Deployment of Remote Systems in U.S. Department of Energy Decontamination & Decommissioning Projects*

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Abstract

This paper presents recent experiences from the U.S. Department of Energy (DOE) Robotics Crosscutting Program in the deployment of remote systems for use in deactivation and decommissioning (D&D) projects at various DOE facilities. Through discussion of these experiences in this paper, the authors attempt to illustrate the issues encountered during these deployments and the current level of acceptance of these technologies within the DOE complex. Such experiences provide a better understanding of the perception of the role of remote system technology in D&D and provide lessons learned in the area of technology insertion into current D&D field practice within DOE.

Introduction

The deactivation and decommissioning (D&D) product line within the Robotics Crosscutting Program (Rbx) performs technology development, test, demonstration, and deployment of remote systems for use in D&D of U. S. Department of Energy (DOE) facilities. However, most of the recent direction from the focus areas has been on field deployments and not on technology development. This paper presents a discussion of five different remote systems that were developed and deployed by the Rbx D&D product line over the time period from fiscal year (FY) 1996 to FY 2000. These systems were deployed at three different DOE Sites. In FY 1996 and FY 1997, the Rbx fabricated and deployed the Dual Arm Work Platform (DAWP) at the Argonne National Laboratory (ANL) within the D&D of the Chicago Pile Number 5 (CP-5) research reactor. In FY 1998, the Canyon Disposition Initiative Remote Characterization System (CDI RCS) was deployed at the 221-U facility (U-Plant) at the Hanford Site. In FY 1998, the Remote Underwater Characterization System (RUCS) was deployed within the Test Reactor Area, Building 660 D&D project at the Idaho National Engineering and Environmental Laboratory (INEEL). In FY 2000, the Compact Remote Operator Console (CRC) and the Modified Brokk Demolition Machine™ were deployed within the Security Training Facility D&D project at INEEL.

*Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the U.S. Dept. of Energy under contract DE-AC05-00OR22725.

Technology Deployments

Dual Arm Work Platform/Argonne National Laboratory

The DAWP was deployed to support the CP-5 reactor dismantlement and consisted of two Schilling™ hydraulic manipulators on a specially designed base platform (Fig. 1) and operated from a traditional style, control-room-based operator station (Fig. 2). During the deployment at CP-5, Rbx staff supplied only technical consulting because ANL had previously specified that only existing ANL D&D staff would be permitted to operate the system. ANL continued to run the DAWP with minimal assistance from Rbx staff through most of FY 1998. During this time, the DAWP successfully removed the reactor internals as required—more than 60,000 lb of graphite bricks, 2,000 lb of steel, 1,700 lb of aluminum, 1,400 lb of lead, and 620 lb of boral. The use of the DAWP turned out to be essential to the completion of the reactor dismantlement since the radiation levels were much higher than anticipated and would have prevented the use of the intended manual baseline.

However, project level and operations staff did have some issues with the system. Although the core of the previous developed research software was removed to radically decrease the complexity of the DAWP and the graphical user interface was designed specifically with non-technical users in mind, the operators whom CP-5 D&D made available still had some difficulty with the operation of the DAWP. All operators were taken from existing D&D staff, they had little or no previous remote system operation experience, and all had various other responsibilities within the existing operations structure. Many had difficulty with the optional voice-recognition technology, and some did not like the optional stereo viewing capabilities. Some had difficulty coping with basic computer interface concepts such as the use of a graphical user interface. However, a willingness to learn new skills and a certain degree of manual dexterity proved to be the only real requirements for a successful DAWP operator. Out of the approximately eight possible operators, two proved to be exceptional—one was a crane operator (not initially computer literate) and the other was a health physics technician (computer literate). Even these two operators had some productivity problems early on because management would frequently pull them from DAWP operation to do other tasks in their work description. Once this practice stopped and DAWP operations became their primary focus, productivity increased radically.

Many reasonable tooling options were not implemented for deployment by DAWP because of a desire by management and operations staff to only use tools with which they were already familiar and comfortable. There was also concern that the operator control station, which was very much a traditional control-room-based approach, was too big, required too much power, and took too long to set up. A minimum facility burden focus was suggested for future implementations. Technology development staff came out of this experience understanding that a stronger emphasis should be placed on systems being as simple as possible to permit acceptance and use existing non-technically-oriented operations staff. Even though the DAWP technology solution presented to CP-5 was not considered to be a radical advancement, the level of technology used was still almost too far a leap for existing operations staff to make. In addition, programmatic emphasis shifted to near term deployments. These two items together pushed a corresponding shift to lower cost and more incremental solutions using modified commercial hardware where possible in order to get systems more rapidly into the field and to address the critical issues of user acceptance.

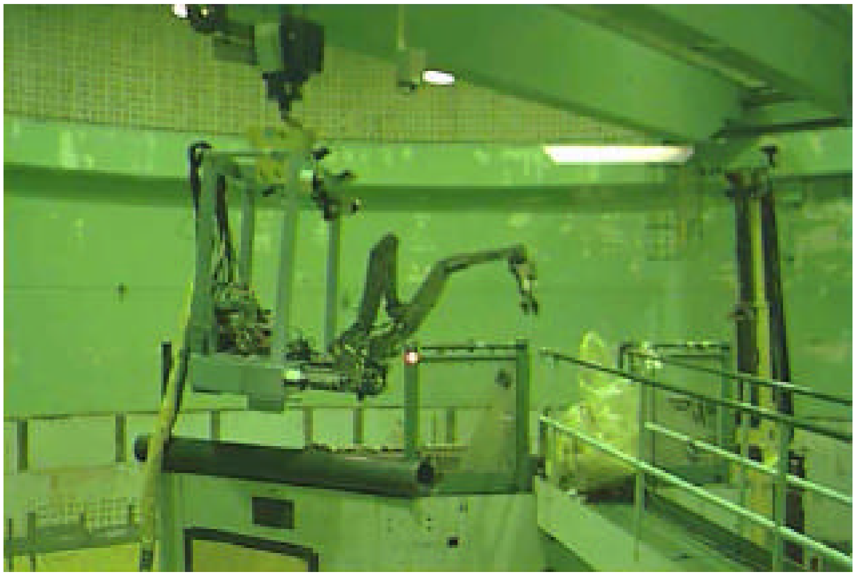

Fig. 1. DAWP suspended from CP-5 overhead crane.

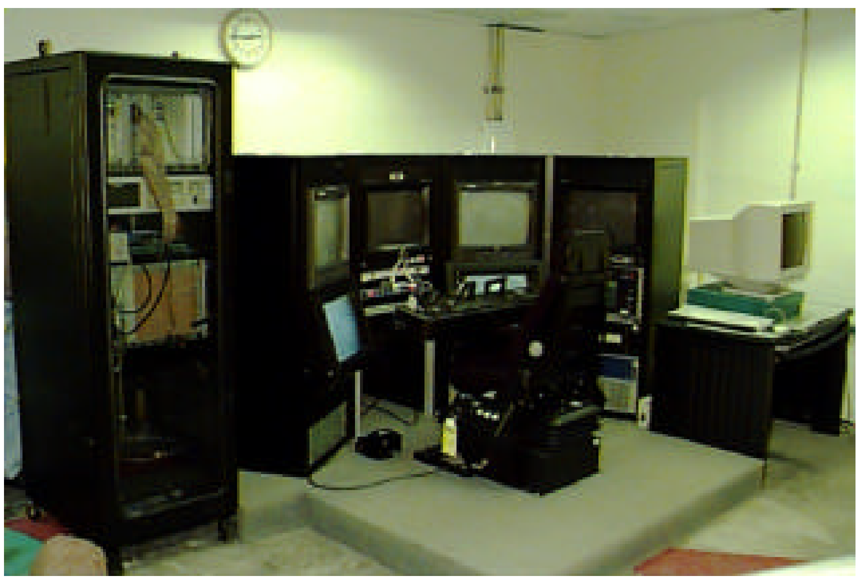

Fig. 2. DAWP operator control station.

CDI RCS Hanford

The CDI RCS started with a Remotec Andros and added facility and system support necessary to complete video and sampling inspections of tunnels at the U-plant facility on the Hanford reservation. The CDI was tasked with evaluating the feasibility of using the five processing canyons at Hanford as assets for disposal of low-level waste in order to eliminate an environmental restoration liability. The CDI RCS was key to the inspection process for the railroad and ventilation tunnels of those buildings to determine site suitability. A remote survey was required since the facility was categorized as having potential high radiation areas with airborne contamination.

The RCS, which is shown in Fig. 3, consisted of a Remotec Andros Mark VI™ with cameras and lights, modified by the Rbx staff to incorporate a gamma detector, a smear sample pad, and a deployment station, which was designed to manage deployment of the Andros hardware as it was lowered into the tunnels. The specific tasks for the Andros hardware included traversing the entire length of the tunnels to be inspected, collecting video footage, documenting the physical condition of the tunnel, collecting gross gamma readings during the entire survey, collecting limited smear samples, and returning safely for extraction from the tunnel. All objectives were met or exceeded. The Andros is shown in operation in Fig. 4.

Lessons learned were collected at the end of the campaign. Facilities and staffing issues were of notable concern. The Rbx staff assigned to operate the RCS did not have the specified training for “work” in the U building. (Research and development (R&D) staffs do not normally maintain Hazardous Waste Operations (HAZWOPER) and/or Radiation Worker training.) A special area was cleaned and posted to permit building access to the RCS operators for the duration of their operations. Priority issues with other activities on-site were difficult to resolve, and there was much lost time due to "suiting up" of personnel. While a few other hardware concerns were noted, one of the main issues identified with the hardware was that the chairs and operator interface, as they were set up, were cramped and tiring for the operators, even for the relatively short campaign.

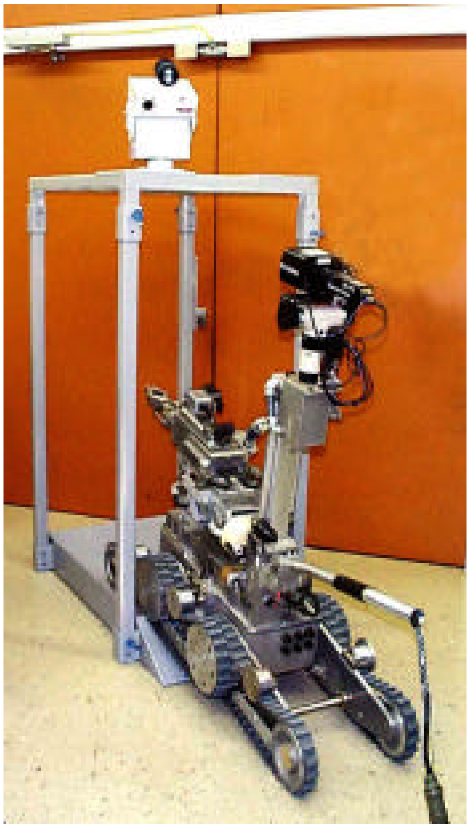

Fig. 3. Andros and deployment system for tunnel inspection.

Fig. 4. Andros deploying gamma sensors in the ventilation tunnel.

RUCS/INEEL

The RUCS, which is shown in Fig. 5, consisted of an Inukten Scallop™ underwater remote vehicle, which was modified by the Rbx staff to support inspection and radiation mapping of underwater fuel pools at the INEEL. RUCS added auto-depth control, vehicle orientation and depth monitoring at the operator control panel, and video and gamma documentation. INEEL worked closely with Inukten during the development process, and Inukten incorporated several of the modifications into its products.

Underwater inspection and characterization of water-cooled and moderated reactors and fuel storage pools have typically been done with underwater cameras and detectors attached to long poles. The purpose of RUCS was to demonstrate the benefits of using a small remotely operable submersible with an integrated detector—with ensuing reduced cost of operation, increased worker safety, and improved capability over the baseline approach. The RUCS deployment, which is illustrated by Fig. 6, occurred at the INEEL TRA-660 facility canal, which was originally built as a fuel storage canal but was later converted to house two test reactors.

The benefits of using RUCS included lower costs resulting from fewer operations staff suiting up and less personal protective equipment requiring disposal afterwards, faster deployment time than the camera on pole approach, significant improvement in maneuverability, good integration of the video and detector information, and access to areas with overhead obstacles, which made camera on pole deployment impossible. Cost reduction gained by using RUCS instead of the baseline approach was about 40%. The single advantage of using the camera on pole technique was that it was easier to drop down into small vertical spaces. RUCS was so well received by the operations personnel at INEEL that it was transferred to INEEL ownership for future use. Though RUCS was a relatively low-cost system, its impact was far greater as it opened the eyes of D&D and operations staff to the possibility that remote systems might yield significant advantages over existing techniques.

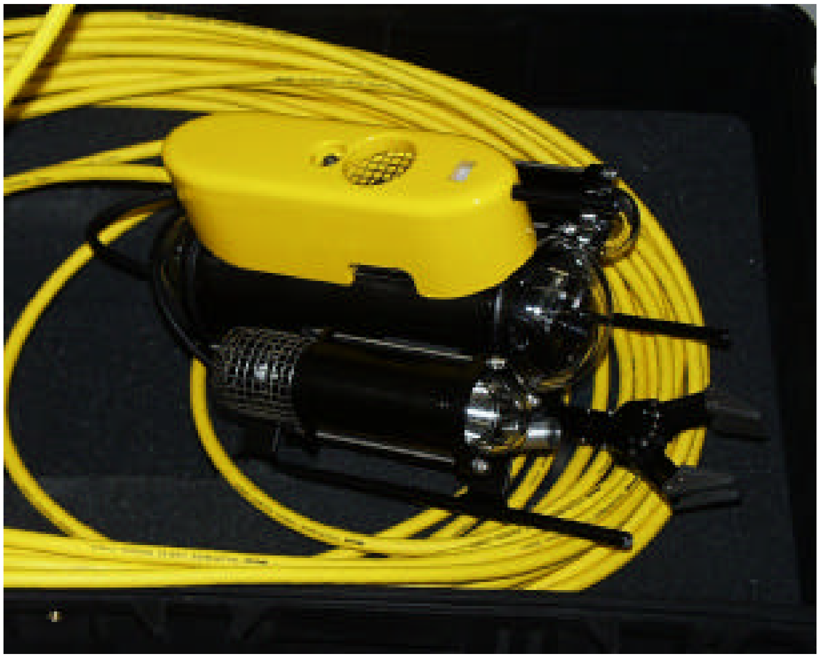

Fig. 5. RUCS with gripper and tether.

Fig. 6. RUCS deployed in a fuel pool at INEEL.

CRC/Modified Brokk Demolition Machine with Remote Console/ INEEL

The CRC, which is shown in Fig. 7, was specifically developed to answer issues from CP-5 management staff concerning the cost, size, power consumption, and set-up time of the operator control station, which was used for the DAWP. At the same time, the design was generalized to facilitate deployment of a wide variety of remote systems that would be used by the D&D community. While several robotic and/or remote systems have been identified for integration with the CRC, its first application was the control of the modified BROKK for dismantlement activities at INEEL. The combined system is identified as the Modified BROKK with Remote Console; however, the two technologies will be treated as separate here.

The purpose of the CRC is to provide remote viewing and viewing control, tooling and peripheral systems control, and, initially, a point of integration for master controllers used by existing remote systems. Ultimately, the CRC is intended to support full-integrated control of advanced telerobotics. The fundamental design approach to the CRC was to make careful compromises in the implementation such that cost could be decreased as much as possible while impacting human factors needs as little as possible. The design involved a major rethinking of standard engineering practices in operator control stations. By eliminating the use of 19-in rack mount video hardware and instead using an array of light crystal display video monitors, significant savings were achieved in station size and cost. Alternative viewing, such as head-mounted displays, was investigated but not used at this point because of concerns about the effects of long-term daily use. The minimal rack-mount, video control hardware was placed in the base of a control chair. The control chair-based approach is a major factor in encouraging long term use by operators. The video array is adjustable so that viewing distances, angles, and levels can be adjusted to prevent operator back and neck pain while maintaining optimum visual detail. Power supplies and control electronics are installed in the platform base on which the chair is mounted. A touch screen-based interface computer resides on a swing out arm on the right side. Communications via RS232 and RS485 serial protocols and ethernet are supported; to minimize cable length and size problems, the CRC Brokk used fiber optics for camera and peripheral systems control. The only difficulties encountered with the CRC have been those of mounting the diverse master controller hardware used by the differing remote systems that have been integrated to date. Initial versions that used a front-mounted arm have been replaced by a swing out side-mounted arm, which has worked well. The video array has required additional stiffening to prevent swaying resulting from operator motions. To date, copies of the CRC have been integrated to the Modified Brokk in use at INEEL and the dual arm Rosie-C mobile work vehicle at the Oak Ridge East Tennessee Technology Park (formerly the K-25 Site). Additional units are being fabricated to support control of the Telerobotic Small Emplacement Excavator with a manipulator end effector and as the interface for the Rbx dual arm telerobot platform for advanced telerobotics research and development. General user acceptance comments will be addressed in the next section on the Modified Brokk with remote console.

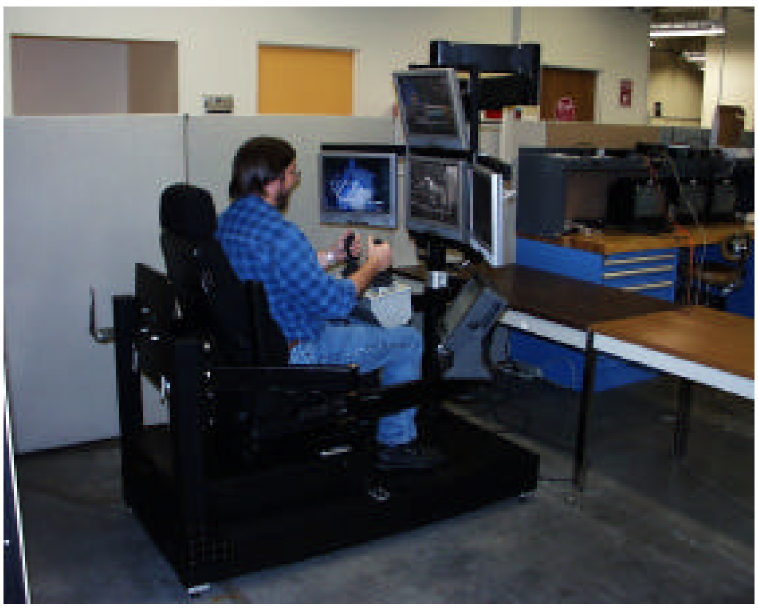

Fig. 7. CRC with Brokk master controller.

The Modified Brokk, which is shown in Fig. 8, is based on a Brokk BM 250™ Demolition Machine, which had already been procured by the INEEL Large Scale Demonstration and Deployment Project (LSDDP) and used in several demolition projects on-site. The normal Brokk operation mode requires that the operator be in fairly close proximity to the vehicle to observe and control all but gross positioning activities. This close proximity, line-of-sight operation would put the operator into the hazardous radiological environment for many D&D activities. The Modified Brokk provided a bolt-on retrofit package for stabilized remote cameras, camera positioning, facility camera, and system communications via fiber optic tether to the CRC, which provides the operator interface. The facility camera has the capability for either rf or tethered operation as does the commercial Brokk controller; however, rf use in and around buildings with steel and concrete and where line-of-sight operations cannot be guaranteed has repeatedly proven to be a bad practice. Therefore, the fiber optic tether was used for all control and video transmission.

The Modified Brokk Demolition Machine with Remote Console was deployed at the INEEL Security Training Facility (STF) in January 2000. The Brokk was already being used to remove, size-reduce, and stage overhead piping and facility equipment located in the STF basement. Initial operation had required that the operator stand next to the Brokk in seriously cold temperatures for extended periods of time. Rbx staff installed the bolt-on integration kit on the Brokk. The CRC was placed in a trailer and moved to the STF. User acceptance of the Modified Brokk/CRC was immediately quite high since it removed the operator from the inclement weather while providing nearly the same performance levels. The same level of performance would be expected in a radiological environment. Users requested audio feedback and joystick camera positioning in addition to the existing touch screen system; both of which were already planned as a fundamental part of the CRC. Site operations requested that they be permitted to keep the Modified Brokk/CRC for future demolition activities in radiological areas. The INEEL D&D staff's prior favorable experience with RUCS and on-going and direct day-to-day interaction with site D&D project personnel improved the probability of acceptance of the Modified Brokk/CRC. Small incremental steps towards a more progressive use of robotics and remote systems seems to have the best chance of success in real world D&D.

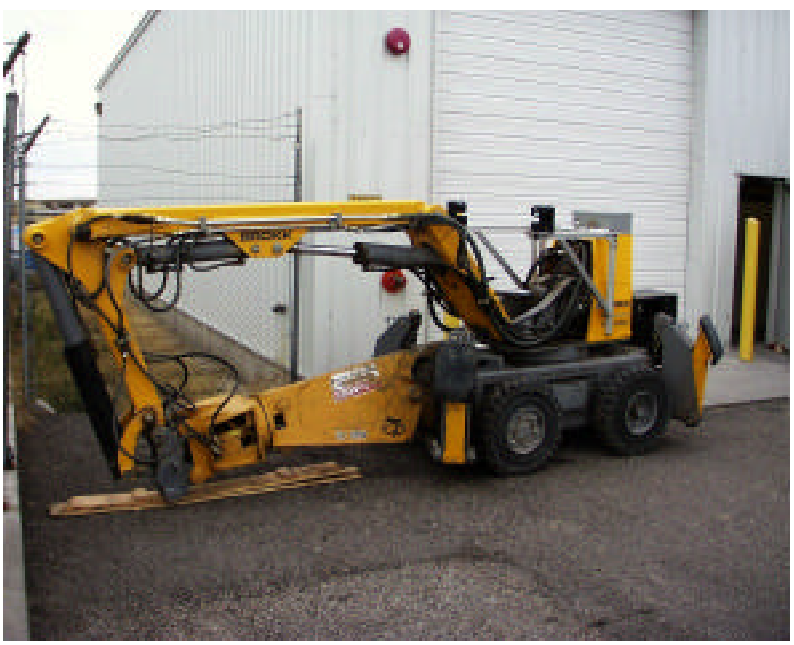

Fig. 8. Modified Brokk.

Conclusions

Several important lessons have been learned from these experiences which technology developers should be aware of for future deployments. Field projects are results-oriented and risk averse. New technology means increased risk. There is a high reliance on the use of existing baseline methods that are heavily biased toward manual methods even when those methods are unproven. Technology solutions tend to be unfamiliar and intimidating to both project management and the site D&D operations staff assigned to fieldwork; however, it is absolutely critical that field workers accept the technology in order for it to be effectively and successfully used. This means that the technology must be implemented in the context of the culture of the field workers and not that of the developers. This has proven to be difficult, and there is a wide gap between technology that is currently available and that is currently in use at DOE facilities. The tendency to introduce too much technology too quickly must be overcome and replaced by the careful incremental introduction of technology to the user community in conjunction with a long-term relationship with that user community. Successful incremental deployment of remote system technology is increasing acceptance of these systems as true benefits are realized in extended field operation. This will eventually facilitate the introduction of much more substantial robotic and remote systems into the user community.

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