CONF-961241--1

Remote Dismantlement Activities for the Argonne CP-5 Research Reactor

Mark W. Noakes

Oak Ridge National Laboratory

Abstract

The Department of Energy's (DOE's) Robotics Technology Development Program (RTDP) is participating in the dismantlement of a mothballed research reactor, Chicago Pile #5 (CP-5), at Argonne National Laboratory (ANL) to demonstrate technology developed by the program while assisting Argonne with their remote system needs. Equipment deployed for CP-5 activities includes the dual-arm work platform (DAWP), which will handle disassembly of reactor internals, and the RedZone Robotics-developed "Rosie" remote work vehicle, which will perform size reduction of shield plugs, demolition of the biological shield, and waste packaging. Remote dismantlement tasks are scheduled to begin in February of 1997 and to continue through 1997 and beyond.

Introduction

The CP-5 reactor (Fig. 1) was built as a heterogeneous, heavy-water cooled and moderated, fully enriched reactor to provide neutrons for research at ANL. Construction of the reactor facility was started in 1951, operation began in 1954, and shutdown of all operation occurred in 1979. CP-5 began operation as a 1-mw reactor, but multiple upgrades brought the final power output up to 4-mw. As part of the final shutdown process, the reactor was defueled and drained of heavy water. System piping, auxiliary systems, and miscellaneous hardware were removed and packaged as waste in order to put the facility in a safe storage mode. Decontamination and dismantlement (D&D) of the reactor started in 1995. Throughout the D&D process, a number of new and innovative technologies from various government and industry groups will be demonstrated and evaluated for future use.

Many of the dismantlement and cleanup procedures will be handled manually; however, where radiation and contamination levels are high, remote completion of D&D tasks is desirable to limit human exposure. Regulatory direction is also forcing a decrease in the level of exposure that is considered acceptable to a level that is "as low as reasonably achievable" (ALARA). Tasks that are now performed by suited humans may have to be performed remotely in the future as these standards are tightened. Additional advantages may also be gained by automating as much of the remote tasks as possible to increase the efficiency of operation and to decrease cleanup costs.

DISCLAIMER

The RTDP is one of the organisations participating in the technology demonstrations for CP-5 dismantlement. RTDP is a major effort within the DOE Office of Science and Technology in the Office of Environmental Management that is performing applied research and development (R&D) pertaining to the practical application of robotics to site cleanup projects. One of the technology application areas being pursued by RTDP is D&D robotics, and the program is responsible, directly or indirectly, for providing or recommending all remote systems necessary for CP-5 cleanup.

The RTDP philosophy for D&D robotics R&D is to emphasise generic capabilities that will have broad applicability across the full range of heterogeneous requirements (e.g., type of prior use, equipment sizes, radiation levels, age) associated with the various facilities requiring decommissioning. D&D robotics is concentrating on reconfigurable and modular hardware and software technologies that can be "assembled" to meet specific requirements while minimising recurring R&D and design costs. In the case of CP-5 dismantlement, the initial development of the generic Selective Equipment Removal System (SERS) and the dual-arm work module (DAWM) led to the implementation of the dual-arm work platform (DAWP). RedZone Robotics, Inc., which was under a Morgantown Energy Technology Centre (METC) contract to deliver a robot mobile platform as one of the SERS deployment options for the DAWM, has also provided an iteration of this remote work vehicle, "Rosie," in support of CP-5. DAWP and Rosie are shown in a graphical simulation in Fig. 2.

Dual Arm Work Platform and Associated CP-5 Tasks

The DAWP predecessor, the DAWM, consisted of two 6-degree-of-freedom (D.O.F.) Schilling Titan II hydraulic manipulators (with a maximum capacity of 110 kg in the elbows-up configuration) mounted to a 5-D.O.F. hydraulic positioning base (Fig. 3) that was designed and built for ORNL by RedZone Robotics, Inc. The DAWM base motions provided a seventh D.O.F. at the base of each Titan II so that manipulation could be approached in an elbows-up, elbows-out, or elbows-down configuration, depending on the task at hand. These rotary actuators allowed a ±90° rotation from the horizontal position. The elbows-up configuration provided an advantage for operation from above on horizontally configured equipment. An elbows-down configuration was advantageous for working on vertically stacked equipment. The elbows-out positions permitted the manipulators to reach around obstacles as required. Two linear actuators located the base of the arms anywhere between a separation of 61 to 152 cm. A centre rotary actuator added a ±90° rotation of the entire torso from the horizontal position, maximising flexibility of the DAWM manipulation capabilities. These positioning

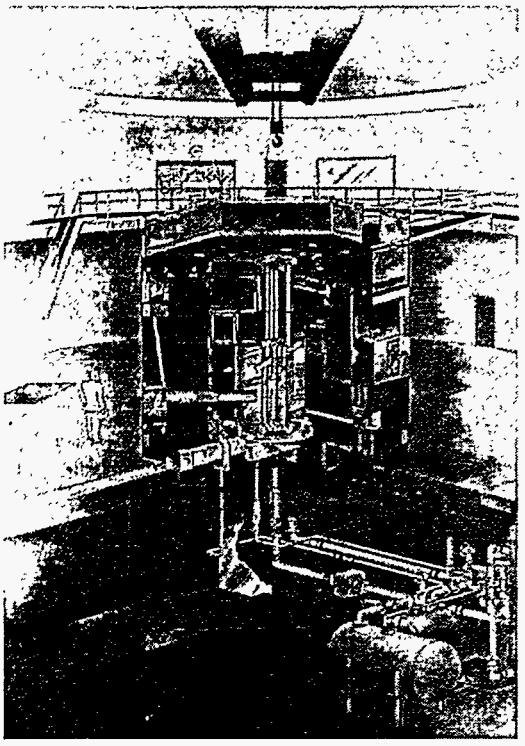

Fig. 1. CP-5 artist's rendering.

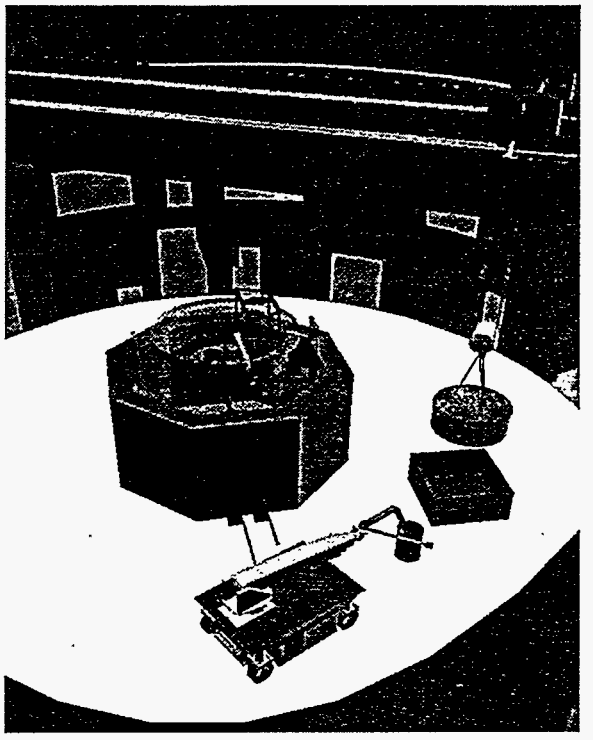

Fig. 2. Remote systems simulation.

capabilities allowed the manipulators to be reconfigured to the best pose for performing tasks in the cluttered and constrained environments expected during D&D activities. Figure 4 shows how DAWM was intended to be deployed for the various types of mobility platforms that would be required in different facilities--rigid boom overhead transporter-mounted, overhead crane hook-suspended, and mobile vehicle-mounted. The initial SERS implementation was installed on a rigid boom overhead transporter in the Robotics Technology Assessment Facility at Oak Ridge National Laboratory.

The original DAWM design was driven by the desire to provide maximum system versatility in the study of deployment options and orientation relative to specific task performance. For 1996, RTDP D&D Robotics was directed to provide remote systems support for the dismantlement of the CP-5 reactor at ANL beginning in 1997. The manipulator system was to be used specifically for the dismantlement of components internal to the reactor block. The only reasonable deployment method was via suspension from the overhead polar crane. Size constraints were an issue since any manipulator system had to fit inside the 3-m steel cylinder that separated the reactor internals from the biological shield. DAWM was designed more to maximise manipulator reach rather than to minimise system footprint. A study of the tasks and constraints involved and the available deployment options led to a rework of the DAWM designated the DAWP (Fig. 5), which was

completed by Idaho National Engineering Laboratory. The operator control station, Fig. 6, was very closely patterned after that of the DAWM. DAWP was specifically designed around crane hook deployment, and the base degrees of freedom were reduced to four instead of five and reconfigured to accommodate reach requirements in the restricted footprint. The base actuator kinematics were chosen such that the manipulator envelope was maximised to reach out across and down into the reactor vessel when the DAWP was placed on top and to the side of the reactor. DAWP made use of the existing base platform hydraulic actuator components, the Schilling manipulators, and a significant portion of the DAWM control system.

DAWP task execution will rely on a range of control modes from pure teleoperation to teach/playback to sensor-based tool deployment under supervisory control (provided by Sandia National Laboratories). The specific tasks include installing and hooking up lifting fixtures for the heavy components that must be removed intact such as shield plugs; unbolting, shearing, or sawing miscellaneous internal support hardware; removal of thousands of graphite blocks; sectioning the aluminium reactor vessel; and assisting with waste packaging and disposition as practical (in this mode, DAWP is placed in an adjustable stand on the reactor room floor). DAWP is designed to carry and deploy up to seven tools at a time, five electric and two hydraulic, to assist in completing the various tasks. The tool philosophy relies on the use of portable power tools fixtured with Schilling T-handle brackets so that tooling costs can be minimised and so that changes in plans and methods of removal may be rapidly accommodated.

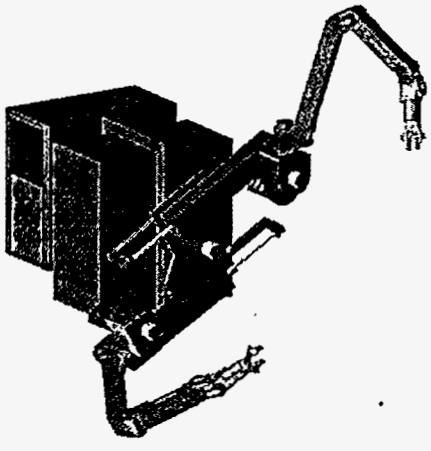

Fig. 3. Dual-arm work module.

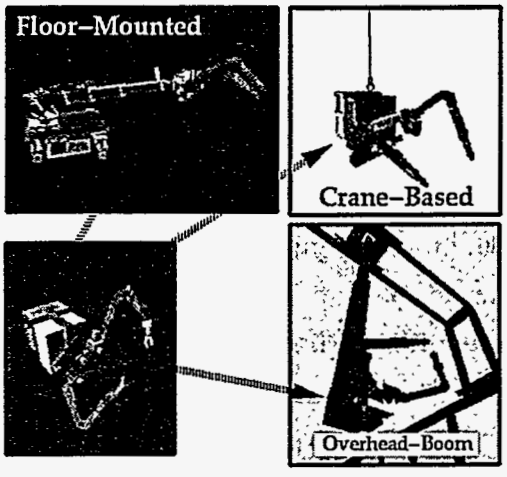

Fig. 4. Mobility for the DAWM.

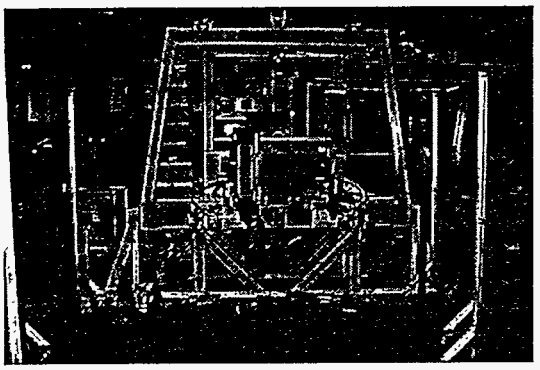

Fig. 5. Dual Arm Work Platform (DAWP).

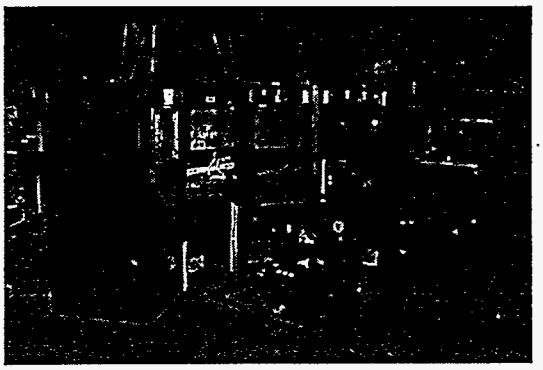

Fig. 6. DAWP Operator Control Station.

RedZone Remote Work Vehicle Rosie and Associated Tasks

For tasks outside the reactor block, the remediation team selected to use the RedZone Robotics, Inc., remote work vehicle Rosie (Fig. 7). Rosie is a heavy lift robotic vehicle with hydraulic actuation of all motions. The base platform has four steerable drive wheels that permit omnidirectional motion in 4-wheel steer, crab steer, or rotate-about-a-point modes of operation. A 4-D.O.F. manipulator with a reach of 6.1-m is mounted on the platform deck and provides shoulder pitch and rotate, prismatic boom extension, and wrist pitch with the wrist terminating in a substantial interface plate that can deploy tooling up to 770 kg, including a subset of the DAWM. The manipulator can be controlled in either joint mode or coordinated Cartesian position control mode. The electrically driven hydraulic power supply is located onboard the vehicle and is connected to the operator control station and power distribution unit via a tether.

Rosie was designed to support a wide range of heavy tooling (Fig. 8) and dexterous manipulation (Fig. 9) tasks, including process equipment removal, reactor dismantlement, hot cell and glove box dismantlement, structural demolition, waste handling and packaging, and decontamination. The particular CP-5 tasks designated for Rosie are all of those activities that will be conducted outside the reactor block but inside the reactor room, including sectioning of the reactor shield plugs, removal and sectioning of any remaining experiments inserted into horizontal thimbles in the reactor vessel sides, waste packaging, and demolition of the biological shield. These tasks will require a variety of heavy tooling as well as the use of a single manipulator; in this case, a Kraft Predator will be installed on the interface plate.

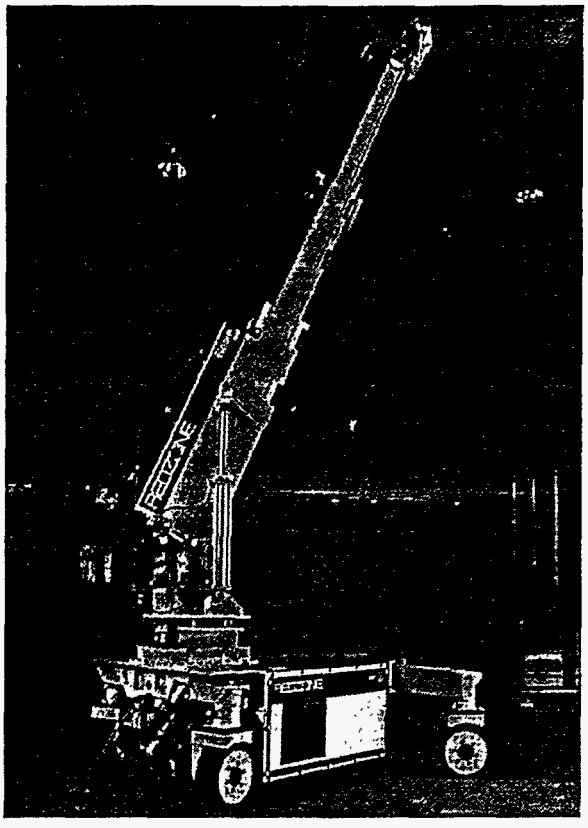

Fig. 7. Rosie Remote Work Vehicle.

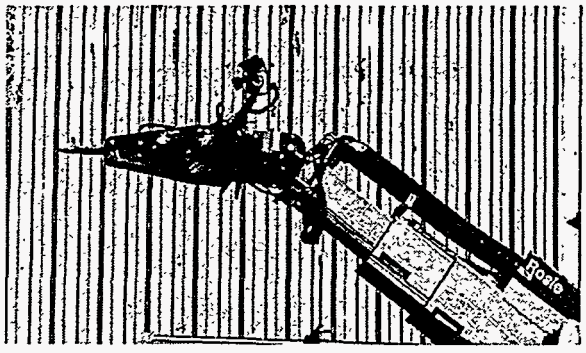

Fig. 8. Jackhammer end-effector.

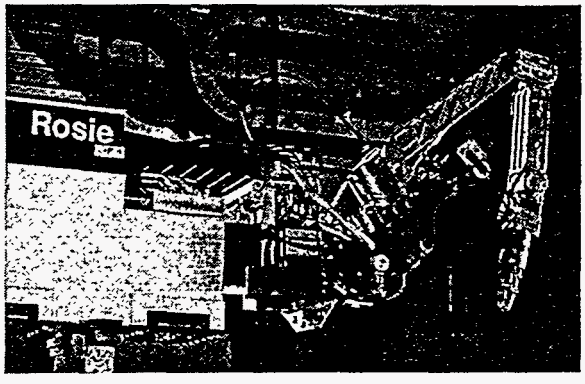

Fig. 9. Single Schilling manipulator.

Summary

The RTDP DAWP and the RedZone Robotics' Rosie remote work vehicle have provided ANL with the systems necessary to complete the CP-5 D&D tasks that must be completed remotely in order to minimise worker exposure. Both DAWP and Rosie represent a philosophy that promotes the use of systems with generalised capability in order to provide cost-effective and reusable remediation hardware rather than the use of one-off custom hardware that is often consumed for each project. Manual dismantlement activities have already begun. Those tasks that require remote systems will begin in early 1997.

Acknowledgements

The D&D robotics technology described in this paper is the result of the combined efforts of a team comprising staff members from Oak Ridge National Laboratory; Sandia National Laboratories; Idaho National Engineering Laboratory; RedZone Robotics, Inc.; and Schilling Development, Inc.

Bibliography

W. R. Hamel and D. C. Haley, "Dual-Arm Manipulation Module for Use In Decontamination and Decommissioning Operations," *1994 International Symposium on Decontamination and Decommissioning,* April 1994.

W. R. Hamel and D. C. Haley, "Advanced Robotics for Decontamination and Dismantlement," *ISRAM '94 Fifth International Symposium on Robotics and Manufacturing,* August 1994.

M. W. Noakes, W. R. Hamel, and W. E. Dixon, "Application of the Selective Equipment Removal System to D&D Tasks," *American Nuclear Society Sixth Topical Meeting on Robotics & Remote Systems,* February 1995.

L. Conley, W. R. Hamel, and B. R. Thompson, "Rosie: A Mobile Worksystem for Decontamination and Dismantlement Operations," *American Nuclear Society Sixth Topical Meeting on Robotics & Remote Systems,* February 1995.