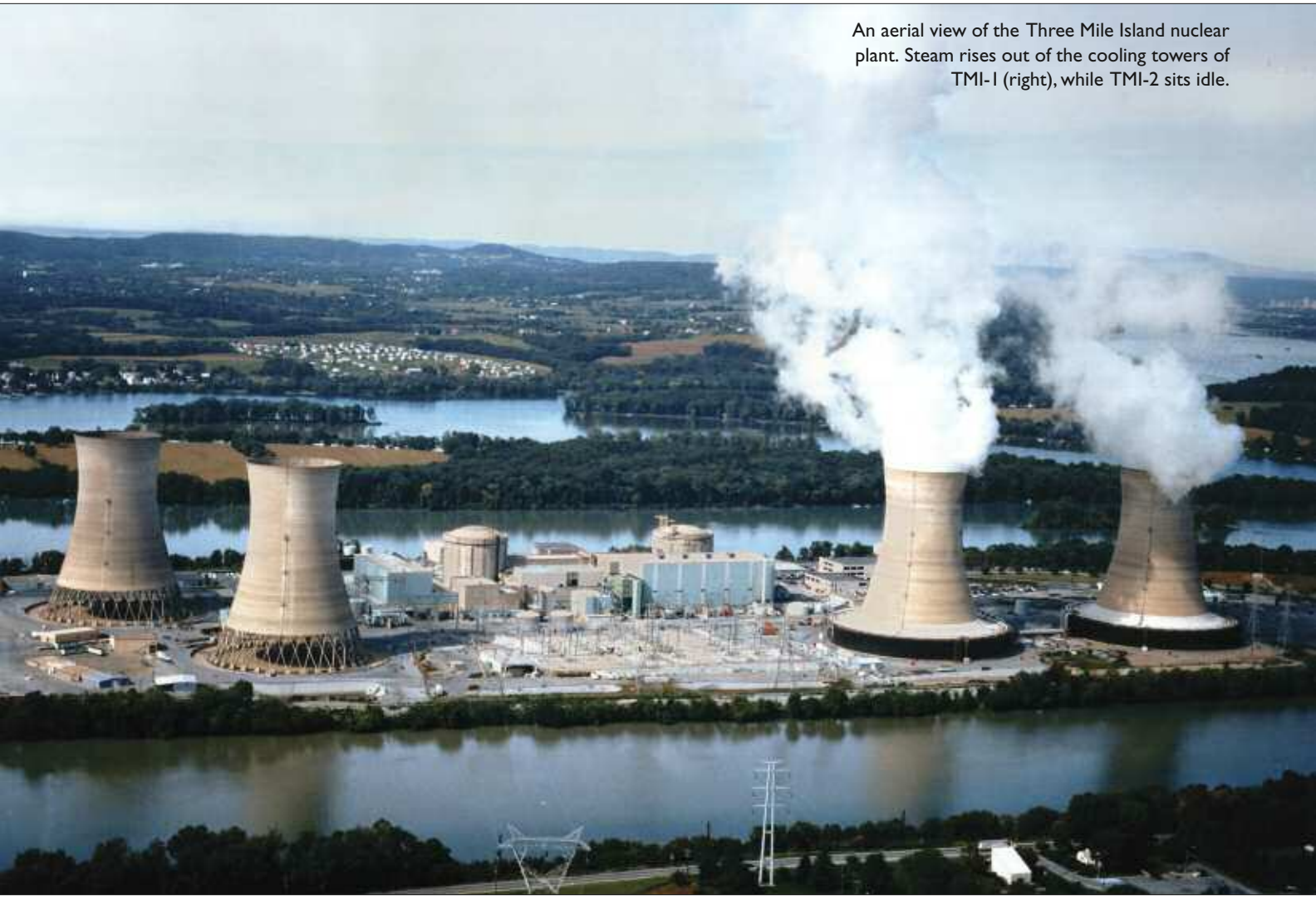


An aerial view of the Three Mile Island nuclear plant. Steam rises out of the cooling towers of TMI-1 (right), while TMI-2 sits idle.

Red Whittaker and the robots that helped clean up TMI-2

BY RICK MICHAL

Prior to the March 28, 1979, TMI-2 accident, there was much speculation about what robots might do and what the technology might become. The TMI experience "propelled a new technology from ideas to implementation."

WILLIAM "RED" WHITTAKER is one of the world's top roboticists. For more than 30 years he has taught robotics at Carnegie Mellon University, in Pittsburgh, Pa., where he and his students developed some of the machines used for the cleanup after the March 1979 accident at the Three Mile Island-2 nuclear power plant.

TMI-2 was a 792-MWe Babcock & Wilcox pressurized water reactor that started commercial operation in December 1978 and was operated by General Public Utilities (GPU). The accident resulted from a loss of coolant to the reactor, which led to a partial core meltdown, but it caused no deaths and released only a relatively small amount of radiation into the atmosphere.

The long-term legacy of the accident was that the nuclear industry changed for the better: The use of computer monitoring was increased, training simulators were improved, and plant designs were made simpler and safer. In addition, the accident led to the formation of the U.S.-based Institute of Nuclear Power Operations and the international World Association of Nuclear Operators, both of which strive to improve operations at nuclear power plants.

The accident occurred when a pressure relief valve failed to close, with the result that too much water flowed through it. When a drain tank filled, a rupture disk broke and thousands of gallons of radioactive water rushed into the lower level, or basement, of the containment building.

"In the course of the accident, thousands of gallons of water swept through the reac-

tor and cascaded into TMI-2's basement, carrying fuel pellets, the radioactive element cesium, and debris from the damaged core," Whittaker said. The cesium in the water leached into the concrete block walls and floor of the basement.

Once it came time to address the cleanup of the basement, Whittaker and his Carnegie Mellon students designed and built three varieties of robots to help with the job. Two of the robots—the Remote Reconnaissance Vehicle (RRV) and the Core Sampler, built in 1984 and 1985, respectively—were sent into the flooded basement of the damaged reactor building and were operated remotely. The third robot, a stainless steel giant called the Workhorse, was never used. (Ultimately, Whittaker bought it back from GPU for $1.)


Whittaker

The robots were outfitted with cameras, lights, radiation detectors, vacuums, scoops, scrapers, drills, and high-pressure spray nozzles. They surveyed the site, sent back information, and drilled core samples to measure the radiation levels of the basement walls and floor.

To commemorate the 30th anniversary of the TMI accident, the State Museum of Pennsylvania, located in Harrisburg (near the TMI site), in March unveiled an exhibit that displayed one of the two original RRVs built by Whittaker and his students, along with other related artifacts. Whittaker said that the plan from the start was to deploy only one of the two RRVs at TMI, with the other to be used for training, analyzing, tool-building, technique development, and hot spares.

First steps

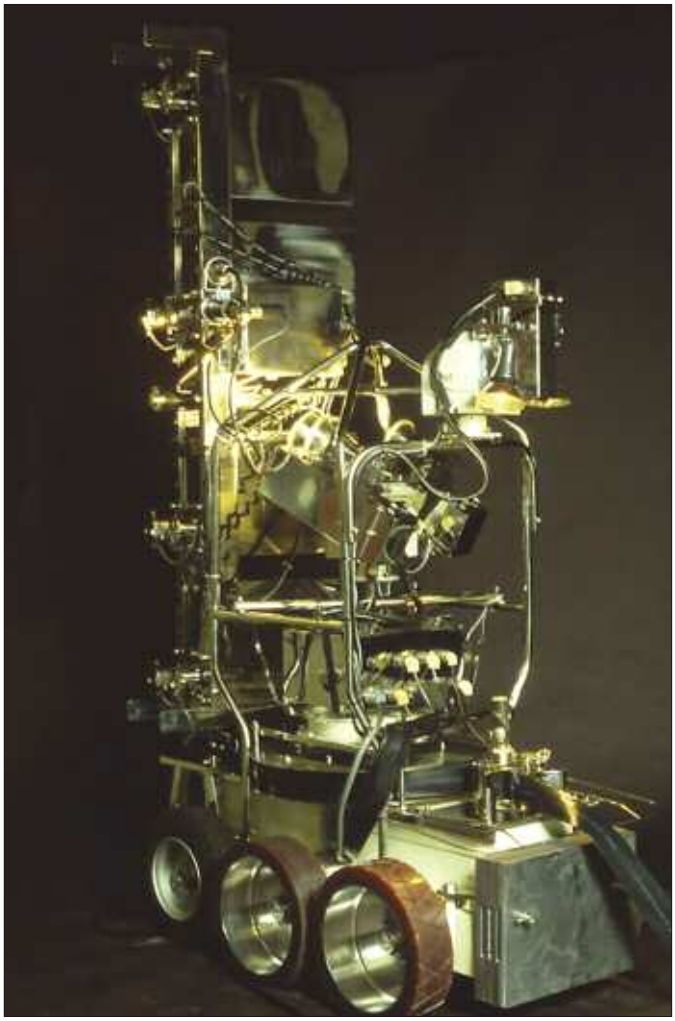
At the time of the TMI-2 accident, Whittaker was a young college professor at Carnegie Mellon, which, by coincidence, in 1979 established the Robotics Institute, part of the university's School of Computer Science. "There was nothing else like it that had the undiluted, unbridled commitment to the future of automation," he said. "Robotics was envisioned as a bold future. At the time, it was the stuff of fantasy and science fiction."

The Robotics Institute was funded by a grant from Pittsburgh-based Westinghouse Electric Company, whose history, of course, is tied to the nuclear industry.

Before the TMI-2 accident, robots existed as factory machines but were not of very high quality or performance, according to Whittaker. They could do things like spray-paint cars at factories in Detroit or put resistors into circuit boards. "Those were the kinds of tasks that would justify some form of automation," he said. "It's important to honor them, but they're a very different class of technology and application than are required for incident response of any kind."

Whittaker noted that no one had ever dealt with a cleanup like TMI-2's. No human would be allowed to enter the flooded basement, nor had sensors or cameras been placed to get insight into what was down there. "It was all very much unknown," he said. "Since there was no clear sense of the depth and severity of the accumulations, no


The Remote Reconnaissance Vehicle characterized the basement at TMI-2 and then went on to perform most of the robotic cleanup work. In the background, Red Whittaker sits at the control console in the operator station. (Photos: Carnegie Mellon)


The Core Sampler extracted samples from TMI-2's basement walls. From these samples, the depth and severity of contamination was determined at several heights.

one knew what kind of mud and terrain had to be negotiated, nor the depth of the water and the material in places."

Because TMI-2 had started commercial operation just months before the accident, there were questions about how much of the plant's infrastructure had been completed and how much had not. "Were doors hung or weren't they? Were pinch-points passable? Many things that would affect operations and the eventual success of the cleanup needed to be determined," Whittaker said.

This uncertainty led to an engineering process that would formalize methods for the cleanup, making sure that what was chosen would meet specifications and regulatory requirements.

Whittaker said that GPU and its prime cleanup contractor, Bechtel, looked at many solutions and decided to stop by the Robotics Institute, a few hours away from TMI by car, in early 1983. An agreement to use robots was reached—first by handshake in June 1983 and then under contract in September 1983—and the first of the robots was delivered by rental truck to TMI in April 1984. After training, tests, health effect evaluations, and operations planning, the first robot—one of the RRVs—entered the basement in November 1984.

Rolling along

The robots moved along the ground on wheels, a design decision that succeeded because of its simplicity, mobility, and reliability. Tracked mobility had been considered for the robots, but was rejected because of concerns about intricacy, failure modes, and the difficulty of cleaning and decontaminating the tracks. And the robots had to be made of materials that could be aggressively washed without harming their components. "These were sealed and submersible, and had to handle high-pressure washdown," Whittaker said. "The purpose was to get most of the contamination off the outer surfaces so that they would be approachable by suited workers if and when a tool change or servicing was needed."

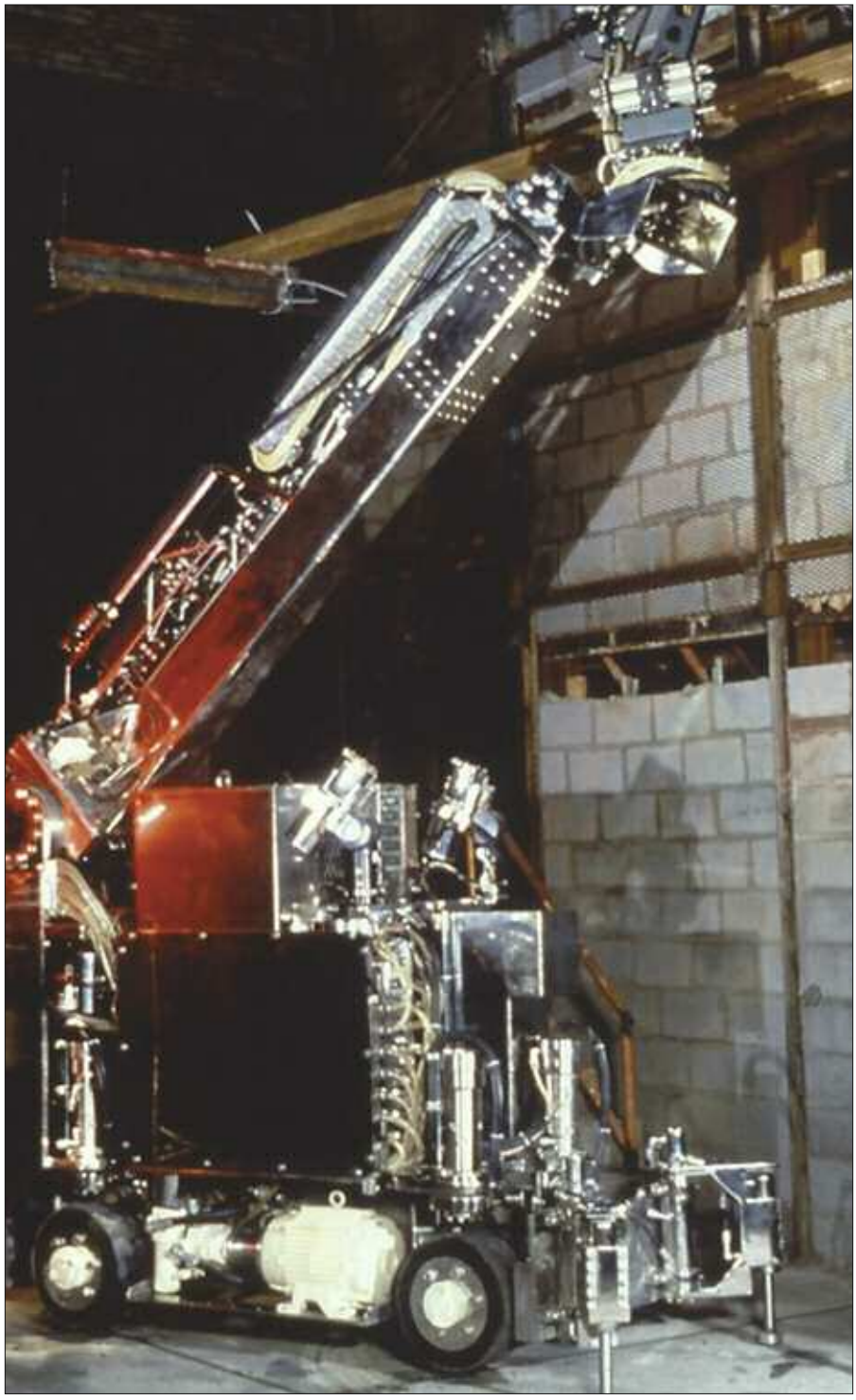
The robots proved to be durable enough to succeed at the job, which at first entailed exploration and assessment. This step determined the extent of the damage, the severity of radiation levels, and which areas of the basement were accessible by robot. The interim agenda entailed core boring into the walls for concrete samples to test the depth and severity of the contamination. The test results revealed how much of the surfaces needed to be taken off to remove the high-level radionuclides to meet cleanup standards. A later agenda included the deployment of tools, vacuums, waterjets, and pressure washes to implement the cleanup.

By design, the RRV was the scout machine, while the Workhorse was intended to do the demolition, shearing, and large-diameter coring. Technological advances, however, allowed the RRV, and later, the Core Sampler, to be equipped with better tooling so that the Workhorse, which arrived at TMI-2 in 1986, was never needed.

"In robotics, the half-life of technology is about two years, so you expect advances to double in that time frame," Whittaker said. "Consider that robotics at least subsumes that, but in addition has the advantage of all of the marvelous sensors, technologies, gyros, and advanced energy solutions such as batteries."

The robots were operated by technicians working in remote locations outside of containment. The electricity to power them was provided by hundreds of feet of electrical cord that snaked through corridors inside the containment building. Over the years, the robots cleaned up enough radiation in the basement to allow humans to enter briefly to evaluate conditions.

After four years of work, the robots' cleanup chores were completed. The RRV and the Core Sampler were left behind in TMI-2's containment for the eventuality of future work. Overall, the basement cleanup



The Workhorse remote work system, with upraised boom

The robotic development team in the 1980s at Carnegie Mellon. Red Whittaker is at the back left, leaning on the Workhorse.

took 14 years and $1 billion to complete.

Still slightly contaminated, TMI-2's containment building remains sealed and won't be opened up again until TMI-1, which is still in commercial operation, is closed down and decommissioned.

The RRV's twin, which was never deployed at TMI-2, is in the Pennsylvania State Museum in Harrisburg. The Workhorse made it back to Whittaker's shop in Pittsburgh and was the precursor of machines to be built in the future. It is now on public display at the shop, along with an illustrated history of the TMI-2 cleanup.

Post TMI-2

Following his experience with the cleanup at TMI-2, Whittaker went on to establish RedZone Robotics, which delivered robotic solutions to the Department of Energy for its cleanup work at New York's West Valley Site and for some development work on the damaged Chernobyl-4 reactor, among other things.

His research team at Carnegie Mellon University won the Defense Advanced Research Projects Agency's $2-million Urban Challenge in November 2007.

Since then, Whittaker and another of his companies, Astrobotic Technology, have been pursuing the $30-million Google Lunar X Prize. Whittaker hopes to have a roving robot ready for a 2011 launch to the Moon. After landing, plans call for it to make a trek of 500 meters through the Moon's Sea of Tranquility, which would take it to the site of the Apollo 11 landing. The robot would also transmit a message back to Earth.

Whittaker called the TMI-2 experience a galvanizing one for the fledgling robotics industry in that it sparked a movement. The TMI experience, he said, "propelled a new technology from ideas to implementation." NN