PIONEER ROBOT TESTING PROGRAM AND STATUS

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ABSTRACT

The U.S. Department of Energy (USDOE) and Ukraine established a joint program in 1997 to address the need for remotely operated systems for unstructured environments in Ukraine such as the highly hazardous conditions inside the failed Chornobyl Nuclear Power Plant (ChNPP) Unit 4, or Shelter Object. The environment inside Shelter Object is extremely hazardous due to ionizing radiation fields, high airborne contamination, and major industrial safety issues. Although Ukrainian workers have explored and mapped much of the internals of Unit 4 in the time since the accident during the morning hours of April 26, 1986, there remain areas where humans have not entered to this date. Based on the agreement between USDOE and Ukraine, the USDOE, in cooperation with the U.S. National Aeronautics and Space Administration (NASA), developed the Pioneer Robot and has provided it to the ChNPP within the framework of international technical assistance. Pioneer is capable of mobile platform movement and manipulation under teleoperated control, 3-dimensional mapping, and environmental data collection. The Pioneer is radiation hardened for conditions like those of Shelter Object. Pioneer has been evaluated on site in Ukraine for use in both the Shelter Object environment and the more general conditions of ChNPP decommissioning. This paper summarizes the results of these testing activities and describes the status and near-term activities in support of the Pioneer Robot integration into Ukraine.

1. INTRODUCTION

The U.S. Department of Energy (USDOE) and Ukraine established a joint program in 1997 to address the need for remotely operated systems for unstructured environments in Ukraine such as the highly hazardous conditions inside the failed Chornobyl Nuclear Power Plant (ChNPP) Unit 4, or Shelter Object. The environment inside Shelter Object is extremely hazardous due to ionizing radiation fields, high airborne contamination, and major industrial safety issues. Although Ukrainian workers have explored and mapped much of the internals

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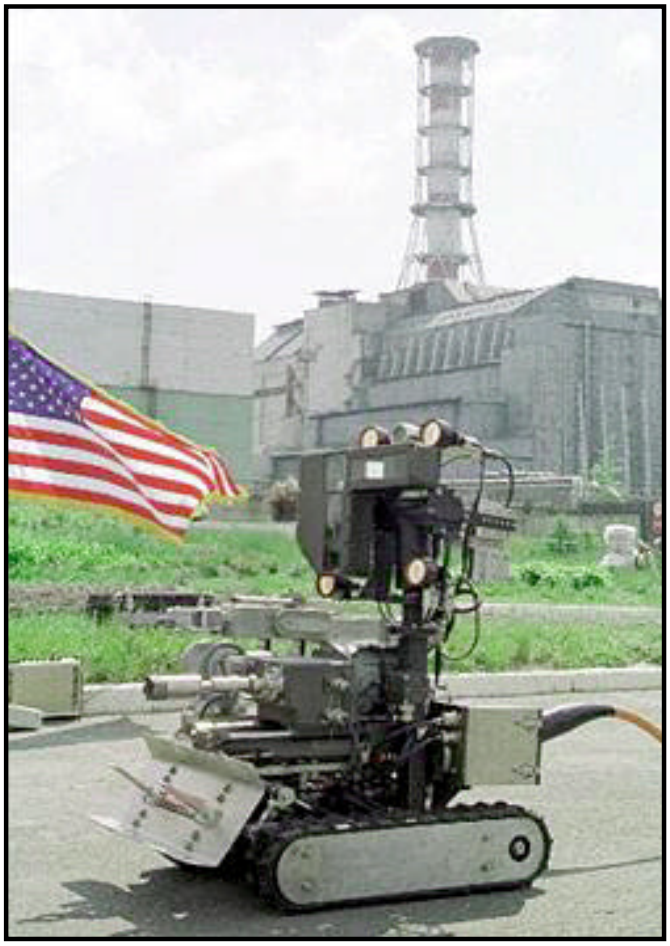

Figure 1. Pioneer Robot at ChNPP Shelter Object

The Pioneer Robot system was shipped to Ukraine in December 1998 and delivered to the ChNPP. A series of training and evaluation programs have been conducted to provide qualified operations crews for Pioneer and to demonstrate its capabilities in typical envisioned missions. Pioneer during operation at Shelter Object is shown in Figure 1. The following sections describe these training and evaluation programs.

2. PIONEER DESIGN AND CAPABILITIES

Pioneer was developed in a cooperative program by the USDOE and NASA to provide inspection and remote operations capabilities in unstructured, high-radiation environments. In addition, specific capabilities were provided to allow for successful operation in the highly access constrained and rubblized environment of Shelter Object. The missions were to 1) assess Shelter Object structural integrity through dimensional and physical inspection, 2) gather environmental data for the conditions inside Shelter Object using onboard sensing, and 3) support unstructured remote work tasks with manipulation and rad-hardened television. Pioneer incorporates a highly reliable mobility platform and onboard manipulator that operate under full teleoperation

control.[1] Communications and power are delivered to the platform through a tether system. The design is modular for ease of manual transport and maintenance. Radiation hardening has been incorporated in the platform design and demonstrated by irradiation testing to the design levels of 3,500 rads per hour gamma, and neutron fields up to 1400 neutrons per square centimeter-second. These hardening levels represent the requirements established by the Shelter Object.[1] The control console for Pioneer has been designed to provide teleoperation control for the platform, manipulation, and all of the additional mission packages onboard the platform. The control console can be located at a distance up to 500 meters from the platform, providing highly flexible arrangements for radiation exposure reduction to the operation staff.

Two major additional mission packages have been provided by the NASA part of the development team for use on Pioneer. A 3-dimensional mapping system[2] using radiation-hardened trinocular stereo vision, based on NASA Pathfinder and Carnegie-Mellon University (CMU) Artisan technologies, provides mapping capabilities for architectural and debris pile measurements and mapping, previewing of past data for future mission planning, and databasing of collected environmental data in 3-dimensional maps of the environment. A concrete sampling drill, based on NASA small body exploration and CMU technologies for Three Mile Island, provides the ability to acquire concrete samples to evaluate concrete embrittlement, stresses, and degradation.[1]

3. INITIAL TESTING AT ChNPP SHELTER OBJECT

During the spring and summer of 1999, USDOE and Oak Ridge National Laboratory collaborated with ChNPP Shelter Object to execute a series of Cold Tests and Demonstrations of the Pioneer system. These tests were conducted in a non-radiation area and included simulated operations typical of those encountered in the unstructured environments of the Shelter. During this program, operations specialists from Shelter Object and the Interbranch Scientific and Technical Center “Shelter” were trained by the USDOE and NASA Team. Topics for the training included 1) overall Pioneer theory of design and operation, 2) unpacking, transport, and assembly in operational environments, 3) component and system level operations and maintenance of all subsystems, and 4) full system operations in cold demonstration tasks simulating mission conditions encountered in Shelter Object. Phases of the training and testing are shown in Figure 2.

The Ukrainian specialists became skilled Pioneer operators while performing these cold demonstrations of Shelter Object-like remote tasks, and became fully competent at operating and maintaining Pioneer. In addition, the Ukrainian team identified both Pioneer modifications and infrastructure provisions for operation inside Shelter Object. This Cold Testing program identified both the path forward and the potential challenges for future robotic and remote system operations inside Shelter Object.

Figure 2. Pioneer Training and Testing at ChNPP Shelter Object

4. PIONEER TESTING AT THE ChNPP EMERGENCY MANAGEMENT CENTER

The year 2000 was a year of major transition for the ChNPP staff and the Ukrainian town of Slavutych, as Ukrainian President Leonid Kuchma announced that ChNPP Unit 3 would cease operation on December 15, 2000, ceasing all power generation at the ChNPP site. Further he announced that the ChNPP would proceed into a decommissioning phase for the entire plant. At the request of the ChNPP General Director, the Pioneer Robot was transferred from USDOE ownership to Ukrainian/ChNPP ownership during the summer and fall of 2000. This transition to ChNPP ownership allowed for a broadening of the missions for Pioneer into ChNPP activities related to ChNPP decommissioning and emergency response to unplanned events, as well as in Shelter Object.

The present near-term focus for Pioneer is to support the ChNPP decommissioning as the highest priority. It is expected that it will take five to seven years to remove all of the fuel from the three onsite reactors as the first phase of decommissioning. During the fuel unloading of these RBMK reactors there is high probability for highly activated graphite rings, fuel assembly fragments, and control rod pieces to fall to areas where retrieval is required. These items are highly activated and must be removed remotely. Pioneer is being prepared to accomplish this task. Additionally, remote cutting tooling for use with Pioneer is a high priority.

Pioneer has now been moved and stationed at the ChNPP Emergency Management Center under the management of the Slavutych Laboratory for International Research and Technology (SLIRT) as shown in Figures 3 and 4. Translation, technical review, and completion of all required operational and maintenance documentation for operation in Ukraine have been completed. Final operational and maintenance training was completed with ChNPP and SLIRT staff participation, resulting in a trained operation crew which provides resident operations capabilities for Pioneer to support decommissioning and emergency response. The high priority tasks described above can be accomplished with Pioneer, and modifications to allow rapid response to emergency conditions across Ukraine are under evaluation.

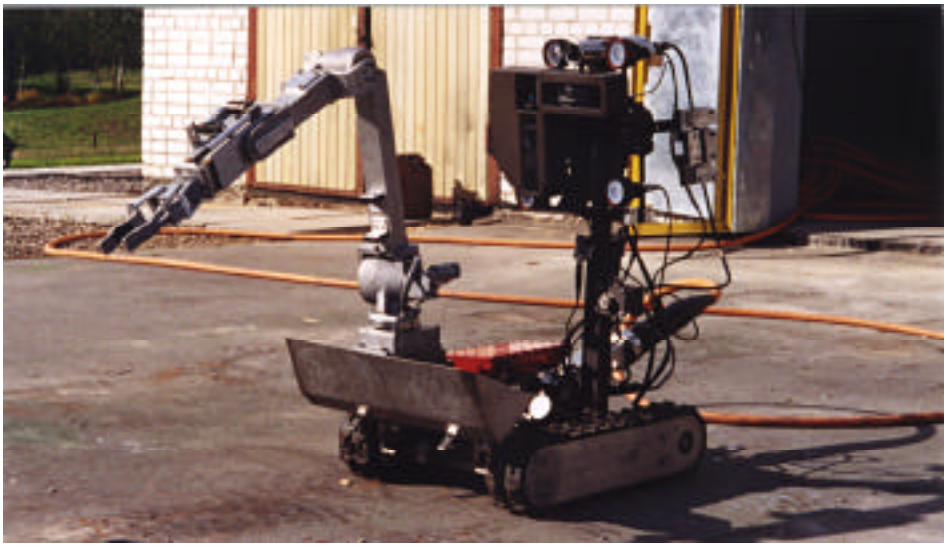

Figure 3. Pioneer Operation at the ChNPP Emergency Management Center

Figure 4. Pioneer Control Console during Remote Operations testing at the ChNPP Emergency Management Center

5. CONCLUSIONS

The USDOE and NASA team, in collaboration with Ukraine, have produced and fielded a highly capable remote operations platform, and Ukraine now has full capabilities for operation and maintenance of this system. Pioneer is providing a new capability for remote operations in hazardous environments for the ChNPP/Slavutych area, which will be applied to ChNPP decommissioning and emergency response tasks. Ukrainian personnel, through the work with Pioneer at the ChNPP Emergency Management Center, have become highly competent remote systems operators in a short period of time. It is expected that Pioneer will provide major benefits in radiation exposure reduction during the ChNPP decommissioning phase over the next decade.

6. REFERENCES

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2. M. Maimone et al., "A Photo-Realistic 3-D Mapping System for Extreme Nuclear Environments: Chornobyl," Proceedings of the IEEE/RSJ International Conference on Intelligent Robotic Systems, 1998.