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Robots Working with Hazardous Materials

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While many research and development activities take place at Sandia National Laboratories' Intelligent Systems and Robotics Center (ISRC), where the "rubber meets the road" is in the ISRC's delivered systems. The ISRC has delivered several systems over the last few years that handle hazardous materials on a daily basis, and allow human workers to move to a safer, supervisory role than the "hands-on" operations that they used to perform.

Sandia has delivered 3 systems to the Mason & Hanger Pantex Plant in Amarillo, Texas, for various operations handling radioactive parts from disassembled, retired nuclear weapons. Pantex is the part of the Department of Energy's Nuclear Weapons Complex where all the U.S.'s nuclear weapons were assembled, and for several years now have been taken apart. The first system that was delivered was the Stage Right system, which handles pallets of containers of "pits", the radioactive core of the nuclear weapons. Since the number of dismantled nuclear weapons has increased since the end of the Cold War, Pantex needed to fit more containers of pits into a limited amount of space. They solved this problem by stacking the drums on their sides in pallets of 4 or 6 (see Figure 1) instead of vertically on the ground. This allowed significantly more containers to fit in the available space, but because the density of the containers increased, the radiation dose in the storage magazine also increased. This means that it was preferable to have an unmanned AGV, Automated Guided Vehicle, carry the drums into and out of the magazines and perform surveillance and inventory operations with sensors on the AGV, rather than have people drive a forklift, or manually carry instruments into the magazine to perform these same tasks. Now these operations are performed by the operator sitting in a small trailer on the road next to the magazine. He or she sits in front of a computer interface that mimics the layout of the magazine's storage array and allows him/her to place or remove pallets of containers and perform appropriate inventory operations. This system has been in operation since June 1996.

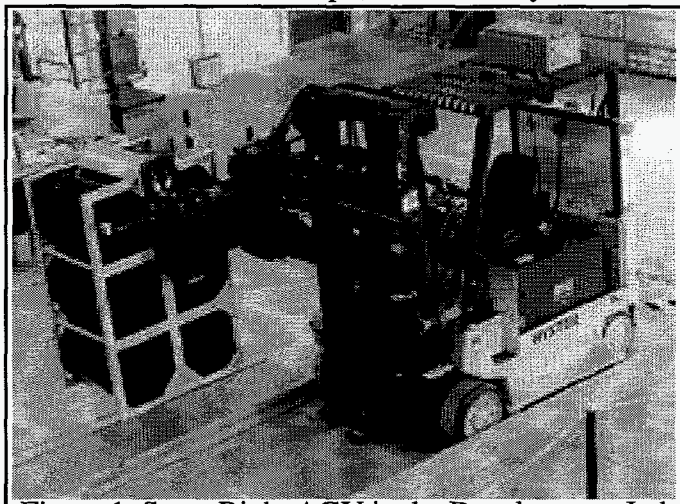

Figure 1: Stage Right AGV in the Development Lab

The second system delivered to Pantex was a system to robotically disassemble gas generators. Gas Generators (see Figure 2) are components used in nuclear weapons to produce gas to open a parachute on a certain class of weapons. The generators are about the size of a beer can and have several components that need to be unscrewed from the casing, including the igniter, which is sensitive (see Figure 3). Once the disassembly is far enough along, the propellant can be poured out into a separate container for further processing specifically designed for explosive powder. The propellant and the igniter in the generators are old enough to potentially be unstable. So there is a possibility that it could blow up in a worker's hand if manually disassembled; thus, an automated process that allows the operator to supervise the system

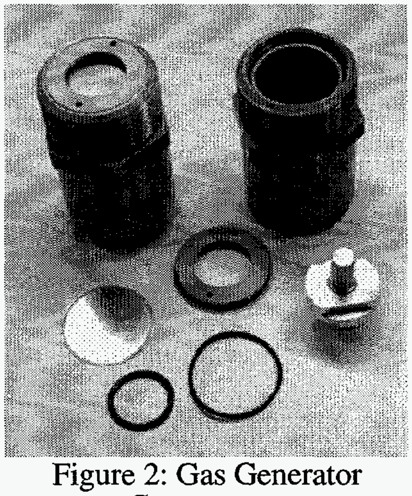

Figure 2: Gas Generator Components

from behind an explosion-proof wall was preferred to a manual disassembly process. This system has been in operation since April 1997 and has disassembled about 1800 generators.

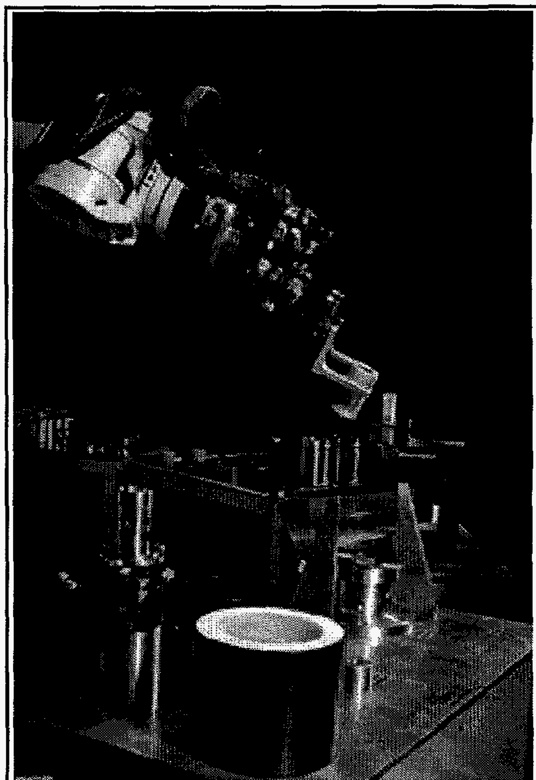

Figure 3: Automated Gas Generator Disassembly System

A third system has been delivered to Pantex for handling of and surveillance confirmation measurements on the pits - it is called the Weigh and Leak Check System, or WALS. WALS (see Figure 4) takes a pit from the same containers that are stored by the Stage Right system, takes the pit to several weigh and leak check operations, records the results of those operations, and repacks the pit into an appropriate container -- many times the same type as the container from which it came -- to return it to staging in the magazines. Again the idea here is to have the operator involved within viewing distance of the robotic system at an operator control console. The amount of radiation in processing one pit is not very high, but in this operation it is the accumulation of exposure to radioactive components over time that restricts the time that a person could do this hands-on. With the robot performing the hands-on tasks, the operator is far enough away to receive extremely low radiation exposure and can perform this much longer than he/she would be able to hands-on. This system is unusual compared to typical industrial uses of robots in that the robot performs operations at many stations in a single workcell with several specialized grippers and tooling stations. This differs from more typical industrial operations -- for example, a robot performs a number of weld operations on a car body before the car moves to another robot to continue with different weld locations. The WALS system is in operational readiness reviews and is not yet operational.

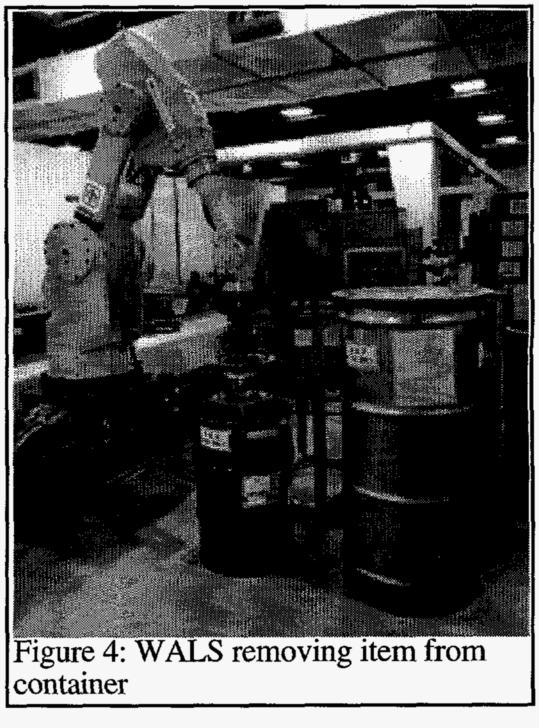

Figure 4: WALS removing item from container

In creating these systems, Sandia typically purchases as many off-the-shelf components as possible, such as the robot and the supervisory computer. The engineers then design, fabricate and test hardware; design, write and test software; integrate the whole system together, document and test it; and finally, deliver and work with the receiving site to install the system. A significant development effort has also been necessary in these systems to develop a safety theme [1]. This theme guided us in designing features into the system hardware and software to fail-proof them in case of unusual, but possible, circumstances, such as loss of electricity or house air pressure. The ISRC's experience in developing these safety features and theme made developing the following system much quicker and easier.

The experience gained on the gas generator system led to working with conventional munitions. Hundreds of thousands of munitions remain from as far back as WWII, and like the gas generators, they have unstable explosive materials in them and they need to be dismantled. Again,

moving the operator away from hands-on performance of these operations can reduce the risk of his/her being in an accidental explosion during dismantlement. This year, a workcell was developed to determine the technologies that are required to disassemble fixed round munitions. Fixed round munitions range from 20mm diameter to 105mm diameter rounds, all having a cartridge case, percussion primer, propellant, and a projectile -- the prototype system developed for the McAlester Army Ammunition Plant will dismantle 40mm rounds.

On these specific 40mm rounds, the projectile has an impact fuse, a center section containing high explosive (HE) and an incendiary, and the tail has a tracer compound. Sixteen rounds come four to a clip inside of a container. While currently we are using pick and place operations, advanced vision and force control technologies will be added to locate and remove the projectiles from the container more adaptively. The first clip of rounds is removed from the container and the 4 rounds are separated. Various operations are performed on each round to disassemble it. The robot separates and sorts the parts of the projectile and the cartridge case; at some points in the disassembly the robot leaves the parts at specialized tooling stations to perform the disassembly operations. The operations at these stations include a 3500 lbf pull-apart operation, waterjet cutting of the projectile, and heating and pressing to remove the HE. By the end of the operations, all explosive and mechanical parts have been separated into individual processing streams for all the rounds in all the clips. The first prototype system has been delivered and demonstrated at McAlester, and additional development begins in Fall 1998.

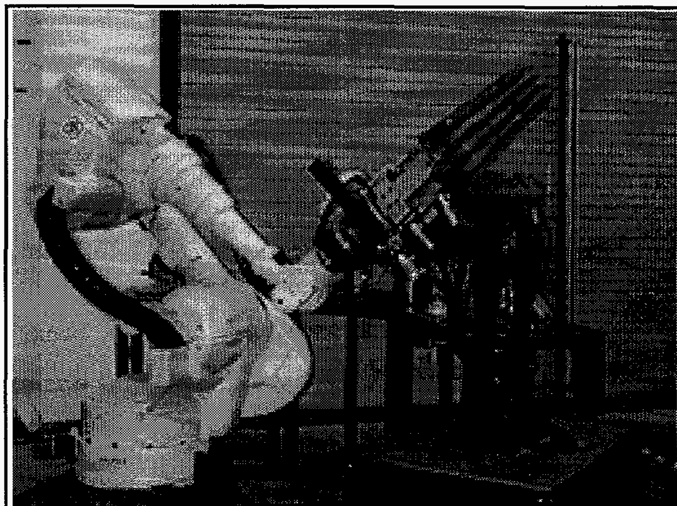

Figure 5: 40mm round system, showing the robot holding a clip of rounds

While all the systems described so far have used robots mounted on the floor indoors, the ISRC also develops mobile systems, including a system for use in hazardous operations at a (nuclear) accident site. The Accident Response Mobile Manipulator System (ARMMS) is a remote-controlled robot vehicle that allows an operator to remotely assess an accident site and manipulate items there if necessary. Rather than send out a team of people in Nuclear/Biological/Chemical (NBC) suits to the accident site, it is desirable to use a remote-controlled vehicle to assess the situation and neutralize any obvious safety threats. ARMMS is compact, self-sufficient robotic system based on a military High Mobility Multi-purpose Wheeled Vehicle (HMMWV, pronounced "humvee"). It is equipped with a pair of hydraulically powered manipulator arms, three video cameras, a high-bandwidth fiber optic system, and a portable operations shelter with electric generator and environmental control (heating, ventilation, and air conditioning). The operator manually drives the ARMMS vehicle to a location near the

Figure 6: ARMMS vehicle in field

accident site, deploys the portable shelter, then remotely controls the vehicle to the accident site using the vehicle control console in the safety and comfort of the shelter. After parking the vehicle at the accident site, the operator views the accident scene from any or all of the cameras and can simultaneously operate the two manipulator arms. Radios can be used to control ARMMS and relay video back to the operator, but fiber optic is preferred for safety and security reasons (no emissions near possibly unstable components, and neither control nor video links can be tapped). This system is currently under development for DOE's Accident Response Group for worldwide use.

The ISRC at Sandia performs a large range of research and development activities, including development and delivery of one-of-a-kind robotic systems for use with hazardous materials. Our mission is to create systems for operations where people can't or don't want to perform the operations by hand, and the systems described in this article are several of our first-of-a-kind deliveries to achieve that mission. If you would like more information about the ISRC or these projects, please see http://www.sandia.gov/isrc.

References

[1] Drotning,W.D., Wapman, W.P., Fahrenholtz, J.C., Kimberly, H.R., and Kuhlmann, J.L., "System Design for Safe Robotic Handling of Nuclear Materials", ASCE Specialty Conference on Robotics for Challenging Environments, 1996.

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