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# RoboExcavator: The Future Has Arrived

"LOOK, MOM, ONE HAND."

That sentence is no longer reserved for children being show-offs. It can also be applied to excavator operators who work with the Haz-Trak robotic excavator, developed by Kraft TeleRobotics Inc.

Not only can this excavator dig with only one hand running the controls, it can be remotely controlled from up to one mile away. In fact, one of the first things you'll notice about the Haz-Trak's appearance is its lack of an operator compartment. All of Haz-Trak's operations are controlled from a remote console using television cameras.

According to Steve Harbur, director of product development, Kraft TeleRobotics, the excavator works on the principal of "master slave bilateral force feedback control." In other words, the controls are operated like an extension of your arm, says Harbur.

"As the operator moves his own shoulder, elbow, wrist, and so on, corresponding joints on the operator's controller and slave excavator arm move together in parallel motion, as if they were physically attached to one another. Any control motions introduced into the master controller by the operator are instantly duplicated by the slave excavator arm."

The force feedback part of the system allows the user to "feel" what the excavator is doing. Harbur says tiny motors in the operator's hand controller respond to information from the excavator, allowing the operator to feel a portion of the resistance the excavator arm is experiencing.

If resistance from a buried object is detected, the operator can stop, look with the cameras positioned on the excavator and then decide how to handle the problem. The excavator can just as easily smash a buried object as it can lift it delicately out of the way.



**Kraft TeleRobotics' Haz-Trak is a remote-controlled excavator that can be controlled up to one mile away with the console. As the operator moves the controller (shown right of the chair), the boom and bucket will move in the same manner.**

But don't think all this technology makes it harder to operate, says Harbur. "Where it might take a couple months to get the feel for a conventional excavator with its hand and foot controls," he comments, "it only takes minutes to learn how to operate the Haz-Trak smoothly."

The excavator took Kraft more than two years to design. It came as a natural extension to the work they had done on force feedback manipulator systems (these are essentially robotic

arms). Kraft has sold manipulators to a number of customers, including NASA for work on the space station and space shuttle, and to utility companies for live-line work.

"We looked at going to work on a larger system with the same technology," says Harbur. "Since excavator booms work like a big human arm, we knew we could greatly enhance the control of such a system."

The team at Kraft bought an excavator and started the conversion process by taking out all the "man"-related parts along with the hydraulic system. They kept the diesel engine, turret, track system and then began the process of rebuilding the machine to make it into an agile, remote-controlled unit.

With the force feedback control technology in place, the excavator turns from a machine that has four different movements to one that has six. On a normal unit you have boom



swing left and right, boom up and down, crowd and bucket curl. With the robotic excavator you get the same three movements plus bucket yaw and bucket roll.

Yaw and roll are two functions that Harbur says would be nearly impossible to incorporate into conventional excavators because controlling them would overwhelm the operator (who is already using both hands and both feet). Having these functions is like adding a wrist between the end of the stick and the bucket; 360 degree rotation is available in both directions.

Currently the Haz-Trak, which was one of *Popular Science's* "Best of What's New" for 1992, is targeted for hazardous waste or other types of cleanup that would be dangerous for a human operator. The Haz-Trak can easily go in, dig the land and manipulate waste barrels while the operators are a safe distance away.

Harbur says, however, the Haz-Trak

can be used for any number of tasks including digging a trench, handling pipe and contouring the walls of an excavation. And, the Haz-Trak operates faster than a conventional excavator.

Specifications on this excavator are similar to those of a typical miniexcavator, although the technology can easily be applied to a bigger model:


- Reach: 16 feet
- Dig depth: 10 feet
- Digging force: 5,000 pounds
- Lift capacity: 1,700 pounds
- Excavator weight: 7,000 pounds
- Attachments include a bucket, a barrel handler and a wrist unit.

In addition, two small manipulator arms can be attached to the end of the boom to allow the excavator to do very delicate tasks. "They can crush concrete or sort eggs," says Harbur.

Because of its size, the Haz-Trak is easily transportable. It can also travel inside a building through a 57-inch doorway.


Harbur says that any type of material handler is a natural for this kind of control technology. "It can convert any of these machines into a dexterous, human arm-like unit."

Ultimately, Harbur says Kraft would like to license this technology to a major equipment manufacturer so they can adapt it to their machines. So far, the only Haz-Trak that exists is the prototype Kraft has been using in demonstrations.

Harbur says the people who come to the demonstrations are amazed at what the unit will do. With the success of these demos, the company is gearing up to produce a few machines for sale. The machines that Kraft makes carry a price tag of approximately \$600,000. Harbur notes, however, when the technology goes commercial, the price will drop considerably; the larger the base machine, the less the robotics will cost as a proportion of the total cost. 

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