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UNDERWATER

MAGAZINE

ASSOCIATION OF DIVING CONTRACTORS
SUMMER 1998

Visions IN Sonar

An Underwater Pictorial Worth A Thousand Words

INLAND PROJECTS • ROV WELD INSPECTION • UW CONNECTORS • UPGRADING YOUR ROV

Force Feedback: Manipulators Put Operators In Touch

By Steve Harbur

With the latest boom in the offshore oil and gas industry pushing exploration into unprecedented water depths, it has likewise brought about further refinements of ROV technology, particularly in the area of manipulators and their applications.

Simply put, manipulators are used as a direct replacement for the human worker in hostile environments. Unlike industrial robotic arms, which perform repetitive tasks in response to a computer program, ROV-mounted manipulator arms respond to the direct commands of a remote human operator, as if the manipulator arm were an extension of that operator's own arms.

A History Lesson

The need for remotely operated manipulator arms was recognized 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 of this technology, the energy crises of the late 1970s and early 1980s 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 manipulator technology was waiting in the wings.

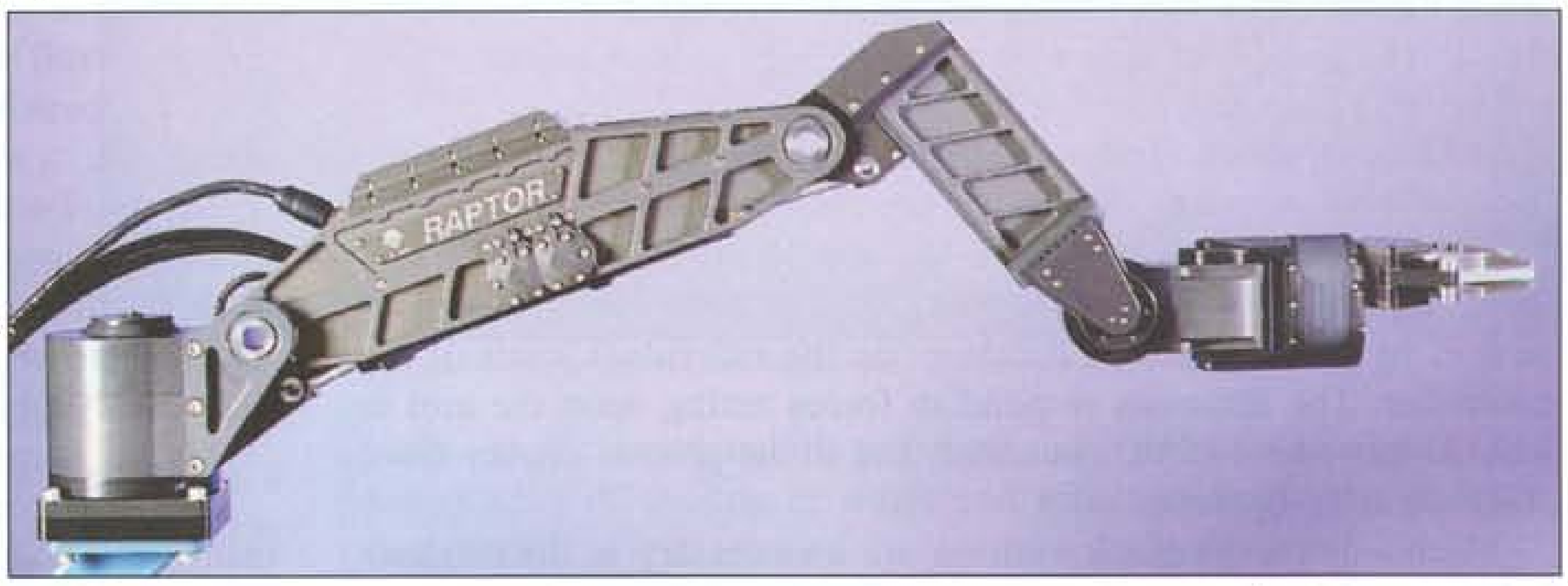
The development of telerobotic manipulator arms for the nuclear industry was very successful, but the environmental situation offshore was dramatically different, and mechanical or electrically powered arms were not suitable. Replacing the human diver would require manipulator arms that could work underwater,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

Force Feedback

During the offshore oil boom, undersea manipulator technology steadily improved. But nuclear systems still had a significant advantage – force feedback. The nuclear industry had demonstrated that force feedback control greatly improves the operator's level of awareness and ability to perform remote tasks.

Force feedback allows the operator to control the amount of force the manipulator arm can exert at the work site. Additionally, unlike conventional hydraulic manipulator arms which must rigidly withstand all the forces acting upon them, force feedback manipulators with bilateral control have the ability to move in compliance to these forces. All the joints in a force feedback arm are compliant, meaning they can move to keep the arm from breaking. The ability of the operator to control the amount of force exerted by the manipulator, and the ability of the arm itself to respond to force, as opposed to resisting it, dramatically reduces the risk of damage to manipulator and the work site. When the manipulator is attached to a dynamic platform, like an ROV, this characteristic of inherent compliance greatly enhances the ability of the manipulator arm to survive extreme forces and heavy work loads.

Despite the enthusiasm over force feedback in the early 1980s, development slowed due to cost and performance issues. In 1988, Kraft Telerobotics in Overland Park, Kan., introduced a revolutionary new force feedback manipulator system for undersea use. Hydraulically powered, the new system employed custom electronics and computer



Kraft's Raptor offers the option of force feedback, allowing the operator to feel the movement of the arm underwater.

technology to provide the operator with a level of dexterity never before realized. However, a slump in the offshore oil and gas industry slowed manipulator development. Today, since the upswing in the offshore market and the introduction of Kraft's Predator and Raptor systems, offshore sales have increased dramatically.

The ROV-mounted manipulator, with a man in the control loop, is an extension of the operator. In the future, even more emphasis will be placed upon the ability of the remote manipulator arm to complete complex and delicate tasks.

Dispelling the Myths

Myth – Force feedback manipulators are delicate devices that provide the operator with a sense of touch and feel.

Fact – A hydraulic force feedback manipulator and a standard position controlled hydraulic manipulator are very much alike. The primary difference is the way in which the arm is controlled.

A standard position controlled manipulator responds directly to the operator's commands as he moves the controller. Moving the controller at one end makes the manipulator arm move at the other end. When the controller is not being moved, the manipulator arm remains rigidly in place. The arm will respond only to movement of the controller. This is called unilateral control.

A force feedback system works the same way, but in both directions. If you move the controller, the manipulator arm will move. However, if you push or pull on the arm itself, the controller will move, and the two will move together. This bilateral control is accomplished by placing electric actuators on the individual joints of the controller. The actuators respond to forces acting upon the arm to provide movement of the controller, and in the process convey force feedback to the operator.

Myth – Force feedback systems are unnecessary in the offshore industry.

Fact – Force feedback allows the operator to control the amount of force the manipulator can exert. Unlike hydraulic arms, which must rigidly withstand all the forces acting upon them, force feedback arms with bilateral control have the ability to move in compliance to these forces. The ability of the operator to control the amount of force exerted by the manipulator, and of the arm to respond to force, as opposed to resisting it, reduces the risk of damage to manipulator or the work site. The joints in the arm keep it from breaking.

Myth – Force feedback manipulators are more fatiguing to operate.

Fact – Force feedback does make the operator perform a small percentage of the work. However, the intuitive nature of a force feedback system greatly reduces the mental fatigue associated with long periods of operation. Reducing mental fatigue is important, as the amount of force feedback, and therefore physical fatigue, the operator experiences is variable and can be adjusted or turned off altogether to satisfy his needs.

Myth – Force feedback manipulator systems are more complicated and are therefore unreliable.

Fact – Force feedback systems have demonstrated exceptional performance and reliability. Force feedback technology does not reduce overall reliability. Indeed, the benefit to the operator of having force feedback significantly reduces the risk of damage to the manipulator arm.

Myth – Force feedback systems are not field serviceable.

Fact – Force feedback systems are not significantly more complex than standard systems and are completely field serviceable. Comprehensive self-diagnostic routines allow the operator to quickly diagnose a problem and bring the manipulator back on line.

Myth – Force feedback manipulator systems are too expensive.

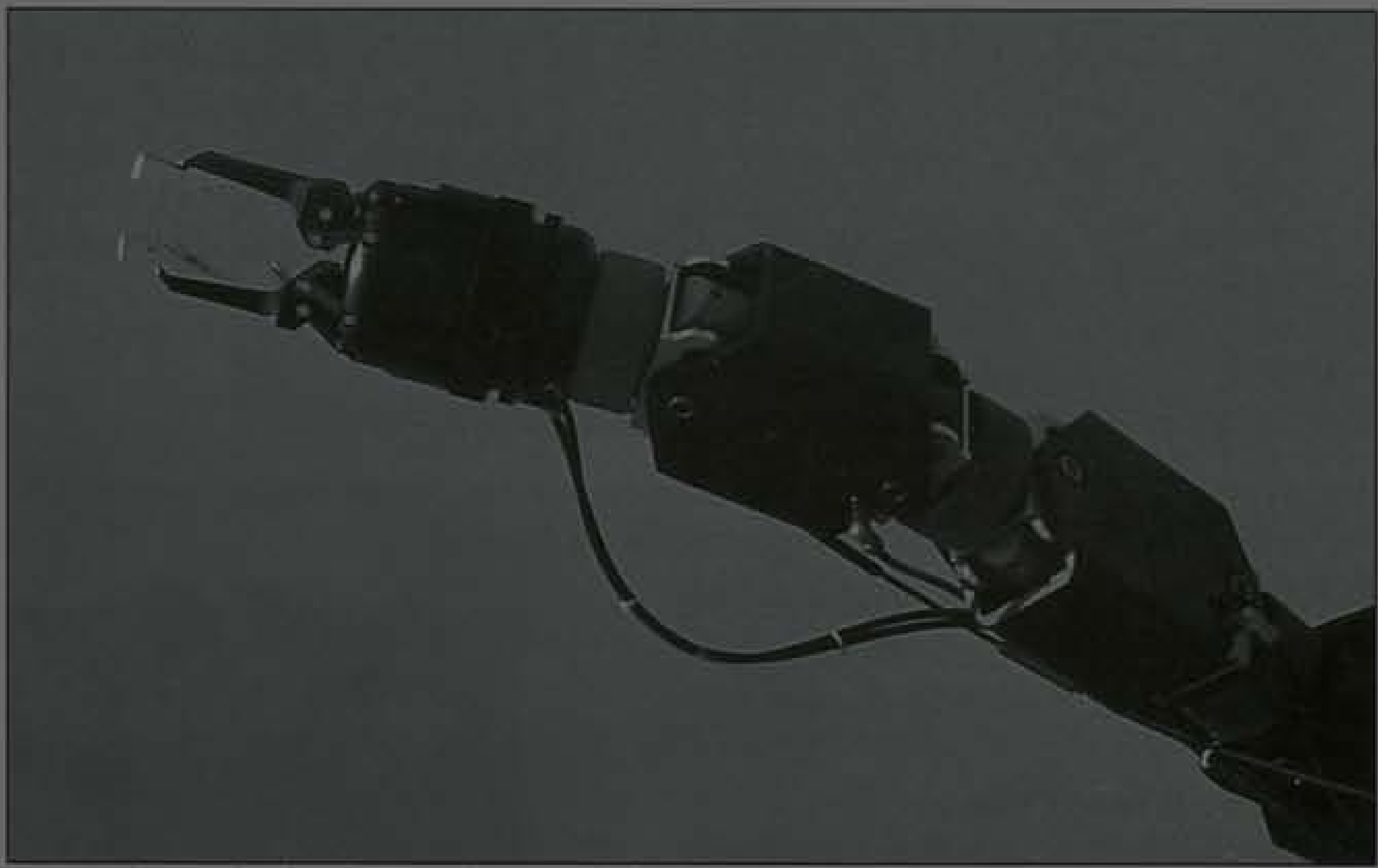
Fact – Force feedback systems are competitively priced and in many cases do not cost any more than conventional systems. **UW**

Steve Harbur, Director of Product development for Kraft TeleRobotics, has 26 years of subsea systems experience.

MANIPULATOR ROUNDUP

"ARMING" ROVS FOR UNDERWATER TASKS

Although advances in ROV manipulators benefit both the inland and offshore service providers, it is the oil and gas industry which is the driving force behind this technological development. The recent upswing in the offshore market means exploration in waters of greater depth than ever before, which in turn sparks new advances in robotic capabilities and manipulator design, which in turn allows even deeper exploration. Here's a look at the latest the market has to offer.



DOE's electro-hydraulic Hawkes tactile feedback sensory manipulator.

ALSTOM SCHILLING ROBOTICS

Last year represented a record sales campaign for SRS, with 166 systems sold, 44 of them the top-of-the-line Titan III arms. Schilling has a number of new products in the works to make remote operations easier, with an emphasis on simplicity. The newest standard manipulator is the rate-controlled Orion 7R. Specifically designed to fill the need for a lightweight, compact remote system, the Orion tackles subsea operations at depths up to 21,320 feet (6,500m). Featuring a maximum reach of 58.5 inches and lift capacity of 550 pounds, it is aimed at ROVs too light to carry Schilling's larger Titan or Conan manipulator models. The new position-controlled model, the Orion 7P, is designed for tasks that require the accuracy and sophisticated control of a closed-loop position-controlled system.

ISE LTD.

International Submarine Engineering Ltd.'s Stear Testbed Manipulator System (STM) has two seven-degrees-of-freedom manipulators with associated control computers. They are similar to human arms, with much greater dexterity than traditional robotic manipulators.

Cartesian and Impedance control have been implemented on STM. Impedance control gives the manipulator the ability to control the forces applied by the end effector. The actuators and control software are modular, allowing easy modification of manipulator kinematics and control strategy.

The STM computer control system is based on a Penitum PC, running Windows NT, with a digital signal processor. The control software, ACE, is also used for industrial automation, with applications including machine and process control.

Jim McFarlane, President of ISE, says one of the company's most exciting recent manipulator projects is the land-based SmartPump, developed for Shell Oil. It's a totally autonomous fueling system that will fill a car with gasoline while the driver sits comfortably inside.

> *"The recent upswing in the offshore market means exploration in waters of greater depth than ever before, which in turn sparks new advances in robotic capabilities and manipulator design..."*

DEEP OCEAN ENGINEERING

Deep Ocean Engineering's standard line includes Hawkes four- and six-function systems with tactile feedback sensors. Each boasts dedicated electro-hydraulic actuators for each manipulator function, and come in large (150 pound payload) or small (20 pound payload) sizes. Applications include grasping and maneuvering objects, and positioning of tooling or other end effectors to depths of 2,000 feet (600m).

DOE's tactile feedback sensor is designed to augment an operator's senses on the job. Dirk Rosen, President of DOE, says, "Electronically generated sounds allow the operator to hear how much force he is exerting on an object. An accelerometer sound allows the operator to hear the difference between different materials. A skilled operator can distinguish between an unpainted metal surface, a painted metal surface, wood, and rock."

KRAFT TELEROBOTICS

The Predator seven-function manipulator is a powerful, long reach system designed to work in deep ocean and hazardous inland environments. Operating as a position controlled, closed loop servo system, movements introduced at the master control arm by the operator are duplicated by the slave manipulator, allowing the operator to perform complex work tasks with human-like motion and speed. Force feedback and computer-aided modeling are optional features.

Kraft's Raptor manipulator shares many common components and capabilities with the Predator, but in a more compact design. Raptor was designed for the new wave of smaller work class ROVs for use in applications such as drilling support. The primary differences are that Raptor has a stowed height of less than 36 inches and a 64-inch reach, while Predator boasts a 45-inch stowed height and an 80-inch reach. Both arms weigh less than 100 pounds in seawater.

SLINGSBY ENGINEERING LTD

Slingsby Engineering Ltd. (SEL) is now completing the design of its latest manipulator, Hydrus (The Water Snake), a six-degrees-of-freedom master/slave system with claw, for underwater applications. High dexterity is achieved by the use of rotary-vane actuators at four of the joints, thereby eliminating the restrictions imposed by