# 'Mighty Mouse' robot frees stuck radiation source

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A Sandia National Laboratories robot recently withstood enough radiation to kill 40 men in freeing a stuck radiation source -- the size of a restaurant salt shaker -- at a White Sands Missile Range lab so that the cylinder could be safely returned to its insulated base.

*Image: Bob Anderson demonstrates the capabilities of the robot affectionately known as the M2, for Mighty Mouse. (Photo by Randy Montoya)*

The robot, for its successful efforts, was unofficially dubbed M2 for the cartoon character "Mighty Mouse."

The operation -- carried out by the robot and a joint task force of White Sands and Sandia RAP (Radiation Assistance Program) team members -- ended 21 days of warning lights flashing and horns blaring at the 3,000-square-foot Department of Defense lab in Southern New Mexico.

## What happened

Alarms were blaring, warning lights flashing, and personnel were monitoring the stricken site around the clock in late October at the White Sands' Gamma Irradiation Facility. The cause was a stuck cylinder the size of a restaurant salt shaker but considerably more deadly: Gamma rays from the cobalt-60 it contained could kill a man in half a minute. Its radiation field was too deadly for a human, even in a protective suit, to get near enough to free it.

The cylinder was used to irradiate circuit boards and vehicles to see how their electronic circuits, made smaller each year, stood up to radiation that would be present were a nuclear weapon detonated on or above U.S. soil.

The cylinder normally arrived and departed through a metal sleeve, driven by pneumatic air. The method resembled that used by drive-up banks, where pneumatic air drives a cylinder containing transaction paperwork first one way and then the other.

At White Sands, a pressure of approximately 20 psi was normally enough to move the container from its secure resting place to its forward exposed, or live, position; the same air pressure in the opposite direction sent it back. Over previous decades, on the rare occasions when the cylinder stuck, technicians had merely increased air pressure to send it on its way.

But this problem was different. From the safety of their control room, technicians increased air pressure in steps until they had reached 50 times normal, or 1000 psi, but they could not budge the cylinder. They speculated it had rammed into a signal switch that formed part of the sleeve's pathway. In design, the switch resembled a teeter-totter. If the switch's forward end was up when it should have been down, it would resist the cylinder's passage. More air pressure would only insert the switch's edge more deeply into the cylinder.

Range management considered its options.

On the positive side, gamma rays decreased in intensity by the square of the distance. That is to say, past a few hundred feet, the surrounding area was perfectly safe. And, unlike neutrons, the rays did not contaminate materials they touched; they were deadly only as they passed through a living organism.

On the negative side, the lab was shut down. It had to be manned around the clock to be sure no security guard wandered into the harmless-appearing area; meanwhile, the continually flashing lights and honking alarms set peoples' teeth on edge.

There were robots on the East Coast that might be located and flown in.

The facility also had the capability to design, manufacture, transport, and maneuver a very heavy lead shield on a front-end loader to block and then surround the errant source. Technicians drilling through the shield could then send in a probe to force the switch to its normal position.

Within 24 hours, the Range's management decided instead to call the local NNSA RAP team -- the Radiological Assistance Program -- headquartered at Sandia National Labs.

It would shortly seem the best move they could have made.

Richard Stump, Sandia RAP leader, explained the problem to robotics manager Phil Bennett, who said his group had a robot that might do the job. The 600-pound, five-foot-long robot, which became unofficially known as M2, rolled on treads, could maneuver around obstacles, and had a long, multi-jointed gripper arm with the dexterity to reach into awkward places and apply force to drills and screwdrivers. It could remember positions, important in starting with tools at the right height and depth. It was intended as a bomb-disabling unit.

But radiation that can kill a human also can kill a robot's electronics. Bennett estimated M2 could withstand intense radiation for only 50 minutes.

The problem was that the switch was four feet off the floor, set back three feet from any vertical approach, and covered by a protective 3/16-inch steel plate. The plate made a 45-degree angle with the floor. It wouldn't be easy, but if the robot could reach up and across, and drill a hole through the oddly angled steel plate, it could insert a wire through the drilled hole to nudge the switch's bar, which rotated on a hinge pin, to a more appropriate position.

## Lacking a trigger finger

But when the call to Sandia came, M2 was down with a faulty motor control board in its forearm. A call to DOE provided immediate funding to get it working; a replacement part was built and shipped from Agile Manufacturing in Waterloo, Ontario. Manufacturing, shipping, installation, testing, and querying White Sands to learn everything possible about the situation took two weeks.

"Our people at first wondered what the holdup was," says White Sands' Richard Williams, "and then we saw how well [the Sandia RAP team], with all their questions to us, had prepared." Williams is White Sands' associate director for its Survivability, Vulnerability, and Assessment Directorate.

Because the robot lacked a trigger finger to depress and release a drill control, the Sandia team stalked the aisles of local hardware stores, buying cordless drills and other equipment they modified into remotely operated drills, hooks, and grippers. On tests performed at Sandia by Bob Anderson and Jim Buttz on a mock-up of the stuck container and switch sent north from White Sands, M2 performed perfectly.

On Oct. 21, the team made the trip to White Sands, where reality -- as it often does -- proved more complex than the dry run had led the RAP group to anticipate.

Aided by M2's video camera, Anderson steered the robot around two free-standing radiation shields and stopped it at the work site. The robot drilled through the steel plate, opening a space for a probe to pass through and push down one side of the teeter-totter.

The switch did not budge.

The team decided that a differently positioned hole might offer more leverage. The robot drilled a second hole and again shoved the probe against the teeter-totter's bar, with the same negative result.

A third hole, drilled through the switch's hinge pin to take it out and permit the entire structure to slide, failed to dislodge the obstacle.

Undeterred, the robot and its team then attempted to remove the switch by yanking at two wires, linked to each other, that were connected to the switch; the wires merely separated. So the robot grasped one of the separated wires in its pincer, but the wire broke when pulled.

By this time an hour and a half had gone by, and the team was temporarily out of ideas. Phil had estimated that the robot could remain ambulatory in the radiation field for only 50 minutes, and in fact the robot's lower portion was no longer responding to commands.

## Wouldn't touch it with a ten-foot pole

The RAP team, as a precaution against this very circumstance, working with White Sands personnel had tied a rope to M2 before sending it into the work area. The rope, attached to a RAP team winch 100 feet outside the structure, ensured the robot could be hauled out if radiation damaged its drive unit. But radiation shields now blocked a direct haul. M2 was hemmed in.

Using a ten-foot-long pole and standing at the edge of the field (which fanned out like a flashlight beam, strongest at its center and weakest at its edges), team members hooked and then tugged at the rope hauling M2. The deflection of the rope's pull slid the robot around a moveable radiation shield without knocking it over. The RAP team's winch then pulled the robot directly out.

Rebooting the robot and performing other maintenance, Anderson and Buttz found they could reactivate it, and the team finished the day ready to return the next morning.

The new plan was to unscrew six bolts that held in place the 3/16-inch steel plate that blocked the team's direct access to the switch.

When they returned the next morning, however, the robot again would not start. The problem was traced to a damaged fiber optic line. A White Sands facility that worked with fiber optic lines was able to repair the cable break, but it was Sunday morning. It had taken half a day to replace the damaged line.

The time was not wasted. The RAP group, making frequent trips to the local Home Depot and Lowe's, modified its tools.

The drills needed to work in reverse when the trigger was pushed, in order to back the screw out rather than tighten it. It had to move slowly enough that the robot could engage the screw head as it pushed down at the start of each effort. But the screwdriver tip could spiral off the screw head as the head turned, stripping the head. The team purchased a small, clear acrylic bubble that acted as a guide to keep the screwdriver blade in place. Unfortunately, heat from the radiation source melted the plastic.

So ended the second day.

## The third day

An opaque metal guide bought from the hardware store the next morning was small enough in diameter to satisfactorily seat and keep the tool on the screw head and loosen the plate.

The team then tried air pressure to remove the plate. When this failed, they steered the robot out of the area and attached special tips to the end of its gripper. This time M2 succeeded in removing the plate. A blast of air then blew the entire switch out of the cylinder's pathway, and the radiation source at long last was blown back to its storage position.

Inspection revealed the problem: Forceful early attempts to blow the cylinder back apparently had bent the straight switch into a right angle

"It would have been impossible to return the source to storage without removal of that switch," says Stump.

Cleanup extended for another day.

The four-day on-site effort ended the problem, to the exuberance of those working on the project.

"The warning lights and horns that could be heard for miles away finally stopped after 21 straight days of annoying personnel at White Sands," says Stump.

Says White Sands health physicist Douglas McDonald, "The facility is being evaluated. We're looking at what happened and considering what we can do to prevent similar incidents in the future."

Says Williams, "The team effort [between White Sands and Sandia RAP] produced a marvelous job."

Source: Sandia National Laboratories

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