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Six Years After Fukushima, Robots Finally Find Reactors' Melted Uranium Fuel

The Japanese government and companies used radiation-hardened machines to search for the fuel that escaped the plant's ruined reactors.

By MARTIN FACKLER NOV. 19, 2017

FUKUSHIMA DAIICHI NUCLEAR POWER PLANT, Japan — Four engineers hunched before a bank of monitors, one holding what looked like a game controller. They had spent a month training for what they were about to do: pilot a small robot into the contaminated heart of the ruined Fukushima nuclear plant.

Earlier robots had failed, getting caught on debris or suffering circuit malfunctions from excess radiation. But the newer version, called the Mini-Manbo, or "little sunfish," was made of radiation-hardened materials with a sensor to help it avoid dangerous hot spots in the plant's flooded reactor buildings.

The size of a shoe box, the Manbo used tiny propellers to hover and glide through water in a manner similar to an aerial drone.

After three days of carefully navigating through a shattered reactor building, the Manbo finally reached the heavily damaged Unit 3 reactor. There, the robot beamed back video of a gaping hole at the bottom of the reactor and, on the floor beneath it, clumps of what looked like solidified lava: the first images ever taken of the plant's melted uranium fuel.

The discovery in July at Unit 3, and similar successes this year in locating the fuel of the plant's other two ruined reactors, mark what Japanese officials hope will prove to be a turning point in the worst atomic disaster since Chernobyl.

The fate of the fuel had been one of the most enduring mysteries of the catastrophe, which occurred on March 11, 2011, when an earthquake and 50-foot tsunami knocked out vital cooling systems here at the plant.

Left to overheat, three of the six reactors melted down. Their uranium fuel rods liquefied like candle wax, dripping to the bottom of the reactor vessels in a molten mass hot enough to burn through the steel walls and even penetrate the concrete floors below.

No one knew for sure exactly how far those molten fuel cores had traveled before desperate plant workers — later celebrated as the "Fukushima Fifty" — were able to cool them again by pumping water into the reactor buildings. With radiation levels so high, the fate of the fuel remained unknown.

As officials became more confident about managing the disaster, they began a search for the missing fuel. Scientists and engineers built radiation-resistant robots like the Manbo and a device like a huge X-ray machine that uses exotic space particles called muons to see the reactors' innards.

Now that engineers say they have found the fuel, officials of the government and the utility that runs the plant hope to sway public opinion. Six and a half years after the accident spewed radiation over northern Japan, and at one point seemed to endanger Tokyo, the officials hope to persuade a skeptical world that the plant has moved out of post-disaster crisis mode and into something much less threatening: cleanup.

"Until now, we didn't know exactly where the fuel was, or what it looked like," said Takahiro Kimoto, a general manager in the nuclear power division of the plant's operator, Tokyo Electric Power Co., or Tepco. "Now that we have seen it, we can make plans to retrieve it."

Tepco is keen to portray the plant as one big industrial cleanup site. About 7,000 people work here, building new water storage tanks, moving radioactive debris to a new disposal site, and erecting enormous scaffoldings over reactor buildings torn apart by the huge hydrogen explosions that occurred during the accident.

Access to the plant is easier than it was just a year ago, when visitors still had to change into special protective clothing. These days, workers and visitors can move about all but the most dangerous areas in street clothes.

A Tepco guide explained this was because the central plant grounds had been deforested and paved over, sealing in contaminated soil.

During a recent visit, the mood within the plant was noticeably more relaxed, though movements were still tightly controlled and everyone was required to wear radiation-measuring badges. Inside a "resting building," workers ate in a large cafeteria and bought snacks in a convenience store.

At the plant's entrance, a sign warned: "Games like Pokemon GO are forbidden within the facility."

"We have finished the debris cleanup and gotten the plant under control," said the guide, Daisuke Hirose, a spokesman for Tepco's subsidiary in charge of decommissioning the plant. "Now, we are finally preparing for decommissioning."

In September, the prime minister's office set a target date of 2021 — the 10th anniversary of the disaster — for the next significant stage, when workers begin extracting the melted fuel from at least one of the three destroyed reactors, though they have yet to choose which one.

The government admits that cleaning up the plant will take at least another three to four decades and tens of billions of dollars. A $100 million research center has been built nearby to help scientists and engineers develop a new generation of robots to enter the reactor buildings and scoop up the melted fuel.

At Chernobyl, the Soviets simply entombed the charred reactor in concrete after the deadly 1986 accident. But Japan has pledged to dismantle the Fukushima plant

and decontaminate the surrounding countryside, which was home to about 160,000 people who were evacuated after accident.

Many of them have been allowed to return as the rural towns around the plant have been decontaminated. But without at least starting a cleanup of the plant itself, officials admit they will find it difficult to convince the public that the accident is truly over.

They also hope that beginning the cleanup will help them win the public's consent to restart Japan's undamaged nuclear plants, most of which remain shut down since the disaster.

Tepco and the government are treading cautiously to avoid further mishaps that could raise doubts that the plant is under control.

"They are being very methodical — too slow, some would say — in making a careful effort to avoid any missteps or nasty surprises," said David Lochbaum, director of the nuclear safety project at the Union of Concerned Scientists, who was a co-author of a book on the disaster.

"They want to regain trust. They have learned that trust can be lost much quicker than it can be recovered."

To show the course followed by the Manbo, Tepco's Mr. Hirose guided me inside the building containing the undamaged Unit 5 reactor, which is structurally the same as two of the destroyed reactors.

Mr. Hirose pointed toward the spot on a narrow access ramp where two robots, including one that looked like a scorpion, got tangled in February by debris inside the ruined Unit 2.

Before engineers could free the scorpion, its monitoring screen faded to black as its electronic components were overcome by radiation, which Tepco said reached levels of 70 sieverts per hour. (A dose of one sievert is enough to cause radiation sickness in a human.)

Mr. Hirose then led me underneath the reactor, onto what is called the pedestal.

The bottom of the reactor looked like a collection of huge bolts — the access points for control rods used to speed up and slow down the nuclear reaction inside a healthy reactor. The pedestal was just a metal grating, with the building's concrete floor visible below.

"The overheated fuel would have dropped from here, and melted through the grating around here," Mr. Hirose said, as we squatted to avoid banging our heads on the reactor bottom. The entire area around the reactor was dark, and cluttered with pipes and machinery.

To avoid getting entangled, the Manbo took three days to travel some 20 feet to the bottom of Unit 3.

To examine the other two reactors, engineers built a "snake" robot that could thread its way through wreckage, and the imaging device using muons, which can pass through most matter. The muon device has produced crude, ghostly images of the reactors' interiors.

Extracting the melted fuel will present its own set of technical challenges, and risks.

Engineers are developing the new radiation-resistant robots at the Naraha Remote Technology Development Center. It includes a hangar-sized building to hold full-scale mock-ups of the plant and a virtual-reality room that simulates the interiors of the reactor buildings, including locations of known debris.

"I've been a robotic engineer for 30 years, and we've never faced anything as hard as this," said Shinji Kawatsuma, director of research and development at the center. "This is a divine mission for Japan's robot engineers."
