Pit Viper Strikes

at the Hanford Site

Pit Maintenance Using Robotics at the Hanford Tank Farms

Containing jumper lines, valves, pumps, and other equipment used to transfer radioactive waste throughout the tank farms at Hanford, the "pits" are difficult for workers to access and most are contaminated. To the rescue: the new "Pit Viper."

By Lynne Roeder-Smith

In an effort to dispel the myth that "someone's got to do the dirty work," a remotely operated system called the "Pit Viper" was put to task in mid-December at the Hanford Site north of Richland, Wash. The Pit Viper, developed through a collaboration funded by the U.S. Department of Energy's Office of Science and Technology and Office of River Protection (ORP), was designed to replace manual operations, such as debris removal and cleaning, at Hanford's 600 tank farm pits.

Valve pit upgrades in Hanford's tank farms are part of baseline activities under the authority of the DOE's Office of River Protection. (Photo courtesy ORP.)

What are pits? Imagine installing an underground sprinkler system in your yard. Depending on the size of your yard and the number of irrigation lines needed to supply water to the various sprinkler heads, you may need one or more junction boxes to control and divert the water in different directions. The pits at the Hanford tank farms serve a similar purpose, but are much larger, located in a highly contaminated environment, and transfer radioactive waste instead of irrigation water.

The pits, made of concrete, contain jumper lines, valves, pumps, and other equipment used to transfer radioactive waste throughout the tank farms at Hanford. Most are contaminated and are difficult for workers to access. In support of waste retrieval efforts for upcoming vitrification activities, ORP's tank farm contractor, CH2M Hill Hanford Group (CHG), plans to upgrade hundreds of these pits. Unfortunately, operations in the pits rank among the highest in worker exposure to radiation in the tank farms.

Pits Present Difficulties in More Ways Than One

Workers typically perform pit work using long-handled tools, similar to pike poles, to position tools approximately 15 feet below ground level. Manipulating these poles, workers reach down into the pit to perform tasks such as cleaning, debris removal, and concrete repair—a method that is time consuming and difficult. The

The Pit Viper integrates a typical industrial backhoe with a robotic manipulator arm controlled from a remote location, effectively removing workers from high-radiation zones within the pit area.

Pit Viper

The Pit Viper consists of a robotic manipulator arm mounted to a backhoe, which serves as the mechanism for moving the arm into the pit area. The manipulator arm is controlled by an operator situated at a remote console located in a trailer outside the tank farm. Cameras mounted to the robotic arm and within the pit containment tent allow the console operator to see the entire pit area. Surrounded by a set of monitors for these cameras, the operator uses joysticks to position the robotic arm for the task at hand.

Various tools (including off-the-shelf power tools) fitted with a tee-handle allow a gripper attached to the arm to latch on and put them to work. Meanwhile, inside the backhoe cab, a video monitor with quad screen displays of the camera views inside the pit allow the "driver" to adjust the gross position of the arm within the space limitations of the pit area.

By removing tank farm operations staff from the immediate pit area, site users and project staff estimate that using the robotic system for pit work may reduce the radiation dose to workers by as much as 75 percent.

enclosure surrounding the pit further complicates these operations; sometimes workers must use overhead mirrors to reflect the image of the tools they are placing. In these instances, the operator must reverse the image he sees in the mirror. Imagine using a mirror to change your car tires, and you have to use a long pole to maneuver your tire jack and wrench, which might be suspended by a crane. Are you ready to call AAA yet?

Compared to baseline pit operations methods shown here, remote systems will reduce worker exposure and enable more thorough removal of discarded materials in Hanford pump pits. (Photo courtesy ORP.)

To compound matters, radiation doses in the pits can reach 50 000 millirem per hour (though most are around 30 to 100 mrem/h). The maximum allowable dose to tank farm personnel is 500 mrem/year. When that limit is reached, the worker must stop working in the pit. If a task is only half finished, too bad—it has to wait until someone else who is "clean" can be brought in to complete it. While the radiation dose potential is the biggest problem faced by workers, the mirrors, poles, and radiation levels all combine to make pit work "the pits," to say the least.

"The combination of protective clothing, pole tools, radiation exposure, and contamination turns ordinary tasks into complex operations," said Dennis Crass, technical lead on the Pit Viper project for Numatec Hanford Corp., a lead contractor supporting CHG. "One of the goals of the Pit Viper project was to demonstrate a concept that would provide tank farm workers with a safer, more effective way of performing these tasks."

A High-Function, Cost-Effective Remote Pit Operations System

In the late 1990s, CHG identified the need for a safer, more efficient method for conducting activities in the pits. After a preliminary evaluation of technical options to meet this need, a system capable of remote operations was agreed upon. Through funding provided by ORP and DOE's Tanks Focus Area program, CHG and experts from DOE's Robotics Crosscutting Program (Robotics) began developing a remote pit operations system—or Pit Viper—in 2000.

After completion of acceptance testing at the vendor (FERMEC) site, the backhoe was delivered to PNNL in December 2000.

Input from tank farm operations staff clearly leaned toward a deployment method that was familiar and easy to maneuver for gross positioning of the system. Robotics staff at Pacific Northwest National Laboratory (PNNL) reviewed a number of concepts, including crane-mounted equipment. Based on their review and operations input, they recommended a backhoe equipped with a "six-degree-of-freedom" manipulator arm. An independent review, conducted under the auspices of the American Society of Mechanical Engineers, validated the team's evaluation methodology, and the project moved forward with system development.

In addition, one of the primary objectives of the Pit Viper project was to minimize costs while still furnishing a robust system. This included both the hardware (equipment) and labor (operator training).

At the project's outset in 1999, CHG identified three areas where operational costs could be reduced:

1. Environmental enclosures to reduce weather-driven downtime.
2. Deployment platforms for remote operations.
3. End-effectors for performing remote operations in the pits. With technical advice from Robotics staff, CHG prepared functions and requirements for the weather enclosure and subsequently emphasized the need for the project to focus on concepts for the remote system and end effectors.

A Backhoe, HAMMER, Some Joysticks, and an Old Lunchroom—Meeting the Challenge

In July 2000 PNNL issued a call to industry for the modified backhoe deployment platform. Because of the standard hardware configuration, PNNL selected the winning bidder, FERMEC, based on price and delivery once the ability to meet specification requirements was assured. After acceptance testing at the vendor's facility in Spokane, Wash., a FERMEC 860SB backhoe was delivered to PNNL's warehouse in December 2000.

Following a competitive procurement process for the manipulator arm, PNNL awarded a contract in September 2000 to Cybernetix, a robot and automation company located in Marseilles, France. The Cybernetix SAMM hydraulic manipulator chosen for the system includes six joints along its 7-ft length and can rotate 360 degrees at its base. It is capable of lifting 200 pounds when fully extended.

With the two main pieces of hardware lined up, the next step was finding a testing and training facility. PNNL Robotics staff approached the site's Hazardous Materials Management Emergency Response (HAMMER) training facility with a request to conduct testing there. HAMMER is a state-of-the-art test facility constructed in 1995 as one of the nation's most advanced hands-on worker safety training centers (see "HAMMERing It Out: Training As Real As It Gets," *Radwaste Solutions,* Jan./Feb. 2000, p. 8). After reviewing the project goals, HAMMER representatives agreed to let the Pit Viper project use their training facility for free. Talk about cost-effective!

For the Pit Viper's remote operations, the project team purchased a Compact Remote Operator Console. The console, originally developed by Robotics staff at Oak Ridge National Laboratory (ORNL) to assist in remote deactivation and decommissioning work, allows remote

At the Hanford Site, radioactive waste is stored in 177 underground tanks. The oldest tanks, built from the 1940s through 1960s, were constructed with a single protective inner liner. These are called single-shell tanks. Newer tanks built from the mid-1960s through the 1980s, called double-shell tanks, include an extra steel liner to provide better protection from potential leakage. The tanks are grouped into "farms" with anywhere from 2 to 18 tanks per farm. Each farm also contains the necessary underground piping and equipment, including valve pits, used to route the waste among the tanks. Located in the Central Plateau, a remote area of the site, the tank farms occupy two adjacent areas of real estate known as the 200 East and 200 West Areas.

A vacant trailer was refurbished to house the control systems for the robotic arm, with room for several project staff to work closely and comfortably.

Surrounded by a bank of viewing screens, an operator uses joysticks to control dexterous movements by the Pit Viper robotic arm.

viewing and audio and remote tool control. Joysticks enable fine positioning of the arm, gripper, and tools. By using a previously developed and proven technology, ORNL Robotics staff needed to implement only slight modifications for the Pit Viper application.

To house the control console, the project team searched for a mobile unit big enough to accommodate typical office workstation equipment, as well as the bank of computers and television screens used by the control system. To avoid the costs associated with building a custom mobile unit, CHG staff suggested a trailer previously used as a lunchroom for tank farm personnel.

In total, the Pit Viper system costs about $1 million for hardware and operator training. Although financial figures on cost savings using the Pit Viper haven't been refined yet, when compared to the cost and risk of keeping numerous tank farm personnel tied up and "maxed out" in pit work, using the Pit Viper is a win-win proposition.

"We're a Team"

Given the high expectations placed on the effectiveness of the Pit Viper system, it quickly became apparent to the project team that everyone's full cooperation and support would be required to deliver the right system on schedule. In 1999, soon after the project began, the project partners developed and signed a memorandum of agreement (MOA). This agreement detailed which organizations were responsible for the various aspects of the integrated project, based on the separate funding sources. It also demonstrated to the ultimate user of the technology—tank farm operations—the team's commitment to the project.

"The MOA represented an overall agreement to work together to accomplish a common goal," explained Sharon Bailey, PNNL technical lead for Robotics on the Pit Viper project. "An MOA isn't contractual in any way, it just says we're a team, we're heading this direction, I'm doing this part, and you are doing that part."

Further strengthening the overall project commitment, PNNL and HAMMER also signed a memorandum of understanding. This basically served the same function as the MOA between the project partners, except this one solidified the arrangement between the project lead and demonstration facility.

"Not only did they offer to let us use the training grounds free of charge, but they also agreed to put it in writing," said Bailey. "I can't emphasize enough how important this aspect of the project was. It would have cost significant project funds to lease training facilities—and that cost would have reduced funds available for hands-on integration and testing."

Numerous demonstrations for various groups and interested parties took place at the HAMMER mockup site during the months leading up to system deployment, contributing additional valuable testing and training hours. Had the project been required to pay for the use of training facilities, this would not have been possible.

The Nature of the Beast

Any technology development effort is bound to encounter some unanticipated problems along the way—that's the nature of the beast. The Pit Viper was no exception.

In addition to the multiple partners involved, the project concept required integrating numerous pieces of equipment into one system. The equipment then had to be demonstrated for operations in high-radiation fields, which had not been attempted before.

In December 2000, an unexpected delay in the delivery of the manipulator arm by the international vendor affected the schedule for integrating and testing the other Pit Viper components. To try to make the best out of the situation, the project team changed their focus to nonmanipulator tasks while awaiting delivery.

Initially, PNNL Robotics staff used a wooden mockup arm and computer simulation to test the backhoe/tent interface. Later, the project team mounted an available Schilling Titan II manipulator arm to the backhoe to continue testing the other system components. Although not representative of the Cybernetix arm, the Titan II and wooden arm substitutes proved valuable for evaluating effectiveness of the system and developing operating procedures.

Following acceptance testing of the Cybernetix arm in March 2001, it was delivered to the HAMMER facility—completing receipt of the four major system components. The project team attached the arm to the backhoe and began range-of-motion and manipulation testing.

The Pit Viper suffered a major setback in September 2001 when during a deployment practice session, an actuator broke on one of the joints of the manipulator arm. The project team weighed several options, including borrowing an actuator from a neighboring government contractor whose design was compatible with PNNL's. Ultimately, the project team received, under warranty, a replacement actuator from Cybernetix. Although the de-

Robotics staff at PNNL constructed a wooden mockup of the Cybernetix arm to conduct cold testing and operator training.

Snow flurries arrived in mid-December at the Hanford Site, just in time for the Pit Viper deployment. The top of the backhoe is visible just in front of the C-104 pit containment tent.

ployment schedule was delayed by more than one month, the project team persevered by pushing forward toward deployment following receipt of the replacement parts.

These problems are typical of any project of this size and magnitude. One or all of these challenges could have stalled the project, but close and continual communication and teaming among all parties in the project team made this project a success.

"The Tanks Focus Area, Robotics personnel, HAMMER, and CHG worked together to adapt off-the-shelf technology and make the best use of available resources to ensure the system would work as intended," says Joe Cruz, ORP Retrieval program manager and site representative for the Tanks Focus Area. "The Pit Viper is an excellent example of a teaming approach to ensure engineering efforts meet a field-identified need."

Get It in Writing (and on Video)!

Unfortunately, technology development doesn't begin and end with nuts and bolts (or computers and hardware, in this day and age). In addition to system tooling and testing, the project team spent many hours developing procedures and safety documentation, documenting system performance, and even taking videos.

As a final product, the team also prepared a setup and takedown procedure for the tank farm hot deployment. This document included arrangement of equipment within the tank farm (the Pit Viper) and external to the tank farm (the control trailer and staging areas), setup steps, start-of-operations checks, end-of-day activities log, specific task plan for the C-104 heel pit activities, breakdown steps, trailer setup checklist, camera setup, cable/hose routing and connections, backhoe deployment, tool rack setup and hydraulic hose connection procedures. The team held dry runs using this procedure as a guide, which proved invaluable as they readied for hot deployment.

The Pit Viper Attacks Tough Territory

After considering three different tank pits during the course of the project, the project team eventually select-

A brush tool was attached to the Pit Viper manipulator arm to scrape and scoop debris from the floor of the Tank C-104 pit. This was the final of five required tasks (size reduction and foam removal, wall spraying, wall grinding, scraping/scooping, and debris removal) to demonstrate the system's capabilities in a highly radioactive environment.

ed the heel pit of Tank 241-C-104 for deployment of the system. Tank 241-C-104 is one of 149 single-shell tanks at the Hanford Site. It was constructed in 1944 and removed from service in 1980; it contains approximately 259 000 gallons of high-level radioactive waste sludge. CHG is currently transferring waste from the old single-shell tanks (like C-104) into 28 newer double-shell tanks. Waste will then be transferred from the double-shell tanks to a treatment facility.

In early December 2001, Pit Viper project staff and tank farm operations personnel moved the system from the HAMMER facility to the pit area of Tank 241-C-104. Tank farm operations staff then constructed a tent enclosure over the pit area to contain the operations and to prevent the release of any potential contamination to the environment. The containment tent also served to protect the equipment from the oncoming winter weather. Finally, with temperatures dipping into the low 30s, CHG tank farm operations personnel and PNNL Robotics staff put the Pit Viper into action. On December 17–19, 2001, they successfully deployed the Pit Viper in the heel pit of Tank 241-C-104 at the Hanford Site.

During the first day of the three-day deployment, the Pit Viper's water knife began cutting through a large piece of insulating foam that had previously come unglued from the pit cover and fallen to the pit floor. The foam turned out to be about two to three times thicker than originally anticipated, and the water knife was able to cut only halfway through it. After an unsuccessful attempt using a commercial foam cutter (modified with a tee-handle attachment) to complete the task, the team decided to tackle that challenge the next day. They turned their attention to demonstrating a wall-cleaning tool and successfully used a water jet to remove dirt and paint from one wall.

On the second day, the team decided to use the manipulator gripper to pull, rip, and tear apart the foam into manageable pieces. This method worked, and the pieces were picked up by the gripper and placed into a nearby waste box, along with pieces of absorbent used to soak up water generated by the water jet.

The Pit Viper performed wall grinding, scraping, and debris removal tasks on the final day, completing the deployment. Robotics personnel reported no systemic problems during the three days of operation, and no personnel entered the containment area at any time during the deployment.

"The entire campaign was completed without any personnel required to enter the pit containment area," said Bailey. "Additionally, the cold weather conditions that would have slowed the pace of manual methods were not a problem for the Pit Viper."

Project Partners

The Office of Science and Technology (OST) is part of the DOE's Office of Environmental Management. The OST utilizes numerous programs, including the Tanks Focus Area and Robotics Crosscutting Program, to help develop solutions for the various cleanup activities. Established in 1995, the Tanks Focus Area integrates science and technology development for tank waste remediation efforts at five sites across the DOE waste complex: the Hanford Site, Idaho National Engineering and Environmental Laboratory, Oak Ridge Reservation, Savannah River Site, and West Valley Demonstration Project. (For additional information, see "A Team of Seven—The Tanks Focus Area: Providing Technical Solutions for Cleaning Up the DOE's Radioactive Tank Wastes," *Radwaste Solutions,* Sept./Oct. 2000, p. 43.)

Safer, Faster

Close cooperation and teamwork between the DOE's Tanks Focus Area and Robotics Crosscutting Program, ORP, and CHG resulted in the Pit Viper deployment, which demonstrates a safe, cost-effective method for conducting dose-intensive pit operations.

"Using the Pit Viper allows us to protect our workers by significantly reducing the potential radioactive dose," says Ryan Dodd, CHG project manager, Mission Analysis and Technology Integration. "This means upgrades to the process pits can be done more efficiently, putting us that much closer to retrieving the tank waste for treatment at the planned vitrification plant."

Robotics staff at PNNL continue working with CHG to investigate improvements to the existing system and integration of new tools for use by tank farm operations staff. ■

Lynne Roeder-Smith is a technical communications specialist at PNNL in Richland, Wash. She provides technical communications expertise to the DOE's Tanks Focus Area.