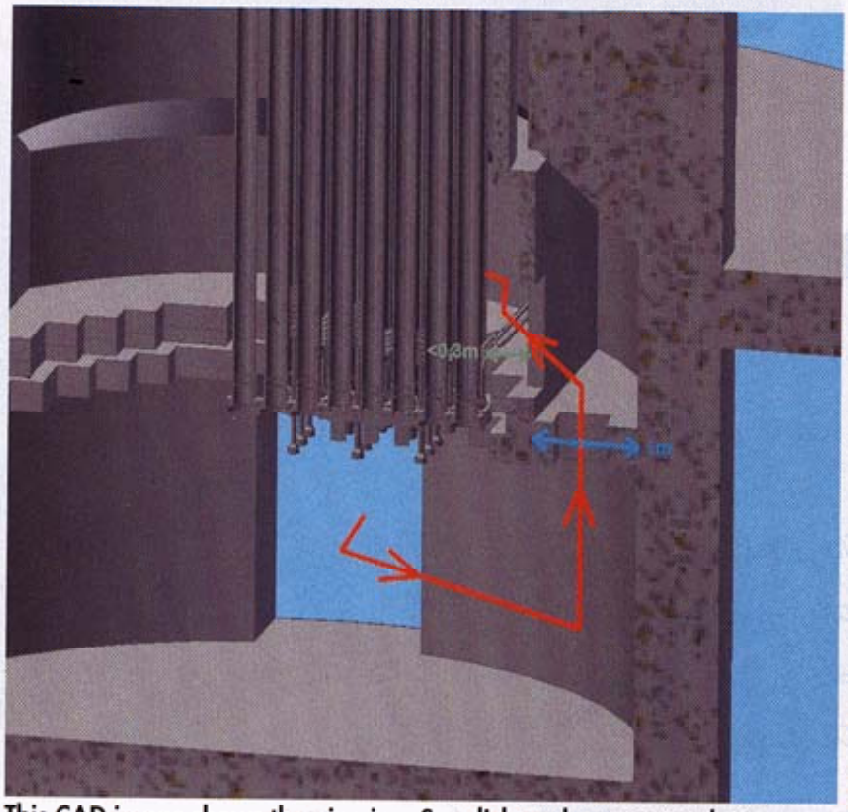
Snake let loose in reactor



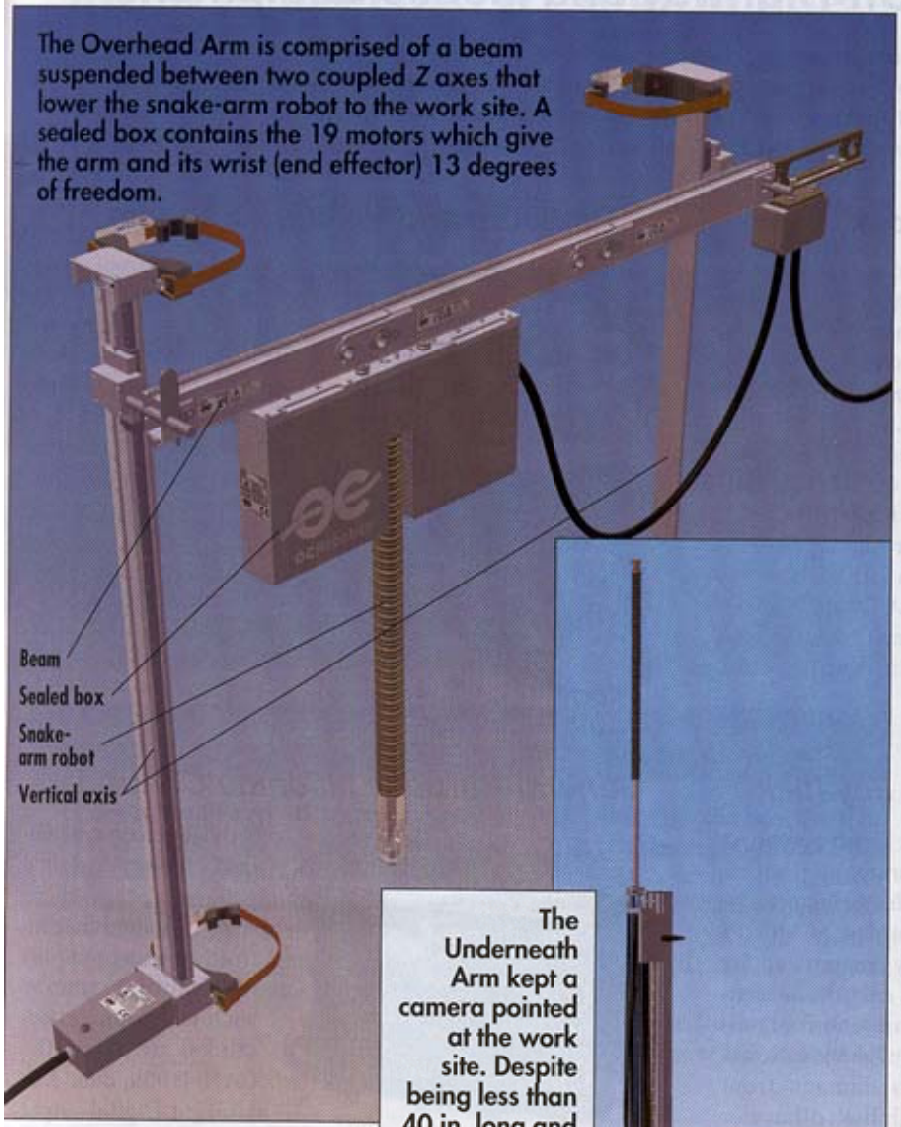
This CAD image shows the pipe in a Swedish nuclear reactor that needed repairs, along with obstacles in the way.

On paper, **Ringhals AB**'s problem was no big deal: the Swedish company had to replace a section of stainless-steel pipe that was part of a safety system activated when its nuclear reactor went offline in an emergency. But there was no physical line of sight to the 8-in.-diameter pipe and the largest access path was a 3.5-in.-wide, 31.5-in.-high corridor. The pipe is one of 157 spaced 4 in. from each other and running floor to ceiling along the edge of a circular room, nicknamed the Jungle, beneath the reactor core.

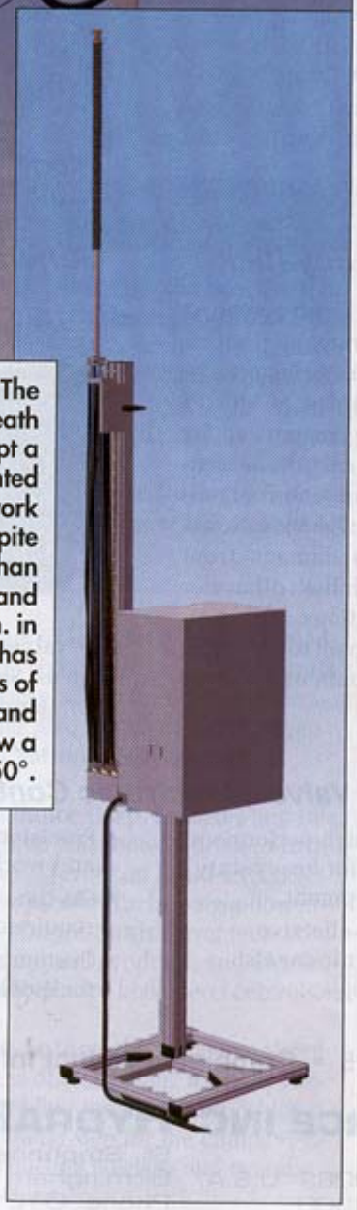
Only three companies bid on the project, and two wanted to cut away enough pipes in the Jungle to make a human-sized path. But there was no guarantee the pipes could be replaced, which meant the 800-MW reactor would have to shut down. The winning bid from **Uddcomb Engineering SA**, however, relied on snake-arm robots from **OC Robotics in Bristol**, U.K. (*Ocrobotics.com*). (See *Scanning the Field for Ideas*, June 19, 03).

Snake-arm robots are composed of stacked circular sections operating much like a human spine. Controlled sections attach to three actuators via three wires. The wires and other hardware connections are inside the sections, so the external surface is smooth. Software working at 350 Hz with a CAN-enabled servoamp controller calculates how much the actuators must push or pull to twist the robot into the desired shape. The robot can carry 22 lb at its tip and has three operating modes. Joystick path-following lets operators drive the tip by viewing a tip-mounted camera, and the computer forces the rest of the robotic arm to follow. The robot can also back up along the same path. Cartesian-tip mode lets operators move the tip with respect to a reference object. In this case, the reference point was the pipe itself. In this mode, the computer

Continued on page 37



The Overhead Arm is comprised of a beam suspended between two coupled Z axes that lower the snake-arm robot to the work site. A sealed box contains the 19 motors which give the arm and its wrist (end effector) 13 degrees of freedom.



The Underneath Arm kept a camera pointed at the work site. Despite being less than 40 in. long and 1.5 in. in diameter, it has 23 degrees of freedom and can follow a curve of 450°.

Continued from page 35

ensures the rest of the robot misses any obstacles the arm previously avoided. And joint mode lets each controllable section of the robotic arm be maneuvered independently.

OC Robotics built two special robots for the project, an Overhead Arm that weaved its way through the Jungle, and the Underneath Arm, which gained access to the repair site through a 2.5-in. hole drilled through the Jungle's 6-in. steel floor. After much practice in a mockup, technicians replaced a section of pipe in less than a month and showed Swedish nuclear regulators that the same solution would work for repairing any of the other pipes. This was a condition for letting operations continue at the reactor, which was already passed its expected end of life. ■