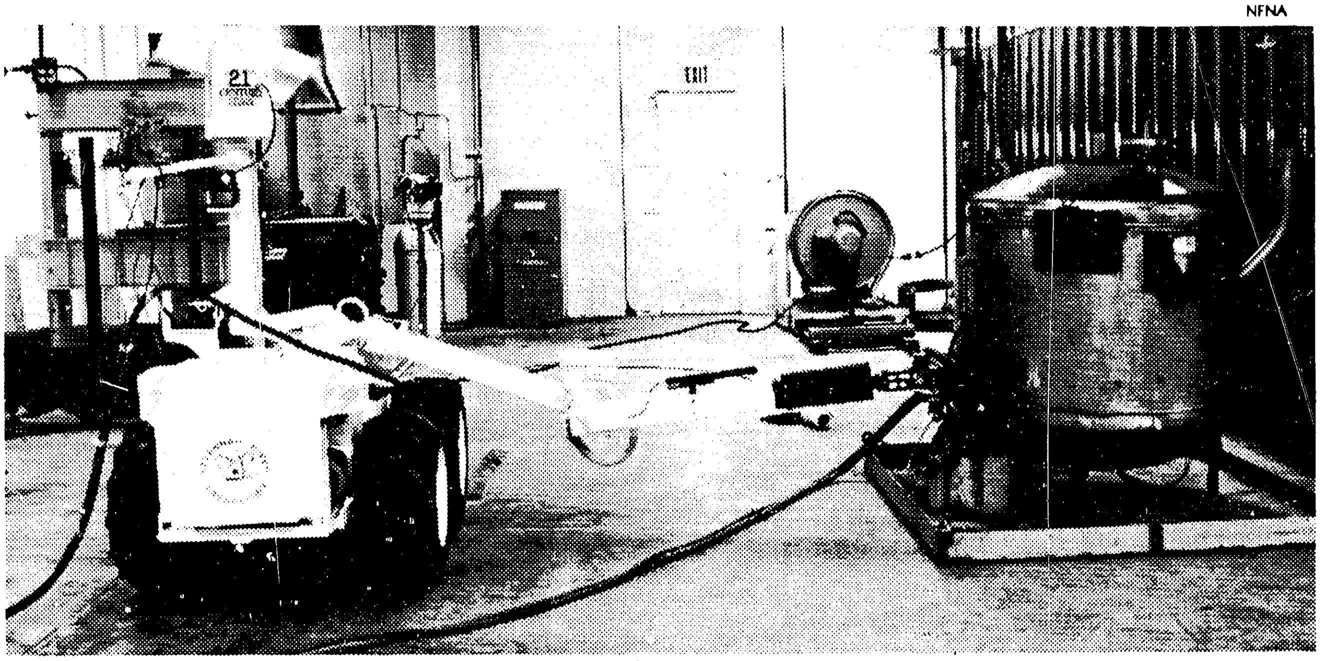

Figure 2. TSR–700 in Mock–Up Facility with Deionizer Vessel

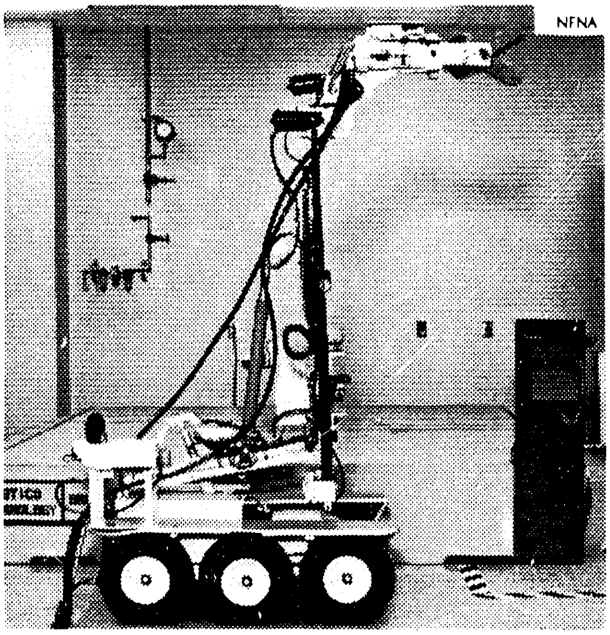

Figure 3. RMI–3 with Modified Arm and Hydraulic Cutter

The vehicle shown in Figure 3 is a modified RMI–3 manufactured by Pedsco in Canada. WSRC used the RMI–3 to remove a wall mounted process junction box that a leak of radioactive liquid had contaminated to a level of 200 R/hr.[3] The remote method performed the task that would have cost an estimated 8 R of exposure to do the job manually.

Researchers extensively modified a Pedsco mobile teleoperator to manipulate a hydraulic cutter that was capable of cutting through 5 cm (2 in) conduit. A new upper arm was assembled with its elbow up, and two additional degrees-of-freedom, wrist rotate and pitch, and a tool-mounted camera were installed.

Operators developed techniques for removing the junction box and refined them in a simulated section of the corridor. Fifteen cuts were required to remove the junction box from the wall; 2 of the 15 cuts were done manually because of small dimensional differences in the contaminated junction box and the mock up box. Total radiation exposure to personnel for this task was 1 Rem.

are stored. WSRC researchers developed a remote method to remove the lead and install a stainless steel counterweight using the TSR–700, a 4–wheel–drive, hydraulically–actuated vehicle with a 6–degree–of–freedom arm capable of lifting 113 kg (250 lb) and reaching 3.05 m (10 ft).

Researchers developed techniques on nonradioactive vessels to test various concepts of cutting and containing the lead shot. The TSR–700 tried various combinations of tooling including pneumatic tools, which performed well and were very forgiving under stalling or jamming conditions.

The lead removal work was performed in a facility where the spent deionizer vessels are purged of any remaining heavy water moderator. To minimize personnel exposure, a crane moves the vessels from their storage area to the work cell. Operators positioned the TSR–700, which was carrying a pneumatic end grinder, near the counterweight. The teleoperator used the grinder to make a straight vertical cut down the side of the counterweight and a curved horizontal cut along its bottom. Setting aside the cutting tool, the TSR–700 used its gripper to snag the cut corner of the enclosure and pull. Containment pans beneath the vessel captured lead shot falling from the counterweight.

Six television cameras were used to aid in the navigation and positioning of the mobile teleoperator and to perform final visual–inspection of the counterweight container. This remote technique of removing lead from a radioactive deionizer vessel allowed two vessels to be processed daily.

Decontamination

The TSR–700, shown in Figure 4, is outfitted with an Admac high pressure spray system made by Flow Industries. RDG developed this system to remove contamination fixed in the surface layer of a concrete wastetank top.[4]

A leak had developed at a high–level waste–storage tank. Condensate seepage from the vapors of the high–activity waste solution stored in the tank contaminated the area on the 85–ft–diameter waste tank. The contaminate liquid penetrated cracks at the base of the concrete curb surrounding a waste–transfer jet "pillbox" located on top of the tank. A portion of the concrete tank top became contaminated. General area dose rates ranged from 10 mR/hr to 600 mR/hr; dose rates at hot spots on the curb ranged from 500 mR/hr to 10 R/hr.

The Admac system removes the surface layer of concrete by using 35,000–55,000 psi of water; it has been successfully used by the West Valley Demonstration Project. For those reasons, it was chosen to remove the contamination. RDG chose the TSR–700 because it was the only mobile teleoperator large enough to carry and manipulate the Admac system.

RDG attached the Admac directly onto the TSR–700 arm and modified the scabbling head of the Admac with a shroud and vacuum attachment, which extracted all expended water and removed concrete into a collection tank. Moving in a

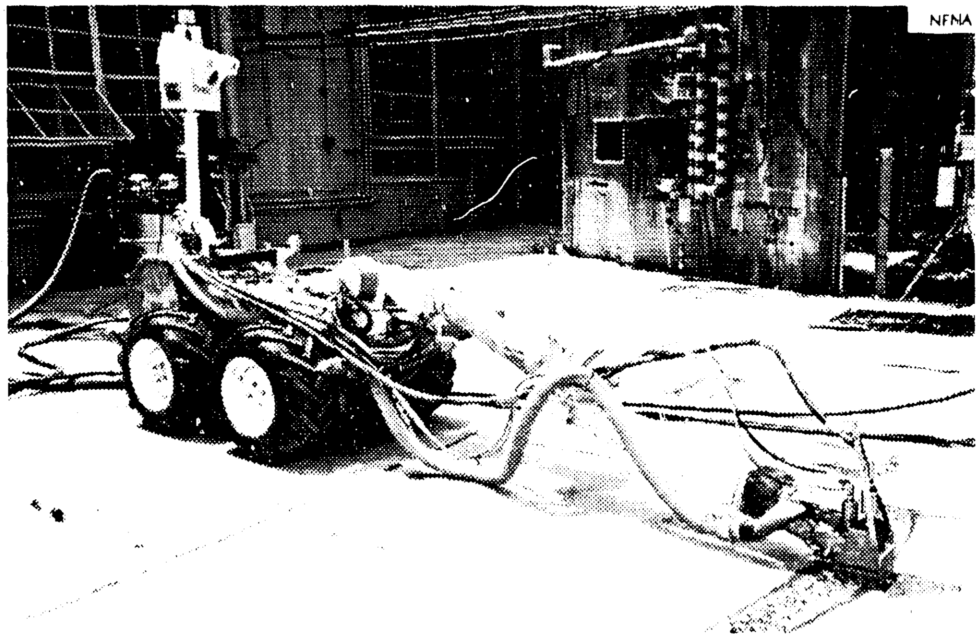

Figure 4. TSR–700 with Admac High–Pressure–Spray System

semicircular path with the arm's shoulder joint, a 7.5 cm (3 in) wide swath of concrete was scabbled on every pass. The general area dose rates were reduced by factors of 3–5. The total personnel exposure to complete the decontamination work was 1.7 Rem.

Radiological and Video Surveillance

The Remote Overhead Video Extendible Robot (ROVER), designed by RDG, is shown in Figure 5. ROVER was developed to provide multiple overhead video views of ra-

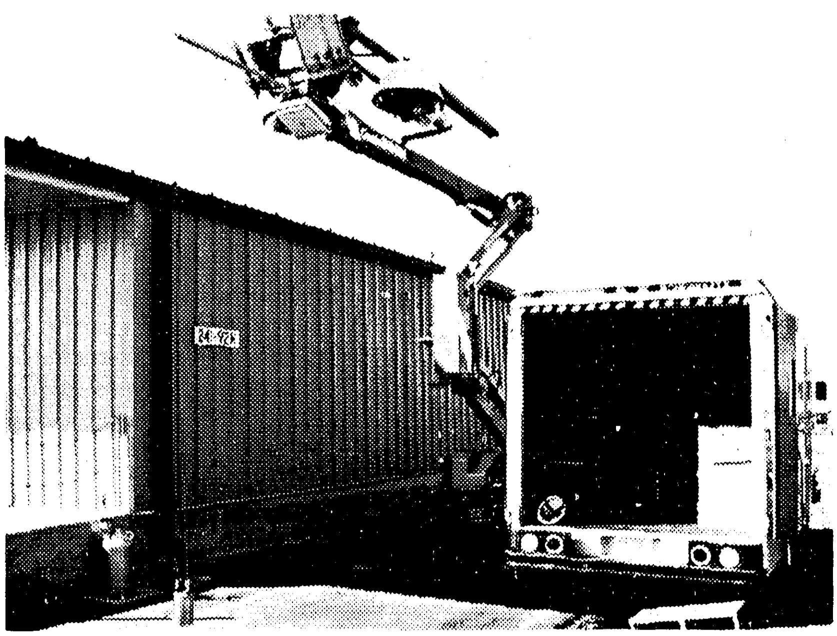

Figure 5. ROVER with Radiation Mission Module

dioactive crane access work sites, which eliminates the need for direct visual viewing.[1]

An operator in a remotely–located [up to 30 m (100 ft) away] control van unfolds and deploys ROVER over the site. It can reach 9 m (30 ft) beyond its base and extend from the ground to 13.7 m (45 ft) above ground level. All controls and video signals are multiplexed over three coaxial cables. Operators also remotely control high–intensity lights, microphones, and speakers. ROVER has been successfully deployed in several radiation work sites to move piping and pumps and clean up high–level contamination sites.

RDG developed a radiation mission module for the ROVER vehicle so that radiological surveys of contaminated sites could be performed without RCA entry by personnel. The module, which is designed for radiation fields of less than 100 R/hr, is located on the boom portion of ROVER between the camera bubbles. Once powered the radiation mission module transmits radiation data to the ROVER operator in the control van. The combination of the hanging radiation probe and the ROVER's cameras allows radiological mapping in a safe manner.

For indoor applications, RDG is developing an autonomous robot to perform radiological surveys of floors in laboratories and buildings where contamination potentials exist.[5] The robot shown in Figure 6 is a Cybermotion K2A manufactured by Cybermotion of Roanoke, Virginia. The K2A scans floors at a speed of 2.54 cm (1 in) per second and stops, sounds an alarm, and flashes lights when it detects contamination. RDG is developing the floor survey system to primarily detect alpha and beta–gamma radiation. Although still in the development stage, the vehicle has been deployed on 2 occasions to locate the origin of some minor contamination incidents.

The K2A is radio controlled, uses dead reckoning to determine vehicle position, and docks with a charging station to replenish its batteries and calibrate its position. The floor survey paths for the robot are preprogrammed. The robot's path can be monitored on a remote screen that shows a graphical map of the environment.

The radiation instrument installed on the K2A is an Eberline RM22A, which is microprocessor based with a serial input/output interface for remote operation. Up to 30 detectors may be configured with the RM22A. In corridor or hallway monitoring applications, two downward–facing gas–proportional detectors scan the floor and one upward–facing detector compensates for background radiation.

The K2A and Eberline detectors will survey corridors and hallways at night, which will reduce disruptions to business activities during the day and the chance of collisions with personnel. RDG plans to center future development work on constructing graphical radiation contour maps of the areas surveyed by the robot.

NFNA

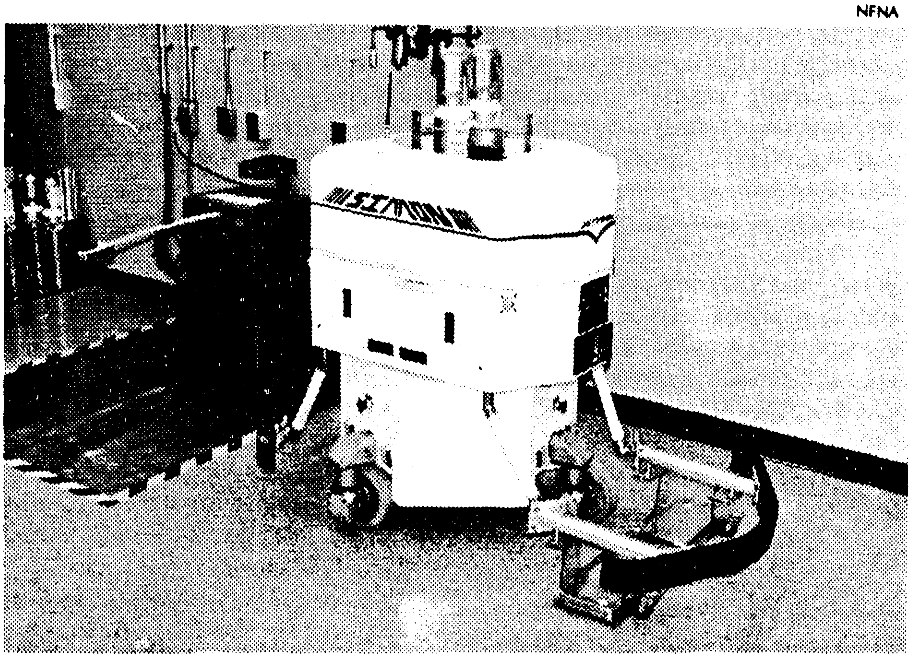

Figure 6. K2A and Radiation Instrumentation

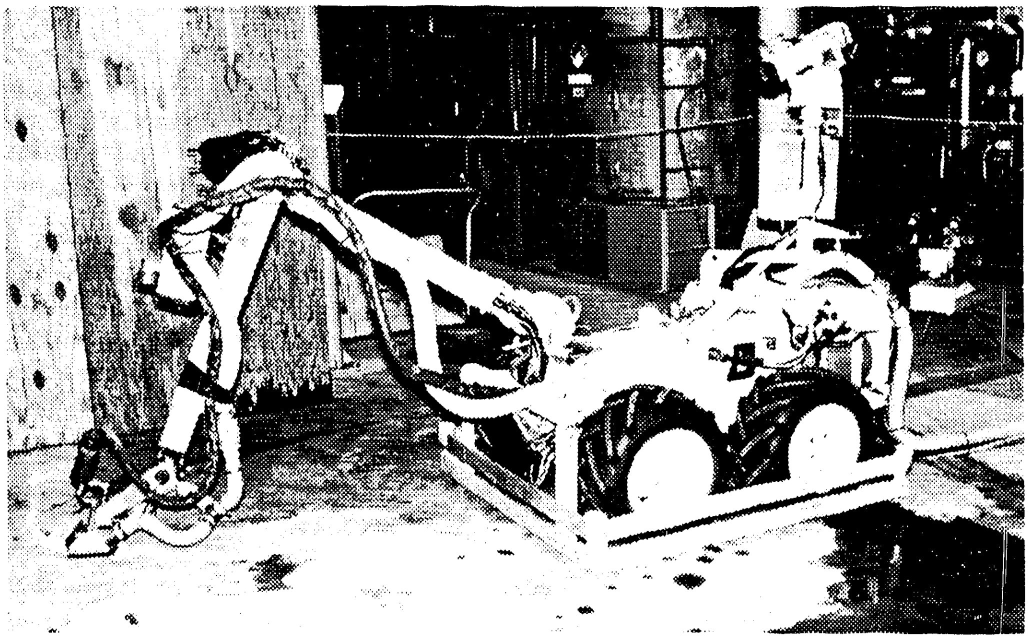

Figure 7. TSR–700 with Kelly Spray/Vacuum System

Proposed Teleoperator Applications

Decontamination

The TSR–700 vehicle shown in Figure 7 is being developed to clean the floor of an alpha contaminated process room.[6] Nearly a decade ago, workers began to manually decontaminate two alpha contaminated process rooms in a separations processing facility. The effort required six years to remove gloveboxes, ductwork, and pipes by using personnel protected by several layers of plastic suits and supplied with an external source of breathing air. Because of new measures to reduce personnel radiation exposure, contamination potential, and the large amount of waste generated in disposing of protective clothing, WSRC is investigating a remote method of decontaminating the process room floor using the TSR–700 and the Kelly Spray/ Vacuum System.

The TSR–700 will carry the Kelly spray and vacuum system, which uses a pressure spray of superheated water. Immediately after it contacts the contaminated surface, the water plus dissolved and dislodged material is removed using a strong vacuum. The TSR–700 and Kelly combination have undergone endurance tests and are currently waiting for approval to begin the decontamination work.

Filter Inspection

RDG proposed a radio–controlled tracked vehicle known as the Hornet (manufactured by 21st Century Robotics Inc.) to perform video surveillance work in sand filters located in the separations areas (see Figure 8).[1] Each sand filter is located in a concrete building with dimensions of approximately 110 m (360 ft) long x 46 m (150 ft) wide x 3 m (10 ft) high. The 4.5–6 m (15–20 ft) thick filters are composed of layers of gravel and sand. The sand filters strip any plutonium, uranium, or other radioactive particle that may be present in the process air exiting the separation facilities before it is vented into a tall stack.

Cave–ins of the gravel and sand layers have occurred. When the filter integrity is compromised, it must be inspected and any cave–ins or depressions filled. Operators wearing plastic suits connected to external breathing air currently perform the work by entering the filter building and examining the filter surface for depressions in the sand. Personnel contamination by airborne particles is a risk.

Contamination can be reduced by using the Hornet, a simple, skid–steered, battery–powered vehicle that has a two–degree–of–freedom arm and parallel–jaw–gripper end–effector. A camera and light assembly mounted on a pan and tilt drive are located on the arm. Communication between the operator and the vehicle is over a 2400 bps simplex radio link. An operator console with joysticks and switches controls the vehicle's functions. For the proposed sand filter surveillance work, RDG replaced the Hornet's normal single pair of knobby tracks with a dual set of smooth tracks. That change will reduce the likelihood of disturbing the integrity of the sand filter as the vehicle navigates over it.

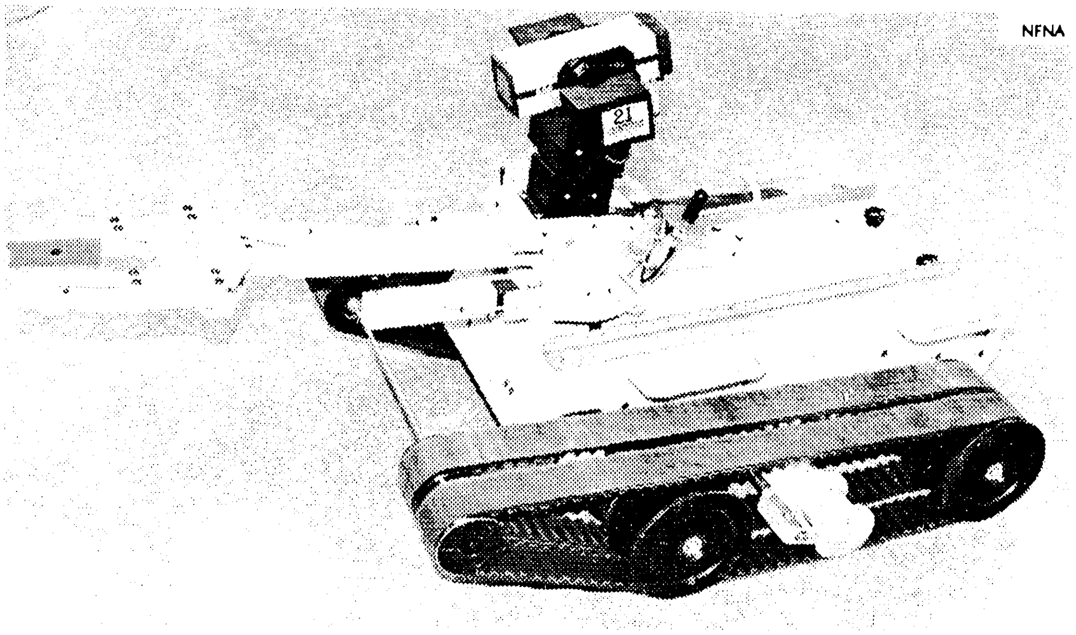

Figure 8. Hornet Vehicle with Dual Tracks

Soil Excavation

A radio–controlled BOBCAT loader is shown in Figure 9 demonstrating remote soil excavation in a clay pit.[7] RDG proposed this vehicle for use in removing contaminated soil surrounding the waste–storage tanks. Operators easily control the vehicle by using joysticks to drive all proportionally controlled features of the vehicle, including the backhoe and dirt bucket attachments. [The backhoe has a digging reach of 2.7 m (9 ft) and a maximum digging depth of 2.4 m (8 ft). The capacity of the bucket is 0.042 m^3 (1.5 ft^3).] To assist the operator in maneuvering the vehicle and excavating at

Figure 9. Remote Control of BOBCAT with Backhoe Attachment

NFNA

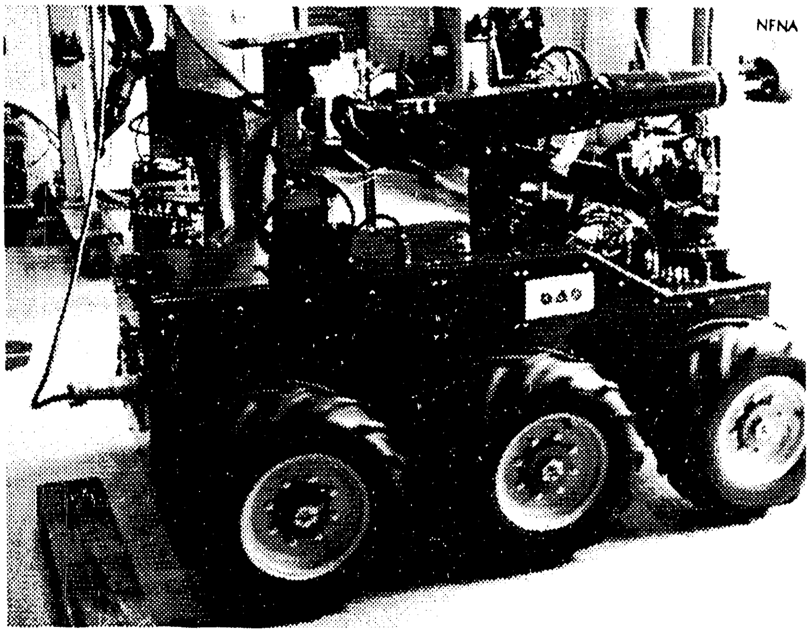

Figure 10. OAO MPR–800

the site, four cameras were installed on the vehicle: Three cameras were located above the cab and one mounted on the backhoe. The video is transmitted over a microwave link to the operator. A video and audio system that uses tripod–mounted cameras, lights, and audio microphones can be used to aid in vehicle navigation.

Dropped Reactor Assembly Retrieval

RDG has proposed several solutions for remotely retrieving a target assembly if it were accidentally dropped by the reactor's discharge machine. (The possibilities for such an accident are very low.) The retrieval system must be capable of recovering an assembly 2–10 minutes after being dropped and delivering it to the deposit and exit (D&E) canal to prevent melting.[8]

The first proposal suggested using the RMI–3 teleoperator. A procedure involving the retrieval of dummy target assemblies was written and a test performed.[9] The robot successfully retrieved several assemblies during a spray test in the L–Area Reactor process room; however, researchers expressed concern about the RMI's ability to remove dropped target assemblies that essentially remained intact, which could weigh several hundred kilograms, and still survive the radiation levels.

To address these concerns, WSRC purchased an OAO MPR–800 (see Figure 10). The OAO is much larger and stronger than the RMI–3, and it has a 7–degree–of–freedom arm capable of reaching 2.8 m (9.3 ft) and lifting 113 kg (250 lbs). The vehicles' electronics are contained in a 317 kg (700 lb) lead box. After some development work, concern arose over the OAO's size and ability to navigate to all areas in the process room.

A third alternative (one that is gaining support) uses a Schilling Gamma–7F manipulator installed on the reactor's discharge machine, which is located in the process room above the reactor tank. The Gamma–7F arm, shown in Figure 11, weighs 68 kg (150 lbs), has a reach of 200 cm (78 in), and can lift 113 kg (250 lbs). The arm employs materials that can withstand 1×10^7 R of cumulative gamma radiation exposure . Tefzel™ is used in the wiring jackets. The hydraulic seals are composed of an ultrahigh–molecular–weight polyethylene alloy, and Kapton™ is used as an insulator material. Currently, a substitute for common hydraulic oil is being investigated; Polyalkalene glycol, radiation tolerant up to 1×10^8 R, is a leading contender. Additionally, a chloride analysis has been completed on materials that will come into contact with the reactor's moderator—all were below the 250 PPM acceptance level.[10]

Since a mock up of this proposal is not feasible, researchers performed a solids–modeling simulation of the Gamma–7F arm and process room using the Silicon Graphics Solid Modeling System (see Figure 12). The model contains a scale representation of the reactor process room, including the discharge machine, reactor tank top, and D & E canal. The Schilling arm, which was assigned inverse kinematics, demonstrated its ability to perform the task by reaching all

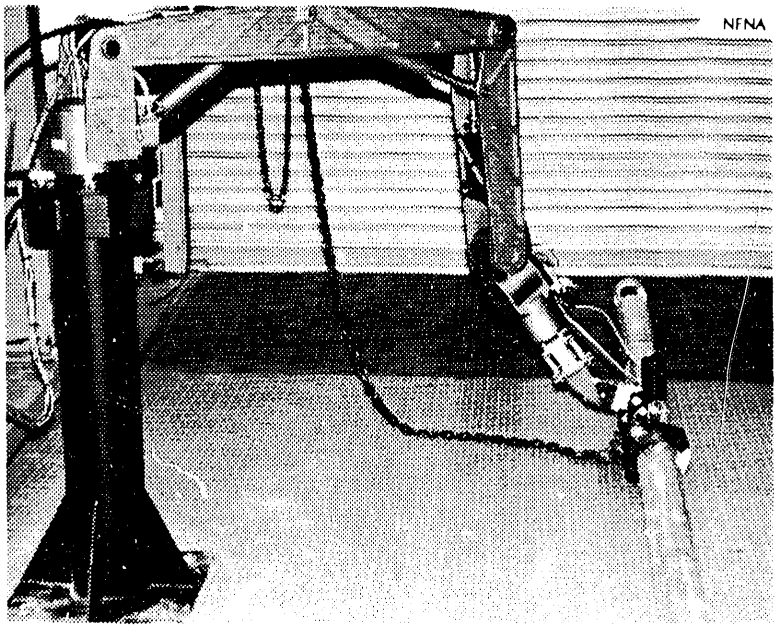

Figure 11. Schilling Gamma–7F Arm

the desired locations in the reactor process room, retrieving the target assembly, and placing it in the D & E Canal.[8] The conceptual system has been accepted by reactor personnel and development of a functional prototype has begun.

Teleoperator Development

Under the Robotics Emergency Response Program, several teleoperated vehicles and remotely controlled devices have been developed or extensively modified to suit SRS applications. The basic design approach for teleoperated vehicles was to develop a general purpose mobile platform that would be highly maneuverable in personnel corridors, confined areas, or over rough terrain; support specialized payloads or mission modules and maintain its integrity under adverse weather conditions. To control the vehicles, a generic operator console was designed. Additionally, RDG developed a five–degree–of–freedom arm known as the Modular Arm and two mission modules. The electronic design of the vehicles, operator console, arm, and mission modules uses off–the–shelf components; many of the components were common to all devices.

MERRV

The Multipurpose Emergency Response Robotic Vehicle (MERRV) shown in Figure 13 is now part of the emergency response fleet.[11] MERRV is a six–wheeled, skid–steered vehicle. Its aluminum chassis is approximately 112 cm (44 in) long, 69 cm (27 in) wide, and 54 cm (21 in) high without the arm.

The vehicle is propelled by left and right 24–VDC drive motor and gear box assemblies coupled through chain linkages to all of the wheels. In an effort to conserve valuable internal vehicular space and provide easy access, the drive motor assemblies are mounted externally on the steel reinforced aluminum running boards, which extend the length of the vehicle on both sides.

The arm is bolted to the running boards, which have been predrilled to accept a variety of lightweight robotic arms and other payloads. The vehicle's optional arm features a continuous wrist rotate, an end effector extension of 46 cm (18 in), the ability to reach 10 cm (4 in) below the robot to 147 cm (58 in) above it, a parallel jaw gripper, and a 45 kg (100 lb) lifting capacity at full arm extension. The arm weighs 41 kg (90 lb) and utilizes 24–VDC actuators.

A unique part of the chassis is a detachable, rear–sliding drawer and interface panel (see in Figure 14). All components for controlling the features of MERRV are located in this drawer, which can be extended from the robot by releasing four latches. All externally mounted hardware (such as the arm, ultrasonics, pan and tilt drive, and other specialized payloads) are connected to the teleoperator's computer system through the rear panel of the sliding drawer.

In an effort to maximize valuable drawer space, some components were mounted on a shelf system comprised of

NFNA

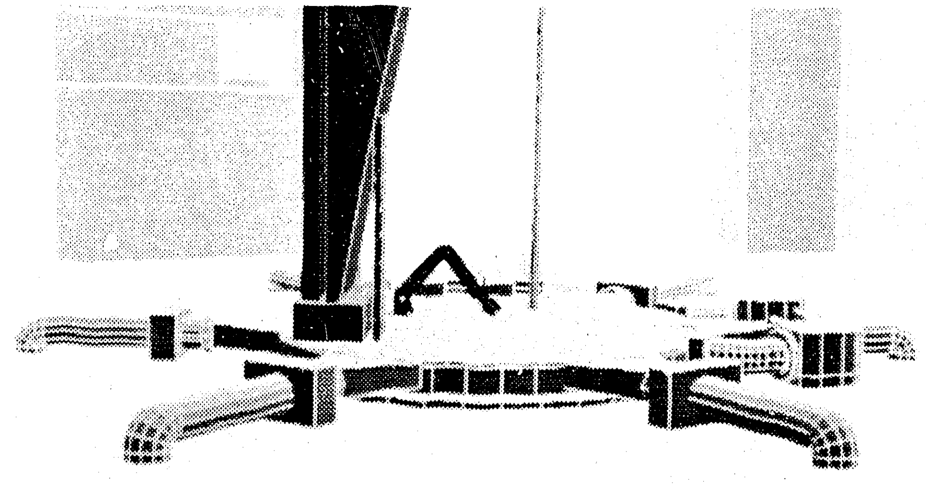

Figure 12. Process Room Simulation of Schilling Arm and Discharge Machine

three–hinged panels located in the middle of the sliding drawer; components on any panel are accessible by removing two screws and lifting the panel above the components.

MERRV uses the simple–to–design (STD) computer bus. The vehicle's STD bus system controls all aspects of the vehicle's functions and is composed of a variety of function–specific boards including digital to analog (D/A) boards, analog to digital (A/D) boards, an RS232 serial communication board, a memory board, and a parallel input/output (I/O) board. MERRV's STD computer system is located on the sliding shelf between the hinged electronic shelf system and the rear connector panel.

MERRV supports four black and white CCD cameras and one audio microphone. Three of the cameras are mounted

NFNA

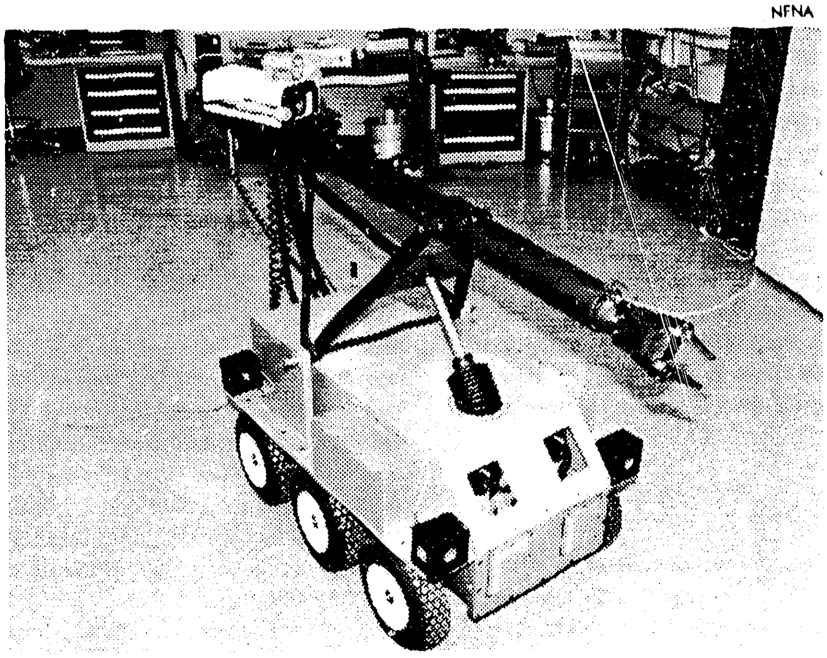

Figure 13. MERRV

M9107143

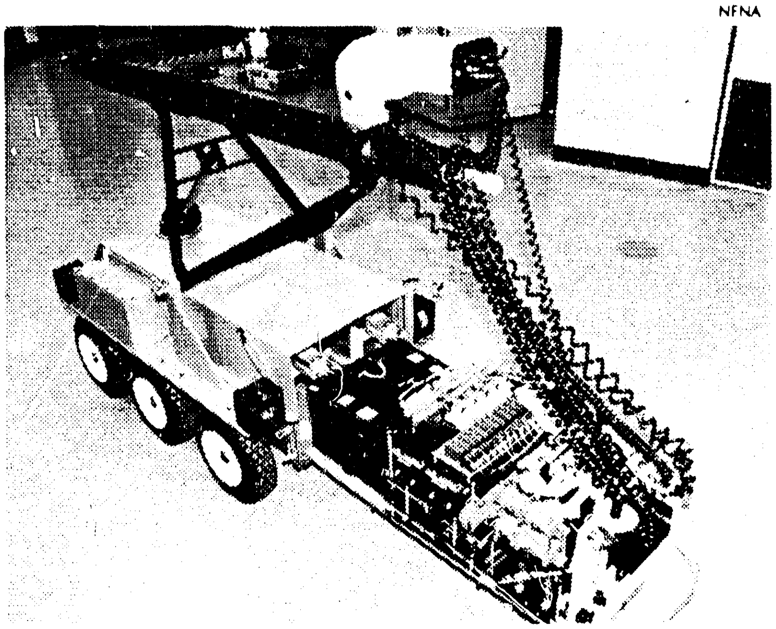

Figure 14. Sliding Drawer on MERRV with All Internal Components

on the vehicle's internal sliding drawer with one facing aft and the other two facing forward. The fourth camera and audio microphone are mounted on a pan and tilt drive located on the arm. The internal cameras have wide–angle, fixed focal length lenses, while the external camera has a zoom lens with its iris and focus features under remote control. A video multiplexer permits simultaneous transmission of all four video signals over a single carrier frequency. The audio from the externally mounted microphone is carried on the main video signal using a subcarrier frequency.

MERRV has not yet been used in an application; however, it is operational and ready should an emergency situation arise. Potential applications for this vehicle include video surveillance and radiological data gathering.

ACEC

Another vehicle in the emergency response program is the ACEC (Figure 15).[7] The ACEC, formerly manufactured by ACEC of Belgium, is one of the more unusual mobile vehicles in the Robotics Response fleet. Unfortunately, the manufacturer no longer makes the robot or spare parts for it. Since there was no manufacturer support for the ACEC, RDG decided to replace the vehicle's custom electronic system with one that was identical or very similar to MERRV's electronic system. The ACEC's upgrade required minimal changes to the vehicle's chassis. The computer system, servoamplifiers, and power supply were removed to make way for off–the–shelf components. The drive motors, electric brakes, and inclinometers were not replaced.

The most unique feature of the ACEC is its articulate track system. It has three sets of tracks: front, middle, and rear. The front and rear track sets can pivot nearly 180 degrees about the midsection of the vehicle. Because of this the ACEC can assume many different postures and adapt to navigation over many types of terrain—unlike MERRV the ACEC can negotiate stairs.

The ACEC has been fitted with an STD computer system that is nearly identical with MERRV and consists of several boards: CPU, memory, RS232, D/A, A/D, and radio interface. The 8088 CPU board has two 8–bit parallel ports, an RS232 serial–communication port, and 128k of erasable programmable read only memory. The vehicle's electric brakes, servoamplifier inhibit lines, pan and tilt movements, and 75–watt floodlight are controlled by the CPU board's parallel ports that are driving solid state relays.

ACEC has four drive motors: front, rear, left and right. A four channel D/A converter board is connected to four servoamplifiers that drive the motors. The front and rear articulated tracks have an operational range determined by inclinometer feedback to the computer's A/D converter board. Software controls the articulated motion range.

A four–port, RS232 serial card transmits data between the operator and the vehicle; one serial port is used for tethered

NFNA

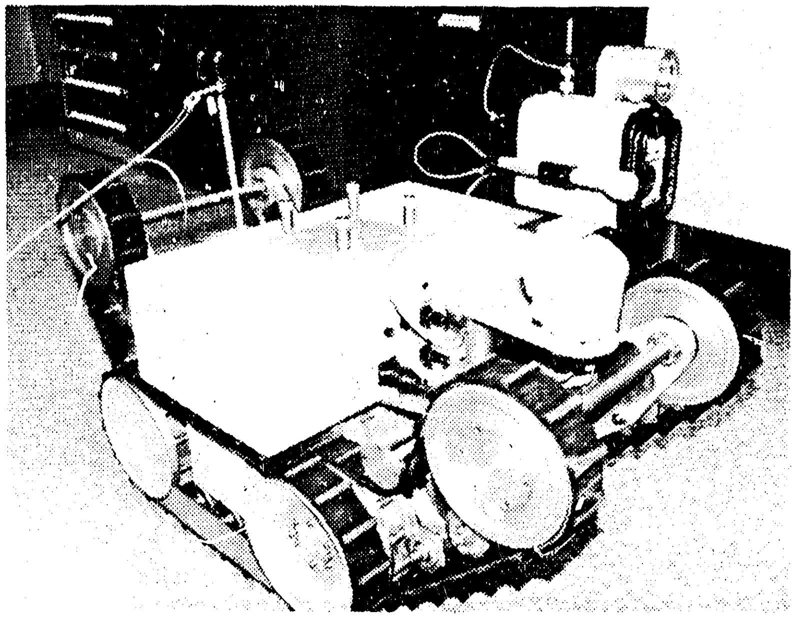

Figure 15. ACEC

cable communication; data transmission over the tether link is 9600 bps. Another RS232 port is dedicated to RF communication if permissible in the application. The other two RS232 ports are available for future expansion.

The electronic system is housed in an aluminum enclosure. The computer system, solid state relays, radio, and ribbon-cable to discrete wire connectors are housed at one end of the enclosure. The servoamplifiers and power supply system are located at the other end. Temperature controlled fans remove the heat produced by the electronics by pulling air into the enclosure through louvered plates and filter meshes.

Weather–resistant connectors are used to connect external hardware to the computer system and its associated electronics. They are positioned at the middle portion of the front and rear ends of the enclosure. The center area of the enclosure is unavailable for use. It was designed as a mounted interface to translate and absorb the moments and forces exerted by a five–degree–of–freedom manipulator arm known as the Modular Arm.

The ACEC is a unique, tracked vehicle in the emergency response program. The redesign and installation of commercially available electronics will make future modification and maintenance of the ACEC much easier.

Generic Vehicle Operator Console

The console shown in Figure 16 can control either the MERRV or ACEC vehicle.[7,11] The console is a weather–resistant, aluminum suitcase containing a variety of features all controlled by an STD bus computer. The console weighs 10 kg (22 lb) and can be powered by a 12 VDC battery or from a 120 VAC wall receptacle.

The STD bus computer system continually monitors the console for operator input. Two joysticks provide proportional control of vehicle drive motors; rocker switches are available for future enhancements. The infrared touch screen and data display is an integral part of the console. A startup menu requests information about the type of vehicle and the communication link required; robot selection, diagnostic information of communication link integrity, raw joystick values, and switch position are displayed on other menus. Additionally, the pan and tilt drive and light on each vehicle can be controlled by touching the appropriate "button" on the display's screen. The use of the touch screen makes adding enhancements easy. New commands or display information can be programmed to accommodate additional vehicle features.

Modular Arm

The Modular Arm (see Figure 17) is a five–axis articulated arm with easily detachable joints and drive motor units.[12] The arm is modular in design so that each drive motor unit can be quickly changed using an Allen wrench. The Modular Arm was conceptualized by RDG, but designed and fabricated by a vendor. The electronic system that was supplied with the unit never lived up to expectations and was redesigned by RDG.

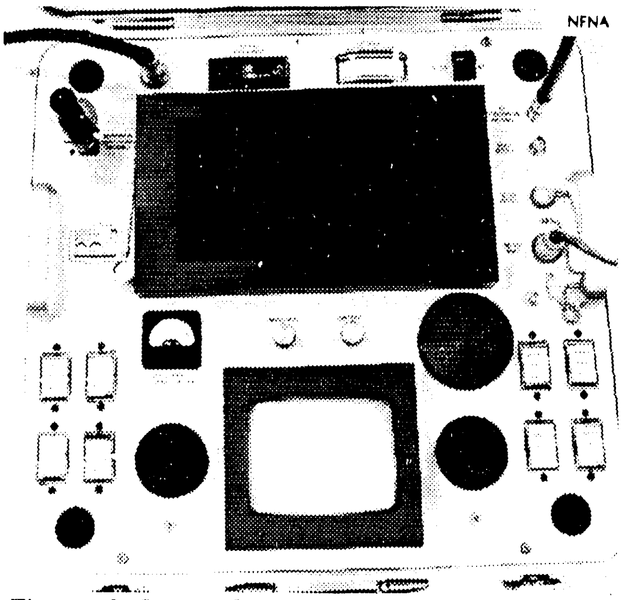

Figure 16. Generic Operator Console Controls for MERRV or ACEC

The electronic enclosure for the Modular Arm is identical to the ACEC vehicle. Four stud bolts located on the top of the vehicle's electronic box allow the arm and its electronics to be easily attached. The arm is capable of reaching 1.2 m (4 ft) and lifting 16 kg (35 lb). It has a base rotation of 360 degrees, shoulder pitch of 110 degrees, elbow pitch of 110 degrees, forearm pitch of 120 degrees, and wrist yaw of 120 degrees. The parallel jaw gripper opens to four inches and was wired so that tooling could be easily added. Each of the five arm joints is driven by DC brush motors operated at 24 VDC. Also, each joint has a drive assembly composed of a motor, gear or belt reduction, and an encoder.

The arm is controlled by an STD bus computer using many of the same function boards as the MERRV, ACEC, and generic operator console. Other similar features include servoamplifiers, solid state relays, and external connectors. The electronics are housed in an enclosure beneath the arm where temperature controlled fans regulate the temperature.

Mission Modules

Two mission modules, shown in Figure 18, have been developed: a radiation mission module and an analog/digital mission module that adds temperature, humidity, and explosive gas detection abilities to mobile robots or to stand–alone applications. Mission modules perform specific tasks and are not electronically connected to the teleoperator. Because of that independence, mission modules add power and flexibility to mobile teleoperators without the need to share programs or electronic systems.

Conclusion

The Robotics Development Group at the Savannah River Site has reduced exposure of personnel to radiation by

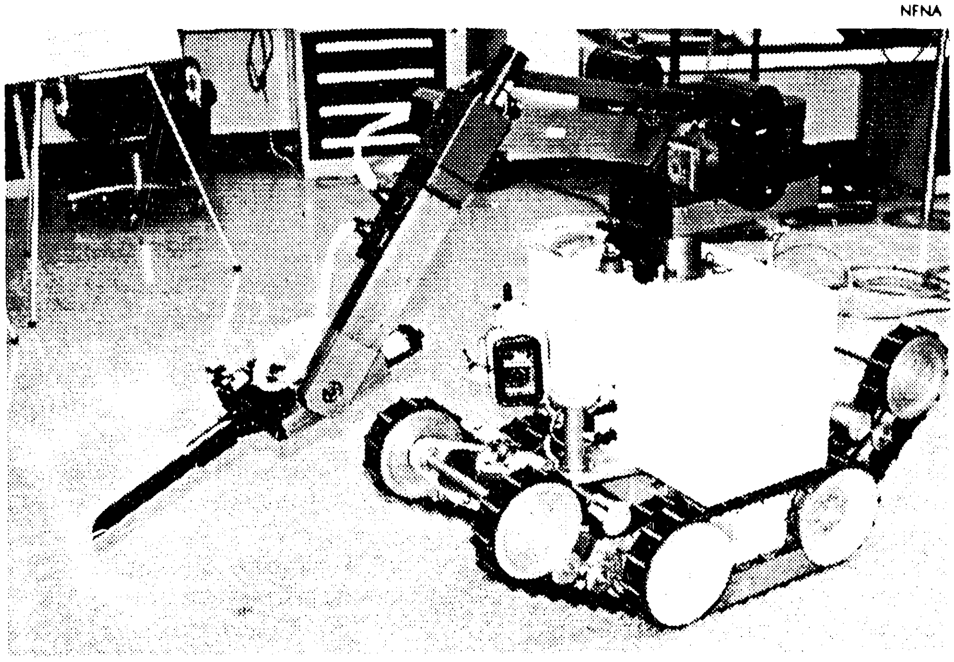

Figure 17. Modular Arm Holding a Saw

NFNA

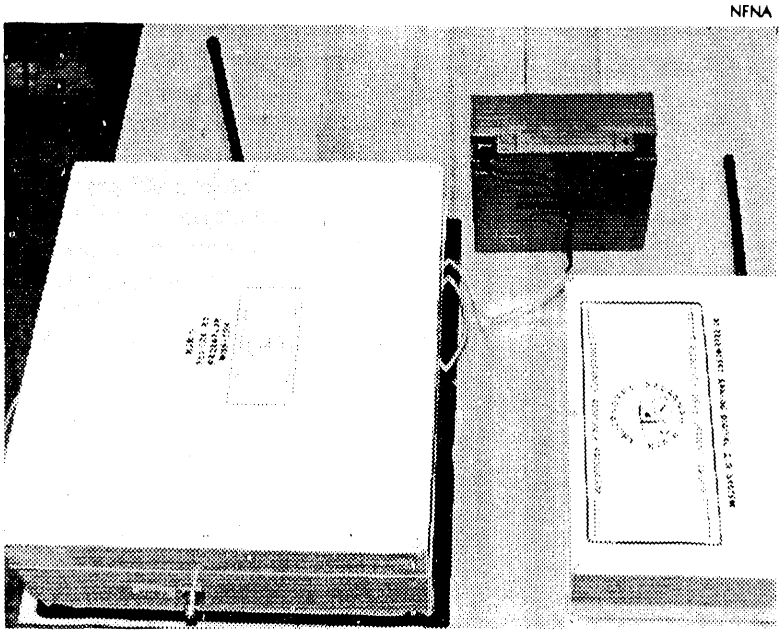

Figure 18. Mission Modules

deploying teleoperated vehicles and support equipment in a number of tasks. RDG will continue to procure and develop equipment to reduce personnel exposure to hazards.

Acknowledgment

The information in this article was developed during the course of work under Contract No. DE–AC09–89SR18035 with the U.S. Department of Energy.

References

1. R.F. Fogle and F.M. Heckendorn. *Teleoperated Equipment for Emergency Response Applications at the Savannah River Site.* WSRC–MS–91–162, (1991).

2. F.M. Heckendorn and R. F. Fogle. "Lead Removal from Radioactive Vessels using a Mobile Robot". *ANS 3rd Topical Meeting on Robotics and Remote Systems Proceedings*, Charleston, SC, (1989).

3. C.R. Ward and W.N. Rankin, "Mobile Teleoperator for Removing a Contaminated Junction Box". *ANS 3rd Topical Meeting on Robotics and Remote Systems Proceedings*, Charleston, SC, (1989).

4. W.N. Rankin and R.F. Fogle, et. al. "Robotic Decontamination at Savannah River". *ANS 3rd Topical Meeting on Robotics and Remote Systems Proceedings*, Charleston, SC, (1989).

5. E.M. Dudar, et. al. "SIMON: A Mobile Robot for Floor Contamination Surveys". *Westinghouse Computer Symposium Proceedings*, Pittsburgh, PA (1991).

6. G.M. Dyches and W.T. Zollinger. "Surface Decontamination using a Teleoperated Vehicle and Kelly Spray/Vacuum System". *5th International Symposium on Ceramics in Nuclear and Hazardous Waste Management*, Cincinnati, OH (1991).

7. R.F. Fogle. "Teleoperated Vehicle for Emergency Response Applications". *ANS 4th Topical Meeting on Robotics and Remote Systems Proceedings*, Albuquerque, NM (1991).

8. R.C. Vandewalle, et. al. *Hot Assembly Retrieval Program.* EES November 1990 Monthly Report, SRL–EES–900158.

9. J.H. Addison, Jr. *Process Room Emergency Response Robot Test.* DPST–85–966, February 1986.

10. R.C. Vandewalle, *Hot Assembly Retrieval Program.* EES May 1991 Monthly Report, SRL–EES–910032.

11. R.F. Fogle and W. I. Lewis III. "Multipurpose Robotic Vehicle Development at the Savannah River Site". *ANS 3rd Topical Meeting on Robotics and Remote Systems Proceedings*, Charleston, SC (1989).

DATE
FILMED
8103192