Cleaning up Fukushima
The Decommissioning Process of Fukushima Daiichi

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Decommissioning Process

Decommissioning the nuclear power plants at Fukushima Daiichi will be a difficult and time consuming process. Not only the process but the equipment being used (the radiation levels are too high for human entry) are essentially being developed on the fly for this particular purpose.

Past nuclear incidents offer no help. The reactor at Chernobyl was entombed in concrete, not dismantled as is the plan for the reactors at Fukushima Daiichi. The reactor at Three Mile Island was defueled, but the pressure vessel and buildings in that case were not damaged, meaning the cleanup was of an entirely different magnitude. Lake Barrett, the site director during the decommissioning process at Three Mile Island and a consultant on the Fukushima Daiichi cleanup, says that nothing like Fukushima has ever happened before.

Inspection → De-contamination → Removal of spent fuel rods → Containment of radioactive water → Removal of nuclear cores

Inspection: Inspection robots developed → Inspection robots delivered to site → Robots travel through site → Robots send information back to operators → Information used to map site

Though the reactors have been shut down since the incident in March, 2011, the radiation levels remain too high for human access (and will be for some time). All access, including for inspection, has to be done by robot.

These inspection robots aren't your run-of-the-mill Roombas. Because of the steel and concrete structures involved with nuclear power, wireless communication is difficult. One type of robot used to survey got stuck in reactor 2 after its cable was entangled and damaged. The next generation of survey robots unspools cable, takes up slack when it changes direction and plugs itself in for a recharge. This last one is particularly important: not only can humans not access the reactor building, they can't handle the robots after they've been in there. The new robots should be able to perform about 100 missions before component failure, pretty impressive for access in a site where the hourly radiation dose can be the same as a cleanup worker's annual limit (54 millisieverts an hour).

De-contamination: Robots clear path through debris → Robots use jets of high-pressure water, dry ice to abrade surfaces → Robots vacuum up radioactive sludge → Radioactive sludge removed from building → Radioactive sludge stored

The next step requires even more robots, with different specialties. One type of robot will clear a path for another type, which will be outfitted with water and dry ice, to be blasted at surfaces in order to remove the outer level, and the radiation with it. The robots will them vacuum up and remove the radioactive sludge from the building. The resulting sludge will have to be stored, though the plan for the storage is not yet clear.

Removal of spent fuel rods: Crane-like machine lowers shielded cask into pool → Fuel assemblies packed into cask → Cask removed from pool → Cask transported to common pool

The decontamination step discussed previously dealt only with surfaces. Next, the fuel assemblies (those that are intact) are removed, further reducing the radiation within the buildings. A shielded cask is lowered with a crane-like machine, which then packs the fuel assemblies into the cask. The cask is then removed and transported to a common pool for storage. (The fuel assemblies must remain in water due to the decay heat still being produced.)

Containment of radioactive water: Stop flow of groundwater → Find leaks in pressure vessels → Fix leaks → Dispose of stored radioactive water

An ongoing issue with the Fukushima Daiichi reactors is the flow of groundwater through contaminated buildings. This water is exposed to radiation leaking from the pressure vessels, providing a constantly growing volume of radioactive water that has to be dealt with. First, the flow of groundwater must be stopped. The current plan is to freeze soil to create a wall of ice and put in a series of pumps to reroute the water.

Then, the leaks in the pressure vessels must be found and fixed. This will also likely be performed by robots (the facility will still not be safe for human entry), though the details aren't yet clear. Finding these leaks won't be easy as the entire pressure vessel is still submerged in water. If the leaks can't be fixed, the entire system may be blocked off with concrete.

Another challenge is what to do with the radioactive water being collected. So far, over 1,000 tanks have been installed. But these tanks have had problems with leaks. Public sentiment is against releasing the water into the ocean, though the contamination is low and of a form that poses a "negligible threat". The alternative would be using evaporation to dispose of the water over years, as was done after Three Mile Island.

Removal of nuclear cores: Flood containment vessels for shielding → Melted fuel mapped by robots → Drills break up pooled metal at bottom of vessel → Debris lifted into shielded casks → Casks removed to storage facility

Finally, the remaining damaged nuclear material must be removed. More mapping is required, to determine the location of the melted fuel, after the containment vessels have been flooded for shielding. This must include determining the properties of the metallic mess, which contains fuel as well as melted structural material in an unknown quantity and distribution.

This fuel must then be broken up using long drills capable of withstanding the radiation that will still be present. The debris will then be taken into more shielded casks to a storage facility, the location of which is yet to be determined. The operator of the plant estimates this process will take at least 20 years.