COMPACT REMOTE OPERATOR CONSOLE
DEVELOPMENT, DEPLOYMENTS, AND TECHNOLOGY TRANSFER

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ABSTRACT

The compact remote operator console (CRC) was developed to facilitate the use of remote equipment in operations such as hazardous waste cleanup. It is portable and can replace larger, more expensive control rooms while maintaining nearly the same functionality and comfort. It has been used successfully several times within the Department of Energy to support remote system deployments. User acceptance has been high, and cost data indicate that the CRC is about an order of magnitude less expensive than a conventional control room. The CRC was commercialized in August 2001 and is now being produced by Agile Engineering of Knoxville, Tennessee. Two commercial units have been sold, and the design was recently enhanced.

I. INTRODUCTION

The compact remote operator console (CRC) was developed to fill a gap in operator stations for remote systems conducting hazardous waste cleanup. Typical operator stations are either large and expensive control room-based systems or small portable systems that ignore human factors design guidelines. In order to support long-term deactivation and decommissioning (D&D) operations, it is critical that operator stations become as cost effective as possible with minimal facility impact while maintaining a human factors-based focus to maximize operator effectiveness. The CRC, shown in Fig. 1, was developed by the EM-50 Robotics Crosscutting Program (Rbx) D&D Product Line to fill this gap. This paper outlines the development, deployments, commercialization, and plans for future expanded capabilities of the CRC.

Fig. 1. Compact remote operator console.

II. DEVELOPMENT

The CRC came about as a result of lessons learned in supplying the remote system for the D&D of the Chicago Pile No. 5 (CP-5) research reactor at Argonne National Laboratory [1]. Since long-term operations were anticipated, a control room approach was used for the operator control station. D&D operations management had several comments with respect to the control room approach. They requested lower cost, smaller equipment footprint, lower power consumption, and shorter setup time, all with, of course, little to no decrease in system capability. From a development perspective, it was also

necessary to package operator control stations for minimum project cost and shortest time to deliver for a field deployment so that more deployments could be completed in less time with less funding. The design of the compact console attempted to answer all of these concerns.

III. DEPLOYMENTS

The CRC provides a modular framework for remote viewing and operator interface that can be adapted or scaled to almost any remote system. To date, the CRC has been used to support four remote systems deployments in either the D&D or Tanks Focus Areas [2]. The CRC, integrated with a commercially available Brokk Demolition Machine, was initially deployed during D&D activities at the Idaho National Engineering and Environmental Laboratory (INEEL) Security Training Facility (STF) in January 2000 (see Fig. 2). Specifically, the Brokk, operated remotely from the CRC, was used to remove, size-reduce, and stage overhead piping and facility equipment located in the basement of the STF. Prior to the availability of the CRC, this work was done by the standard Brokk with the operator exposed to inclement weather and in close proximity to the demolition work and its associated hazards. The CRC was placed in a heated control trailer located approximately 600 feet from the demolition work site. The CRC was so well received by D&D operations that they requested that they be permitted to keep it for the duration of their campaign at the STF.

The second deployment of the CRC was in the summer/fall of 2000. Two dexterous Schilling hydraulic manipulators were mounted to the heavy manipulator of a RedZone Robotics, Inc., Rosie remote work vehicle for work at the K-1420 facility at the East Tennessee Technology Park (formerly the K-25 Site) in Oak Ridge, Tennessee. A CRC was added to the system for teleoperated control of the Schilling manipulators and remote tools (see Fig. 3).

In June 2001, a CRC was deployed for the third time to control a Brokk 330 at the F Reactor Fuel Storage Basin at Hanford (see Fig. 4).

Finally, Pacific Northwest National Laboratory performed cold test demonstrations of the Pit Viper remote system performing several debris removal and tool operation tasks in May 2001. Initial deployment of the Pit Viper system with a CRC providing teleoperated control of a Cybernetix hydraulic manipulator, occurred in December 2001 at the C-104 tank riser pit installation at the Hanford Site (see Fig. 5).

For each of these deployments, the capabilities and functionality of the CRC were scaled to meet the needs of the end user. The CRC used with the Modified Brokk integrated all camera control and video switching into the base of the CRC and provided a graphical user interface and joystick for camera and video switcher functions. Some customers preferred a stripped down version so that they could

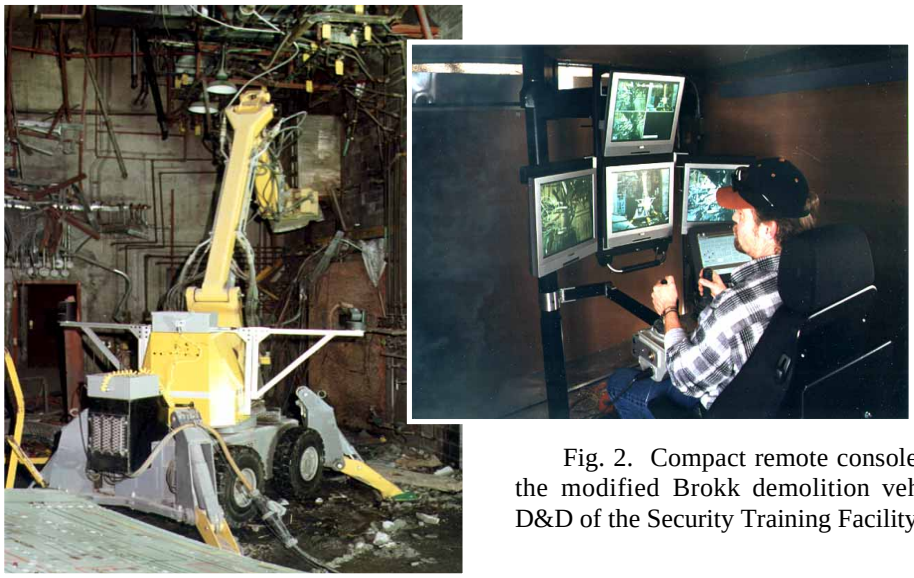

Fig. 2. Compact remote console controlling the modified Brokk demolition vehicle during D&D of the Security Training Facility at INEEL.

integrate their own site standardized camera control. In all of these early deployments, the commercial remote system's master controller was integrated into the CRC in a "drop in" fashion. A custom tray or holder was designed for each master controller box. The custom holder was then mounted to one of the two swing-out side arms available on the CRC. Tool control has generally been integrated in the form of foot switches, but some switches have also been mounted on the custom holder.

Another iteration of the CRC is being used to integrate and test capabilities generated by Deactivation and Decommissioning Focus Area (DDFA)-funded industry and university contracts. This CRC combines the human factors-based remote viewing and operator interface with advanced computer control of hydraulic manipulators to provide a consistent method of testing enhancements to teleoperation. Teleoperation is typically much slower than actual hands-on task execution. This inefficiency drives up the cost of remote D&D, preventing cost effective remediation. By combining automated task execution with teleoperation (telerobotics), task execution efficiencies can be improved, potentially to a cost-effective level. The CRC provides the platform upon which to implement these advanced computer controls technologies.

IV. TECHNOLOGY TRANSFER

The various research activities and field deployments of the CRC proved its merit and created a growing interest in the CRC as a product. After producing several CRCs, it became desirable to find an outside vendor for the CRC. Agile Engineering, Inc., of Knoxville, Tennessee, was selected to produce and sell the CRC commercially, and the existing design was transferred to them in August 2001. In December 2001 they shipped their first commercial unit, which was built to the original design. After building the first unit, Agile Engineering evaluated the design based on manufacturability and customer input. The console was then redesigned, enhancing the compactness and adaptability of the product, while preserving the functionality and basic form of the original design (see Fig. 6) The first redesigned unit was sold in April 2002 and shipped in May 2002. Agile Engineering expects to sell several more units in the next year. It should be noted that while the CRC has been redesigned, the new design is not static. Agile Engineering is able to adapt the CRC to meet any unique needs of the customer quickly. Agile Engineering is also considering designing a more compact, field-portable derivation of the CRC in the future.

Several aspects of the technology transfer of the CRC from the Department of Energy (DOE) to the private sector contributed to its success and should be highlighted. First, the original design, as transferred, was well conceived and substantially mature. The concept for the CRC came out of field deployment experience, and the design approach was adjusted and proven through field deployments. Second, the DOE technology developers were patient, active, and creative in seeking a commercial manufacturer. The CRC is a fairly specialized product that could not support a small company by itself, and probable sales volumes were low enough that larger companies would not have had much interest. Finding a small engineering/ manufacturing company was a good fit for both parties. It gave Agile Engineering a product that had some visibility, could be enhanced over time, and could generate ongoing revenue. At the same time, it gave DOE a successful technology transfer and a commercial source for the technology. Third, and finally, the technology developers have been a supportive resource throughout the process of producing the first commercial CRC and its redesign. This has been invaluable because Agile Engineering had limited expertise in remote operations and human factors, and had not participated in the original design development. If the design had been simply "thrown over the wall," it is unlikely that the technology transfer would have worked so well.

V. RESULTS

In all deployment cases, the CRC functioned as designed. Each CRC is customized to some extent, making cost savings difficult to generalize, but the best estimate shows that use of the CRC, even with customization, is about an order of magnitude cheaper than a small-scale control room installation. An additional interesting benefit of its use has been that operators actually enjoy using it. They are willing to stay on the job longer than with typical remote systems, their breaks are shorter and less frequent, and the operators have been reported to be more enthusiastic about their work.

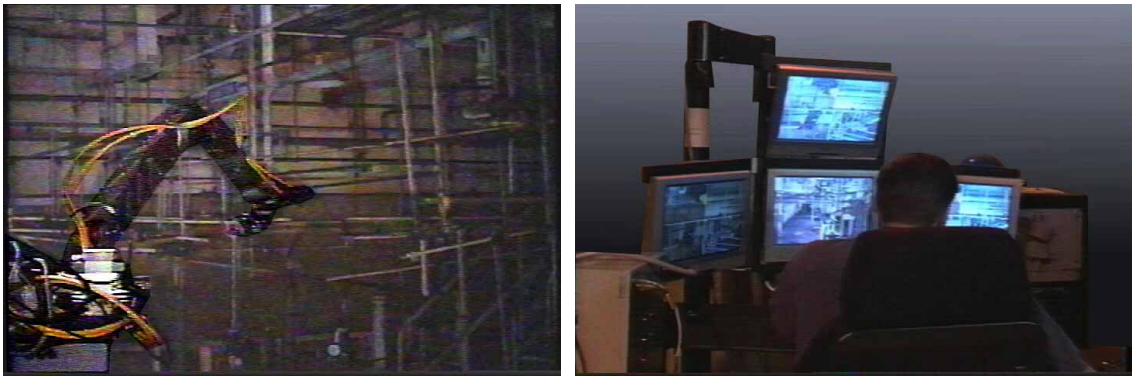

Fig. 3. Compact remote console controlling dexterous hydraulic manipulator at the ETTP in Oak Ridge.

Fig. 4. Compact remote console controlling Brokk 330 at F Reactor Fuel Storage Basin at Hanford.

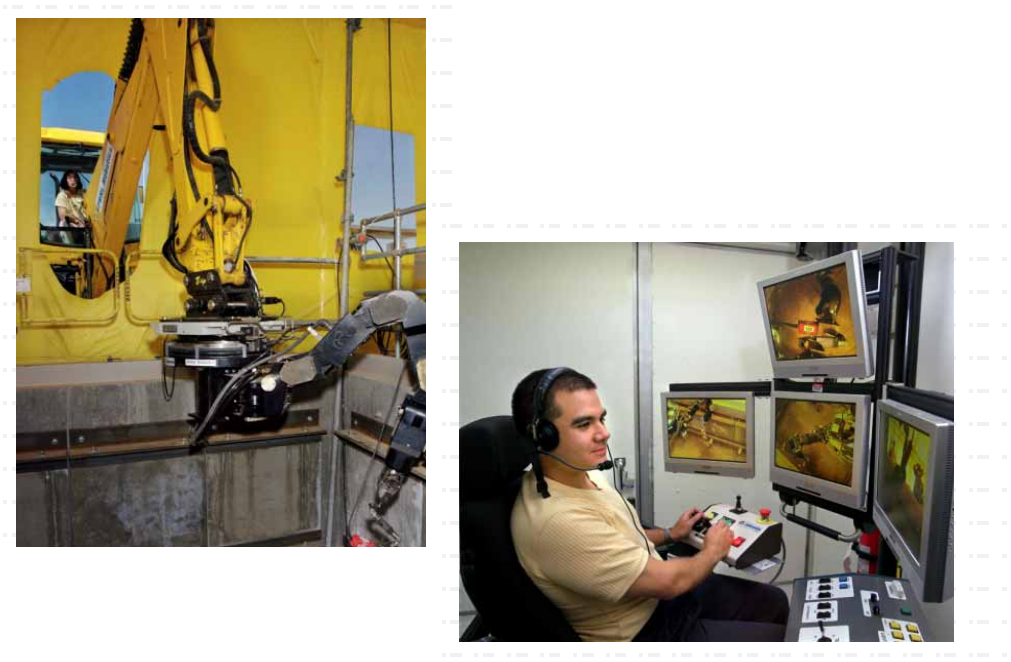

Fig. 5. Compact remote console controlling the Pit Viper hydraulic manipulator at Hanford.

Fig. 6. Redesigned commercially available version of the compact remote console.

VI. CONCLUSION

The modular functionality of the CRC permits faster and cheaper deployment of remote systems while maintaining a human factors-based focus. All of these benefits have been achieved with little or no impact on capability, even when compared to a typical control room installation. User acceptance to date has been high, and comments have been favorable. Enough units were deployed in the field to warrant commercialization, a private company was selected, and the first commercial units have now been shipped. Since remote systems are still inefficient when compared to hands-on task execution, further work is being pursued in telerobotic controls to make remote systems more capable, efficient, and cost-effective.

REFERENCES

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2. Department of Energy, EM-50 CRC Fact Sheet, http://www.robotics.ost.doe.gov/reports/dd_crc_fact_.pdf