# ROBOTIC SYSTEM USED FOR HOT CELL DISMANTLEMENT

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## ABSTRACT

During the dismantlement of the Hot Cell #4 process system at the Quehanna Hot Cell Facility, extremely hazardous conditions were identified. These conditions precluded human entry into the hot cell for dismantlement work. After evaluating potential alternatives, the decision was reached to use a remote-controlled, robotic system (robot) to conduct the dismantlement tasks. The robot base and arm were commercially available and were integrated with special tooling, which was designed specifically for this task. These included tools for surveying, crimping, cutting, grinding, and component removal.

The robot was integrated with an engineered containment system, air handling system, air monitoring system, fire suppression system, waste handling system, and supporting administrative control processes. These support systems were necessary to prevent migration of the volatile, highly radioactive material. The triple-chambered, double wall containment was specifically designed to facilitate deployment, operations, and maintenance of the dismantlement robot and to transfer waste materials. Hot Cell #3, which was previously remediated, was used to receive the dismantled waste from the high-hazard Hot Cell #4 Process System. Alarming constant air monitors were established throughout the containment system to provide an early indication of radioactive material migration.

Although the robot system was effective in conducting its many tasks and saved over a person-sievert (100 person-rem) of deep dose, there were many problems that had to be resolved. These included developing the skills to operate, maintain and repair the robot; long lead time for replacement parts; and, design attributes that were not well suited to this particular application. The lessons learned from deployment of this system should be useful to those considering the use of similar robotic systems.

## INTRODUCTION

The Quehanna facility was originally a site for development of a nuclear jet engine, as well as production of Sr-90 thermoelectric generators used in marine buoys. It is located in the middle of the Quehanna Wild Area, a remote protected elk preserve in the Moshannon State Forest in central Pennsylvania. Beginning in the summer of 1962, Martin-Marietta used Sr-90 in the Quehanna Facility hot cells to manufacture several prototype thermoelectric generators known as SNAP-7 generators. SNAP is an acronym for Systems for Nuclear Auxiliary Power. The power source for the generators was very high specific activity Sr-90 in the form of strontium titanate. The generators were powered by the decay energy of Sr-90 and were to be used as the power source for ocean buoys and remote weather stations. The Martin-Marietta license allowed for the possession of strontium in the range of petabequerels (megacuries).

Although the Quehanna Hot Cell Complex (Figure 1) contained six hot cells that were used for a variety of radiological operations, Cell 4 was the most hazardous. In Cell 4 during operations, the soluble strontium carbonate was converted to the insoluble strontium titanate in the Cell 4 process system. The process system included two stainless steel working "boxes" that were accessed with manipulator arms from the cell face area. The space behind the process boxes was filled with a nest of tubing, ventilation system, a heavy shield wall, and two tanks. Initial manned entries into the process boxes indicated unsealed residual Sr-90 with radiation levels of up to 400 gray/hr (40,000 rad/hr). These extremely high radiation levels and very high airborne contamination levels precluded the use of standard dismantling techniques.

**Fig. 1. Cell Operations Area at Quehanna (circa 1965)**

## REMOTE DISMANTLEMENT SYSTEM SELECTION

Several alternatives to process system dismantlement were considered. These included wire-cutting the entire hot cell and removing it as a single unit. In addition, consideration was given to using long-handled tools to dismantle the system underwater after the hot cell was sealed and flooded. Ultimately, robotic dismantlement was chosen as the most viable approach. The robot system used was a combination of commercially available components and custom made end-effectors (Figure 2). The base of the selected robot configuration was a Houdini, hydraulically operated, parallel track system with a footprint of 81 cm by 97 cm. The parallel track base was outfitted with an off-the-shelf Kraft robotic arm called Predator. The arm, which had 6-degrees of freedom, was capable of lifting 90 kg and could apply 136 Nm of torque. The gripping device on the end of the arm also had a force-feedback system that would allow the movement of objects without damaging them or causing undue strain on the gripper system. The robotic system was controlled and operated from a control room established in the Hot Cell Service Area approximately 30 m from Cell #4.


**Fig. 2. The Quehanna Robot**

Custom end-effectors were developed for the Kraft arm for the process system dismantlement. They included four types of grinders, a tube crimper, a tube cutter, a radiation probe housing, a tank-grabbing device, a nibbler, and a sheet metal cutter. During the dismantlement process, some of the tools worked very well while others were problematic. The grinders worked well but the robot arm could not negotiate non-linear travel with the nibbler. The entire robotic system and its support tools were field tested in a mock-up of Cell 4 prior to its deployment. This mock-up testing proved to be invaluable for testing and refining the robot and its tooling and for training robot operators.

## SUPPORT SYSTEMS

The robot was capable of conducting the necessary tasks in Hot Cell #4. During operation and maintenance procedures, however, incredible amounts of radioactive airborne material and surface contamination were generated. This material had to be contained. This was done primarily through the design and installation of a triple-chamber, double wall containment system (See Figure 3). The containment allowed for access and egress of personnel and the robot; however, by design, the robot only made a single trip into the containment.

**Fig. 3. Installation of the Primary Containment**

The containment was an effective contamination barrier and was assisted by the air handling system. The air handling system was joined to the original Hot Cell #4 ventilation ducting. This allowed clean air to be pulled away from the opening of the Hot Cell, which was a ceiling access opening. Air was subjected to two high-efficiency, particulate air (HEPA) units in series, stage 1 and stage 2. Stage 1 also had a redundant HEPA unit. Electrical power to the HEPA units was also redundant.

The containment system also included four air-monitoring stations that would provide a near-immediate indication of contamination migration. Besides housing the two openings to Hot Cell #4, the containment system also included the opening to Hot Cell #3. This hot cell, which was previously remediated, provided an effective station to accept highly radioactive components that were segmented by the robot for monitoring and packaging. Hot Cell #4 was also equipped with a remote- or locally-activated fire suppression system.

## ROBOTIC SYSTEM PERFORMANCE

Overall, the reliability of the system was deemed poor, especially during initial testing phases where the robot system was down approximately 70% of the time. Once deployed into the hot cell, down time was reduced to about 30%. There were many mechanical and some limited electrical problems.

The suppliers of the robotic system’s parts were not set up to provide technical services. In addition, information provided with the system components was limited and sometimes outdated or inaccurate. As a result, the problems that appeared during testing and in-cell use had to be resolved internally by technicians and engineers who had previously had little or no experience with robotic and control systems. While painstakingly resolving robot system problems, these technicians and engineers developed a broad understanding of the robot’s systems, becoming indisputable experts out of necessity.

Although most of the robot’s problems were resolved relatively quickly, one particular, intermittent electronic glitch proved more difficult to resolve. A seasoned electrical engineer from an internal division was deployed to help resolve the issue. He determined that a twisted-pair cable was improperly shielded (electronically) causing miscues within the control system’s commands.

The lead-time needed for replacement of many of the system’s unique parts was a large contributor to the unit’s downtime. In addition, once the robot system was contaminated, repairs were difficult on small parts since the maintenance technicians had to work with respiratory protection and with several pairs of protective gloves. A design flaw unnecessarily placed many of the system components on the working frame of the robot. In retrospect, many of these components could have been placed in the control area or outside of the hot cell, which would have made their repair and maintenance extremely easy.

## LESSONS LEARNED

The overarching theme stemming from use of the robotic system in the Quehanna Hot Cell System dismantlement was the need for simplicity. For example, the complex binocular vision purchased as an option with the robotic system turned out to be unreliable. In addition, the special binocular goggles had to be taken off to view other cameras. Relatively inexpensive, commonly available cameras were quickly used to replace this viewing system.

Movement of the robot within the Hot Cell proved to be difficult. The hydraulically operated tracks had no method to adjust the track speed. As a result, a small repositioning required a series of short, jerky movements, which were difficult to control.

The arm’s force feedback system turned out to be very useful. This feature allowed multiple settings of force feedback to the operator’s hand and arm. As a result, the arm and its claw could be effective for lighter, delicate tasks such as survey work but could also be effective for heavier tasks such as pulling back metal panels. Although the arm was rated for 90 kg, this was only possible under optimum conditions. The arm was better suited for effectively using tooling with weights no more than about 23 kg.

## SUMMARY

The lessons learned during the robotic dismantlement of the Hot Cell System showed that selection of the simplest system is the most prudent. In addition, a designed robotic system should be, to the extent possible, built with readily available, off-the-shelf parts. Potential owners of a robotic system should have or be prepared to develop in-house expertise to address problems that will undoubtedly arise. In addition, consideration should be given to developing a robotic system from the ground up using readily available components that can be used as-is or modified based on the specific needs of the project.

Despite the problems encountered, the robotic system proved invaluable in the work at Quehanna. The dismantlement evolutions could not have been done manually due to the prohibitively high dose rates and airborne concentrations. A dosimeter mounted on the robot, which was corrected for non-working time, estimated a total avoided dose of 1.1 person-sievert (110 person-rem) of deep dose. The robotic system provided an essential barrier between decommissioning personnel and extreme radiological hazards present within the hot cell.

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In memoriam – During the course of the Quehanna Project, SCIENTECH lost its primary designer and builder of the robotic tooling and support systems. Bob Gilbert, who was an incredibly skilled engineer and friend to all he knew, passed away on January 13, 2004.

**Bob Gilbert**