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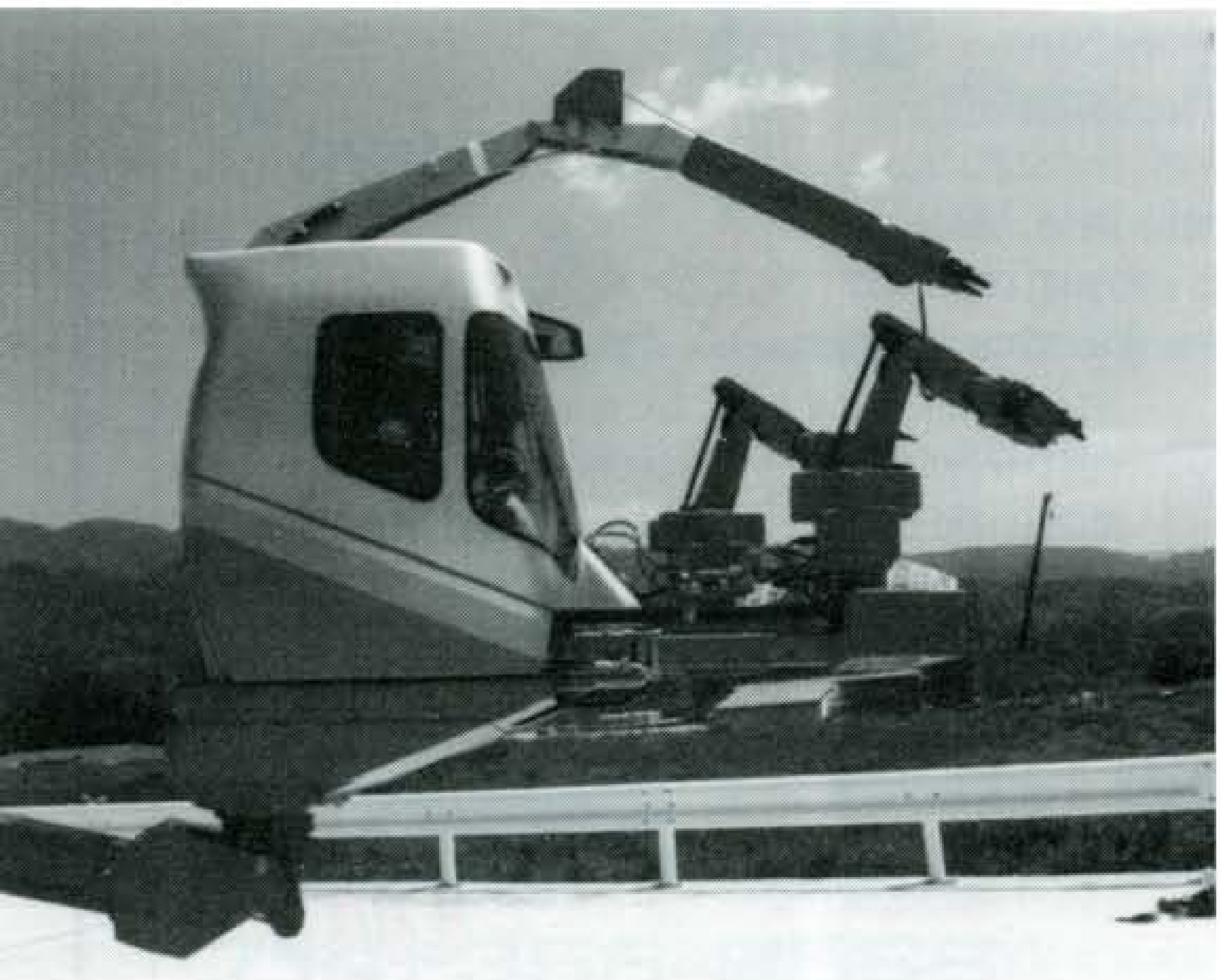
TELEROBOTICS: A TECHNOLOGY WORTHWHILE TO MAN

by Steve Harbur

Two hundred miles off the South Carolina coast, the pilot of a remote control submarine stares with intense concentration at the television monitor directly in front of him. As he slowly maneuvers the massive undersea vehicle, images of a 19th century ship wreck, 8,000 feet below, fill his eyes with anticipation.

Suddenly, an unmistakable yellow shimmer appears on the screen, and a golden treasure reveals itself after more than a century beneath the waves. With the treasure now in plain view, the remote pilot reaches out with a human-like robotic arm, as if it were his own arm, and begins to delicately retrieve gold coins and valuable artifacts from the ocean floor.

The robotic arm technology being used by this modern day treasure hunter is "telerobotics." Simply put, telerobotics is technology for the remote operation of robotic devices. Typically, such devices are manipulator arms, which are used a direct replacement for the human worker in hostile environments. Unlike an industrial robot, which performs repetitive tasks in response to a computer program, a telerobotic system responds to the direct commands of a human operator, as if the robot were an extension of that operator.



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DAWN OF TELEROBOTICS

Telerobotics began in the early days of nuclear power, when mechanical arms were needed to replace human arms in the radioactive environment. Within a few years, hundreds of mechanical and electrically powered manipulator arms were in use within the nuclear industry.

As the world took notice to this technology, the energy crisis of the late 1970s and early 80s was just beginning, and the offshore oil and gas industry, desperate to find new reserves, was moving into deeper waters. A replacement for the human diver was needed, and telerobotics was waiting in the wings.

The development of telerobotic manipulator arms for the nuclear industry had been very successful, but the environmental situation offshore was dramatically different, and mechanical or electrically powered arms were not suitable. Replacing the human diver would require manipulator arms that could work underwater, and hydraulics was the answer.

In the very beginning, hydraulically powered undersea manipulators were no match for their nuclear industry cousins. The primitive control systems and limited dexterity of these early arms could not be compared with the more advanced capabilities of the nuclear manipulator, however, the hydraulic systems worked well in the undersea environment.

During the boom era of offshore oil exploration, undersea manipulator technology steadily improved, but despite all the gains, the nuclear systems still had a significant advantage, and that advantage was force feedback. Force feedback provides the manipulator operator with a physical and mental dimension of feeling. This creates a mental illusion or "telepresence" as if the manipulator were an extension of the operator's own arm. This technology had transformed the nuclear manipulator into a hu-

Unlike an excavator operator, the manipulator operator is intuitively linked to the arm he is controlling through a single hand controller that is responding to his own natural arm motion.

man-like machine, capable of performing tasks of significantly greater complexity, and the development of force feedback control technology for hydraulic systems soon became a priority among the most advanced of the subsea manipulator manufacturers.

In 1988, Kraft Telerobotics introduced a revolutionary new force feedback manipulator system for undersea use. Hydraulically powered, the new system employed custom, state-of-the-art electronics and advanced computer technology to provide the manipulator operator with a level of force feedback, dexterity and controllability never before realized. Telerobotics had experienced a major breakthrough, and new standards of performance, reliability, serviceability and cost effectiveness were established.

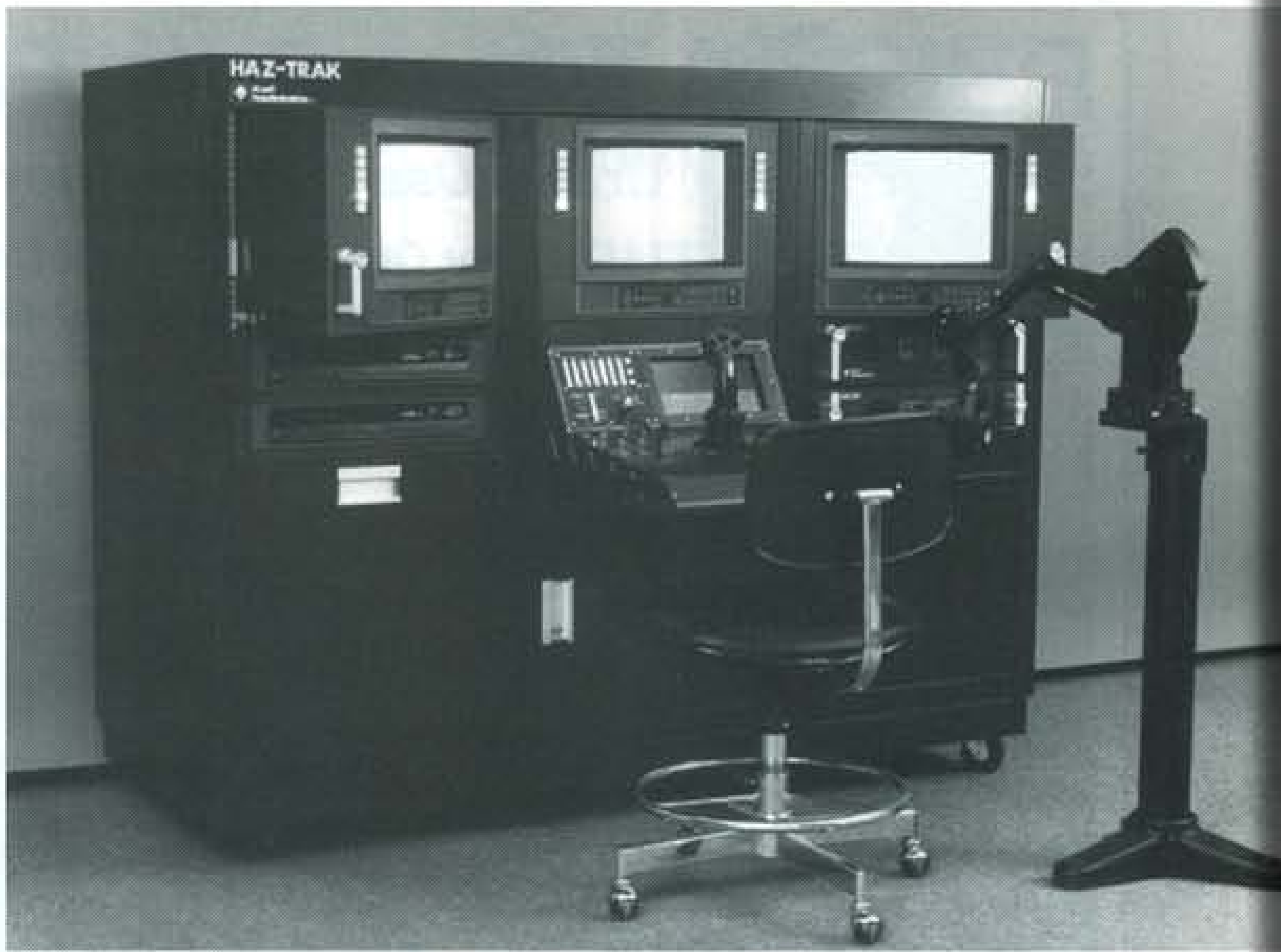
CONTROLLING HYDRAULICS

Today, in addition to its intended use undersea, this manipulator system has found application in a variety of industries, and demonstrated to the world a remarkable new way of controlling hydraulics. The operator of a conventional hydraulic system, like that of a backhoe excavator, is confronted by a control system consisting of multiple levers or joysticks. Although considered modern, this type of control system is not intuitive. It can take an excavator operator, using both hands, 600 to 800 hours of practice to master the controls of a digging arm that has only four basic motions.

By comparison, the same operator using only one hand could easily learn to control the six basic motions of the force feedback control console. The excavator vehicle is a hydraulically-powered, microprocessor-controlled machine with a diesel power plant that supplies all the necessary electrical and hydraulic power for vehicle operation. Locomotion is provided by two independently controllable hydraulic motors each driving a single track.

When operating in confined spaces, counter rotating track capability allows the vehicle to execute 360-degree turns about its own axis.. System versatility is further enhanced by a hydraulically powered dozer blade that can be used for grading, backfilling, or leveling of the vehicle on sloped surfaces. The excavating and material handling capabilities of the system are provided by the mater/slave force feedback excavator arm.

Basic arm motions include boom swing, boom elevation, crowd, and bucket curl, with yaw and roll motions optional for material handling and other tasks. Additional system flexibility is afforded by the vehicle's turret with attached excavator arm, which can be rotated continuously through 360 degrees. The excavator is also equipped with a viewing system designed to provide the operator with optimum camera perspective for remote operation of the tracked vehicle and excavator arm. The basic viewing system includes two fixed color cameras for peripheral vision, and a single pan and tilt-mounted color work camera with auto iris, auto focus and zoom. The pan and tilt unit can be configured with various combinations of video and still cameras.



The control console is designed to permit full system operation by a single person from the center bay.

CONTROL CONSOLE

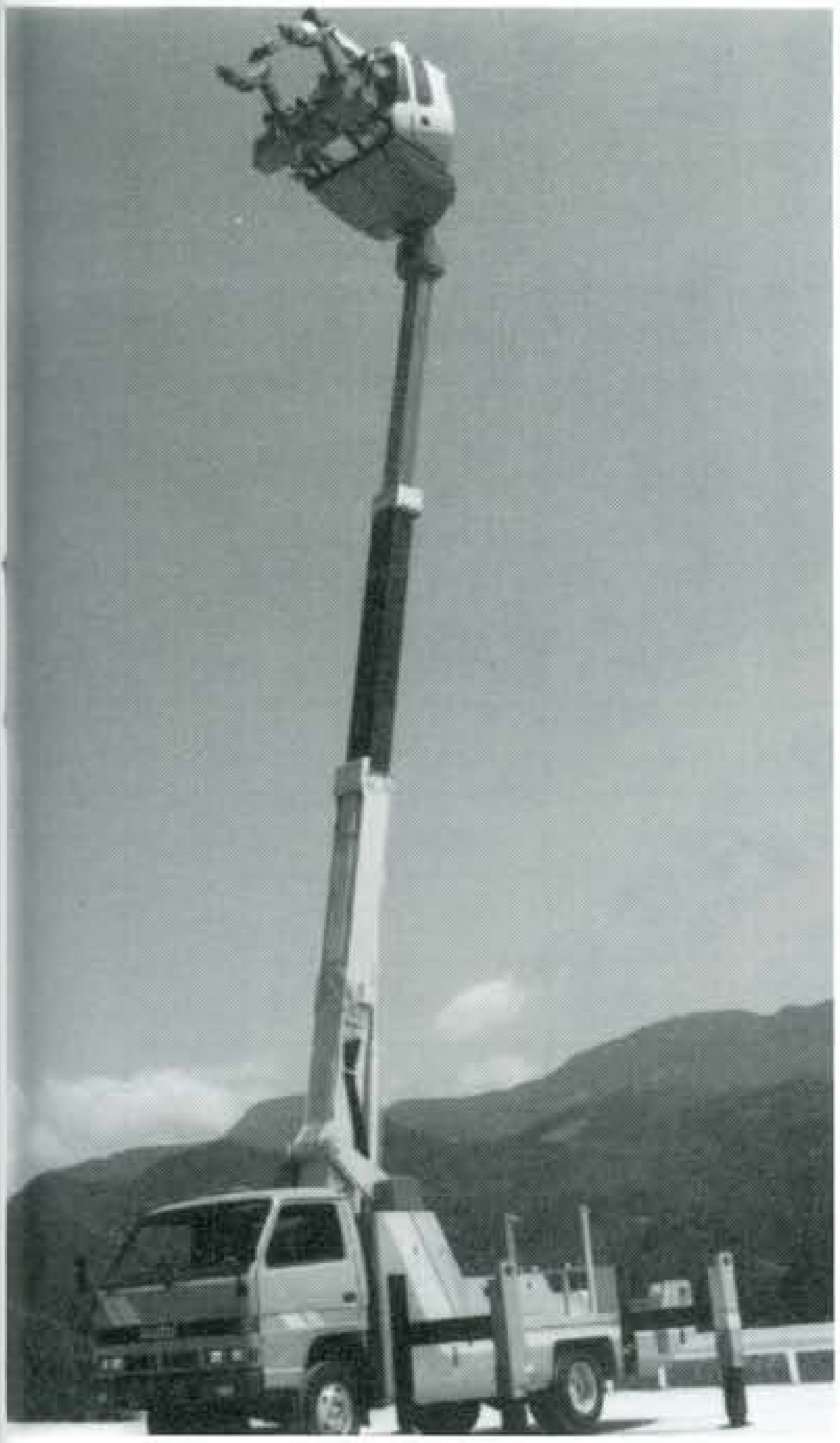
The operator's control console incorporates a variety of controls and displays for the remote operation and supervision of the system. The control console is divided into three 19-inch rack mount bays. All rack mounted equipment and major assemblies are carefully integrated to produce a rugged, reliable operator station with an emphasis on human factors design.

The control console is designed to permit full system operation by a single person from the center bay. High resolution 13-inch color monitors are mounted in the right, center and left bays of the console. The left and right side monitors are hinged and may be adjusted inward by the operator to provide an optimum viewing angle. The panoramic view afforded by these peripheral monitors greatly enhances operator awareness of the excavator's surroundings.

The center bay of the control console features a two axis, fully proportional, displacement-type joystick for control of vehicle speed and direction. Moving the joystick forward or backward will cause the vehicle to move forward or backward at a speed proportional to joystick displacement. Twisting the joystick about the vertical axis, while moving the joystick forwards or backwards, will cause the tracked vehicle to execute a left or right turn.

Twisting the joystick while in the center "off" position will cause the vehicle to execute a clockwise or counter-clockwise 360-degree turn about its own axis. A trigger switch mounted in the joystick serves as a safety interlock that must be depressed by the operator in order to initiate any vehicle motion commands. A thumb-operated switch on the joystick is provided for control of the dozer blade.

The force feedback excavator arm is controlled using a single compact master controller. This controller is in fact, identical to the master controller used when operating the GRIPS force feedback manipulator, and the excavator arm behaves as if it were simply a large manipulator. Similar to the human arm in terms of motion, this controller provides the operator with a comfortable interface, a high degree of dexterity, intuitive operating qualities,



A lineman operator using two insulated force feedback manipulator arms, is ready to perform a variety of complex tasks on energized distribution lines.

and the sense of feel that only a force feedback controller can provide.

TECHNOLOGY DEMONSTRATION

Although this new excavator is remote controlled for the handling of hazardous materials and nuclear waste, this new machine is also a technology demonstration that represents revolutionary new capabilities and design opportunities for the utility construction industry.

New technology is also on the doorstep of the electric utility industry. Inside the air conditioned cab at the end of an insulated boom, a lineman operator using two insulated force feedback manipulator arms, is ready to perform a variety of complex tasks on energized distribution lines. Whatever the task, the operator will perform the whole job in about the same time it would normally take, but it will be done with one person, without ever having to leave the seat in the operator's cab. It's not intended to replace linemen, but rather give them a new, safer tool to work with.

The insulated manipulator arms, which have gripper hands to hold tools and perform tasks, may be extended or retracted from the base of the molded operator's cab. The manipulator arms can be assisted in their work by an articulated boom winch mounted on top of the cabin. The winch, which has a lifting capacity of 300 pounds, can be used to raise objects from the ground that will be positioned and installed using the manipulator arms.

The lineman operator in the cab atop the boom has full control of boom positioning through a fiber optic system, and fiber optics are also used to control the hydraulic manipulator arms. The entire system is insulated to withstand voltages several times greater than the energized line voltage, allowing the lineman operator to work live line, and do whatever work is necessary in any kind of weather. Older more experienced linemen lost to the work force because of physical demands, can now be actively utilized in the field.

You may think of it as futuristic, but fully operational systems are already working in Japan, and the safety aspects, productivity and general usefulness of these systems has been recognized in Canada and Europe as well.

A Canadian utility company has recently completed the fabrication of a prototype that is similar to the Japanese system. The United States has also entered the picture with the purchase of manipulator systems by a major utility company for use in developing their own prototype.

As telerobotics finds its way into the cabs of excavators, material handlers, and electric utility robots, the possibilities seem endless. A solution for new applications and the answer to old limitations has been found. **UCM**

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