AN INTERNATIONAL PERSPECTIVE ON ROV TECHNOLOGY

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Combined Diver & Submersible Operations
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An International Perspective
On ROV Technology

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ABSTRACT
The ROV'92 Conference and Exposition, the 10th in a series of successful high technology events, was held on 9-12 June 1992 in San Diego, California, USA. The conferences, sponsored by the Remotely Operated Vehicle Committee of the Marine Technology Society has been held in San Diego in 1983, 85, 89 and 92. Other locations included Aberdeen, Scotland (86), Bergen, Norway (88), Vancouver, British Columbia, Canada (90) and Hollywood, Florida, USA (91). This paper will provide an overview of the technology presented at the conference and a discussion of its relevance.

INTRODUCTION
The conference exhibition provided an array of products and systems which underscore the maturity of today's ROV technology. State-of-the-art manipulators, displays and deep ocean systems have now reached a level of reliability unknown a decade ago when the first ROV conference was held. The integration of advanced technologies into operational systems was highlighted by the U.S. Navy's exhibition at the entrance of the exhibit hall. The goal of conducting search and work to depths of 20,000 feet was represented by the Advanced Tethered Vehicle (ATV) and the Advanced Unmanned Vehicle (AVS) and the Advanced Unmanned Search System (AUS). The ATV, developed by the Naval Command, Control and Ocean Surveillance Center's Research, Development, Test and Evaluation Division and now operated by the Submarine Development Group's Unmanned Vehicle Detachment holds the present depth record of 20,600 feet. This accomplishment is matched by the success of the Navy's CURV III vehicle operated by Eastport International which was the first to reach 20,000 feet only days earlier. The ATV was designed to be the recovery vehicle, complementing the search capability of AUS. The AUS, a semi-autonomous, acoustically controlled search system was designed to provide an order of magnitude increase in the efficiency of the search rate. Having no tether, it can efficiently search a large area without being tethered to a ship and the constraints imposed by such a large. Sonar images and pictures displayed of a bomber located off the coast of California, which were transmitted topside via the acoustic communication link, provided proof of the maturity of such technology and how a dual system such as ATV and AUS provide a logical compliment. Also on display at the Navy's booth were acoustic communication link techniques, fiber optic communication links, and advanced ceramic pressure hulls, all of which will play significant roles in the future on Navy systems. These technologies will be discussed later in this paper.

It is fitting that the Navy display encompass the overall capability of ROVs since the Navy spearheaded the development of ROV technology. This historical perspective was recalled by Sheafer and Metzler as they discussed the Navy's development of the first Mobile Underwater Vehicle System by VARE Industries in 1961 called the XN-3 (1). This was a time when shaft seals failed, the cameras were damaged by sunlight, the electrical systems were noisy and the reliability was "very poor, hard to maintain and keep operational." The early stages of vehicle development and the associated problems are countered by the latest high tech system under development in Japan by the Japan Marine Science and Technology Center (JAMSTEC) (2). The new system, which is scheduled for operation in 1993, will be a 10,000 meter tethered vehicle which will be operated from the support ship Yokosuka. It will have a towed search capability and an integral ROV with a short tether which can be deployed for work and inspection. The most important consideration, however, is the capability it provides to recover the manned submersible Shinkai 6500, which will operated off the same support vessel, in an emergency. The operational capabilities which exist today and the emerging technologies that allow the development of such 10,000 meter systems will be discussed in the following sections.

OPERATIONAL SYSTEMS
This section will discuss the capabilities which exist with systems which are presently operational in the field.

Recovery and Salvage
The exploits of Eastport International are becoming well known as they tackle jobs from flight recorder recovery to insurance investigations. Their latest venture resulted in the recovery of a helicopter from a depth of 17,250 feet (3). This test of systems and ingenuity was conducted by the U.S. Navy's Supervisor of Salvage working with Oceaneering and Eastport. The initial search phase was conducted using the ORION towed search system, operated by Oceaneering for the Navy which uses 36,000 feet of fiber optic cable. The recovery was ultimately completed by the CURV III vehicle operated by Eastport thorough the use of traction winches, heave compensators and specially built reels of Kevar lift line which are taken to the sea floor for attachment. It is obvious that few objects are now beyond the reach of today's technology.

Complimenting the exploits of the Navy is the work conducted by AT&T's SCARAB (Submersible Craft Assisting Burial And Repair) vehicle (4). These systems (4 in all), operated by their subsidiary, Transpacific Communications, Inc., provide the capability to locate, cut and recover telecommunication cables. In addition, they can use the jetting and excavation skid to re-bury the cable. These systems provide some of the latest control techniques for the operator including computer graphics and pull-down menus which assist in proper deployment configuration based on the underwater operating conditions. The displays provide the data necessary for the operator to complete the burial process. Us:ig these graphical techniques and large high definition monitors, the banks of switches and gauges previously used have been totally eliminated. Such technology is responsible for saving AT&T a revenue loss of $1,000,000 per hour.

Subsea Intervention
In the early days of ROV intervention in the oil patch, the talk revolved around the "all purpose" vehicle, a system which could do everything for everyone. This concept was soon proven to be unworkable, except for very minor tasks. The reality of subsea intervention was that tasks were for the most part very complicated and often required very large "tools" or forces to complete the task. When the work was being performed at dive depths, the ROV intervention techniques were often considered a secondary approach, since one always had the diver. Unfortunately for the diver, the future dictates that subsea wells will be located in waters far beyond their capability, a realm where only ROVs will be able to work.
The future of subsea intervention was highlighted in several presentations where "ROV friendly" subsea equipment is developed. Such equipment can be worked on modular vehicle systems using high-speed data links and bidirectional communication. The latest version of Marguest's SHARPS (Sonic High Accuracy Remote Positioning System) which uses a hardened computer and one-way travel times between transducers on the vehicle and those in the water (13) can achieve a position accuracy of 2 cm at a range of 1000 meters. The Marguest Group is currently investigating the SHARPS system with plans to develop autonomous ROV intervention systems. This technique has been demonstrated, allowing vehicles to automatically dock and undock of an underwater fiber optic connector using a ROV and the development of a high speed micro-cable manufacturing technique which was subsequently transferred to industry. The underwater multichannel capability to transfer 220-Mbps from the remote vehicle back to the launch platform. The new manufacturing process is used to make a 0.35 inch diameter cable by laminating an annulus of fiberglass yarn and an ultraviolet curable resin around a standard, dispersion-shifted, single-mode optical fiber. This is cured through the application of a dose of intense ultraviolet light. This process was transferred to industry via the Navy's Manufacturing Technology Program. The future application of such communication links include use in an expendable systems such as torpedoes or in providing high bandwidth communication links with advanced battery powered systems. The next logical step in eliminating the tether from the ROV is onboard processing capability and sensing continually increases, though the application of expendable micro-cables.

Navigation
Long base line navigation and tracking systems have been around for some time, however, it has just been recently that the capability to accurately navigate a vehicle on a micro scale has been available. The Marguest Group recently developed the SHARPS system which uses a wireless version of the SHARPS system. The Marguest Group is currently working on a system that will be used to provide autonomous navigation and tracking systems for ROVs. The Marguest Group is also addressing remote control of ROVs, allowing the operator to control the vehicle remotely. The development of such systems allows the use of programmable trajectory planners, allowing the operator to choose vehicle velocities, accelerations, paths, and waypoints. The capability to automatically dock a vehicle using this technique has been demonstrated, which can be highly useful by the systems described in the previous sections. This paper.

Lasers and Optics
Lasers are playing a constantly increasing role in underwater applications. New underwater imaging systems are coming on line and various applications are being developed by researchers around the world. Japan is investigating applications of the pulse laser for depth sounding and observation of underwater structures and hopes to develop underwater laser camera systems (15). Work being done in the United States (16) shows that a laser scanning system to present an underwater image can be used to improve the field of view of ROVs. This technique has been demonstrated, a demonstrator which can be highly useful by the systems described in the previous sections. This paper.

Manipulators and Work Systems
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Advances are continueing to be made in the integration of manipulators, vision and control systems. The goal of providing a real "human presence" at the work site continues and will eventually make the ROV system available to the human operator. In work being conducted in the U.S. by the National Aeronautics and Space Administration (NASA), ROVs are being used to investigate teleoperator controlled vehicles for use during the "future exploration of Mars" (17). Their investigations included the use of a head mounted display and a magnetic field sensor to track the position of the vehicle and control the remote vehicle's tilt mechanism. Another area where great strides are being made is automatic cleaning and inspection of offshore structures. The Norwegian Institute of Technol-
ogy is conducting investigations with a manipulator using a force
transducer in the wrist to grind welds for inspection (20). They find
that their technique is workable if a robotically controlled manipulator
can be built with enough bandwidth in the force control loop.
To alleviate the problem of high bandwidth control systems, University
College London is investigating the use of a compliant wrist unit to
absorb errors in manipulator motion (21). They expect this to be a
technique available for use with little prior knowledge of the weld
geometries. A more geometric approach to the problem is taken by GKSS
in Germany (22). As part of the OSMRIS (Offshore Integrated Robotic
Inspection/Intervention System), they are developing a control system
which will use the off line programming and graphical simulation of the
system to allow an ROV operated manipulator to conduct NDT tasks.
Such techniques will eventually be combined with call up graphical
representations of the structure being worked on, and when used with
properly programmed manipulators and end effectors, will be able to
fully automate the inspection process.

Pressure Resistant Structures

Conventional materials used for deep ocean pressure vessels have
included stainless steels, aluminum and titanium. Advances have now
been made where materials such as ceramics can be used which
provide anywhere from 3 to 5 times higher strength for each pound of
material (23). Alumina ceramic pressure housings can now be
developed with weight to displacement ratios in the 0.4 to 0.6 range
for 20,000 foot applications. This can be pushed too 0.35 using boron
advances made since then, the capabilities which will be achieved
with the technology base available during the development of ROV-3 by the Navy over 3 decades ago, and the advances made since then, the capabilities which will be achieved
during the next 3 decades should be truly astounding. The age of virtual
reality, programmed operation and totally autonomous systems is just
around the corner.

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In particular, I would like to thank the officers of the ROV Committee who have organized the conferences and remained loyal to the quest of
providing a "Decade of Excellence".