UUVs: DEEP OCEAN APPLICATIONS

Robert L. Wernli
Naval Command, Control and Ocean Surveillance Center
RDT&E Division

Abstract

Unmanned undersea vehicles (UUVs) have come of age and are conducting successful operations throughout the world's oceans to depths beyond 20,000 feet. This paper will present a listing of undersea vehicles capable of penetrating these extreme depths and the possible applications that may be realized because of them. In addition, the overall philosophy of exploration and work by undersea vehicles is addressed, including a discussion of need, commitment, technological limitations and future requirements.

The Unfulfilled Challenge

"I believe this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to Earth."

> President John F. Kennedy
> Message to Congress
> 25 May 1961

"Our goal is to investigate the world ocean, its boundaries, its properties, its processes. To a surprising extent, the sea has remained a mystery. 10,000 fleets still sweep over it in vain. We know less of the oceans at our feet, where we came from, than we do of the sky above our heads. It is time to change this, to use to the full our powerful new instruments of oceanic exploration, to drive back the frontiers of the unknown in the waters which encircle our globe."

> President John F. Kennedy
> Remarks to the National
> Academy of Sciences
> 22 October 1963

After President Kennedy gave his historic speech in 1961, it took just over 8 years for the United States to place Astronaut Neil Armstrong on the moon on 20 July 1969 [1]. On 23 January 1960, more than 3 years before Kennedy's call to drive back the ocean frontier, the Trieste landed at the bottom of the Marianas Trench at a depth of 35,800 feet, piloted by Don Walsh and Jacques Piccard [2]. The footprints of 12 different men have been imprinted on the surface of the moon for centuries to come. No one, however, has reached the deepest depths of the oceans a second time.

Since Sputnik I was launched into orbit in 1957, hundreds of additional satellites (autonomous vehicles?) have been launched to orbit the earth, sending back valuable data regarding the surface of the earth, its oceans and weather patterns, and providing communication links and navigation beacons. But not one long-endurance autonomous vehicle cruises the oceans to provide in-depth information. One could argue that drifting buoys or instrument packages launched from oceanographic ships are equivalent to a satellite when comparing numbers; however, if they are compared on an equal cost basis, the satellites win unanimously. The cost of a satellite and launching it into orbit is in the range of $30-100 million U.S., enough financing to pay for nearly 5 decades of research and development at levels similar to that in many US Navy R&D programs [3].

The U.S. developed the "Skylab" and launched it into orbit in 1973; it fell back to Earth in 1979. The former Soviet Union has placed seven space stations in orbit, the first, Salyut 1, in 1971. They also hold the record for continuous occupancy by man, 326.5 consecutive days, in the Mir space station in 1987 [4]. Unfortunately, there are no equivalent "sealabs" in existence in the deep ocean. The U.S. Navy had an ambitious program in the 1960's, called Sealab, which ended after the death of one of the aquanauts in Sealab III [5]. Conversely, after the death of 3 U.S. Apollo astronauts in 1967, the space program continued with a vengeance to not only correct the problem but to meet the goal established by President Kennedy [6]. The Space Shuttle program also overcame the explosion of the Challenger in 1986 and is now successfully back on track with missions such as the Hubble telescope repair. Today, plans are underway to put a long-term manned space station into space where research can be conducted continuously. But for the underwater world today, the only manned undersea stations exist in the television series "SeaQuest DSV," and there is no "Inner Space Shuttle" to match the one used for outer space exploration.

Is the lack of deep ocean intervention due to a lack of explorers, men and women with a hunger for knowledge and a thirst for adventure? That doesn't appear to be the problem. The space program has a long waiting list of people who desire to enter the astronaut program. "Space camps" exist where the young can become astronauts in training for a short time, and the Young Astronauts program flourishes throughout the U.S. school system. In the ocean environment, exploration still continues on a limited basis, often by adventurers who seek either fame or fortune by locating and exploiting sunken treasure galleons or exploring long-lost ships.

How can the nations who fund explorers to venture into the heavens to gain knowledge about the universe around them be so ignorant of the untold benefits of a similar exploration program in inner space? Is there a need to explore the deep oceans or should man worry only about treasure hunting and disaster investigations and ignore the most significant geologic feature on the planet?

A Question of Need

Why should we explore the oceans? Is there really a need? It seems that the answer to those questions would be obvious to an elementary school graduate. The oceans comprise 71 percent of the earth's surface, equivalent to 139,500,000 square miles [7]. The portion of the ocean floor below 20;000 feet alone is greater than the surface area of the U.S. [8]. The percentage of the ocean that has actually been seen by man is insignificant in comparison, and very little has actually been mapped using towed sonars or other equipment. Over 60 nations, (the US since 1983), have claims over their own Exclusive Economic Zones (EEZs), which reach 200 nautical miles outward from the shoreline. But even the EEZ is a relatively small area when taking the entire ocean into consideration. The EEZ of the U.S. amounts to 1.7 times the surface area of the U.S. and its territories, some 3.9 billion acres of submerged land, and it has hardly been investigated [9]. The U.S. has been formally in existence for 218 years, yet we are far from exploring the entire surface area of the nation, much less its hidden ocean resources. The potential exists to exploit the tremendous wealth of the ocean, its mineral and living resources, tap the oil and gas supplies, harness its energy, and understand the effects of sewage and hazardous wastes dumping. The ocean provides a pathway for communications, transportation and travel and for many a place of recreational activity. Understanding it is not only desirable, but as important as gaining knowledge about the earth from space, and such understanding is mandatory for mankind's future.

Is The Technology There?

One can say that a lack of technology is limiting the investigation of the world's oceans, but that really isn't the case. There is more technology and equipment available today than can be used over the remainder of the century. And the increase in the number of deep-ocean-capable vehicles over the last several years has been phenomenal. The following sections will present an overview of the many deep-ocean-capable systems available or under development today.

Towed Vehicles

Towed vehicles have been available for search operations and oceanographic investigations since 1960, yet recent developments in sonars, electronic still cameras, data storage and processing have made them extremely more efficient [10]. Shrinking electronics and more efficient equipment have reduced the size and price of many systems to a point where they are available to "financially challenged" organizations, be they academic institutions or small business entrepreneurs. The number of sunken treasure ships that have been found in recent years attests to the viability of this technology. In addition, deep ocean search operations such as the location of the ship Lucona at 13,800 feet by the Ocean Explorer 6000 and the Wake Island operation using the U.S. Navy's ORION search system underscore the deep ocean capability of the towed systems [11,12]. More recently, with the dissolution of the former Soviet Union, the existence of many previously unknown vehicles has been unveiled by Russia. Vehicles such as the MAK-1, ABYSSAL and URAN-1 all have deep ocean capabilities [13]. Table 1 provides a listing of many of the available towed vehicles with the capability to operate beyond a 10,000-foot depth.

Manned Vehicles

Although this paper is primarily concerned with unmanned undersea vehicles (UUVs), the number of manned vehicles that can reach 20,000 feet has increased substantially on the international level and should not be ignored. While other countries build new manned systems, the U.S. remains in a pattern of continual upgrading of the existing Navy-owned fleet of submersibles: Alvin, Sea Cliff and Turtle. France, Russia and Japan have taken the opposite approach with their Nautile, Mir I and II, and Shinkai 6,500 vehicles, developing them from the bottom up while integrating the latest technology available. In Russia's case, the two sister Mir vehicles have provided an interesting approach to dual vehicle intervention. While one works, the other can document the operation. This has resulted in some very dramatic underwater documentation that will help promote underwater operations in the future [14]. The Titanic expeditions by several of these vehicles have brought such technology into homes around the world. The deep ocean manned vehicles are listed in Table 2.

Remotely Operated Vehicles

The technology that holds the most promise for the future exploration of the oceans is that which exists in the realm of the UUVs (Unmanned Underwater Vehicles). These vehicles take the form of both "free flying" tethered vehicles, also known as remotely operated vehicles (ROVs), and untethered "autonomous" undersea vehicles (AUVs).

The deep ocean tethered vehicles have come of age with the back to back breaking of the 20,000-foot barrier by the cable-controlled underwater recovery vehicle (CURV) (20,105 feet) and the advanced tethered vehicle (ATV) (20,600 feet) during the same week in 1990 [15]. With Japan's addition of the KAIKO, not even the depths of the Marianas Trench will be out of reach [16]. But the use of a tether, which provides unlimited power and communication with the vehicle, has its problems. Because the vehicle is tied to the ship by the tether, increases in the cost of the system are experienced. The amount of equipment to launch and handle such massive systems increases and ultimately drives the size and cost of the operational platform. Regardless, the technology to develop such systems is here and they are being used with continued success on salvage, recovery and underwater work operations around the world. The insurance investigation of the Lucona, the wreckage recovery of the Navy UH-46 Sea Knight Helicopter from 17,250 feet of water off Wake Island, and the

South African Airways 747 operation are but a few recent examples [17,18].

Early research and development goals sought a 20,000-foot-depth capability since this depth covers approximately 98% of the ocean floor. The U.S. Navy's Deep Ocean Technology program used this as the design depth during the program's existence. Only recently was a new paradigm considered. Japan decided that it needed to understand what was happening in the deepest ocean trenches and developed the 30,000-foot-capable vehicle KAIKO. The original plan was to have it operational in 1993; however, the tenuous link between the ship and the vehicle once again posed a problem, resulting in umbilical entanglement and damage to the tether termination [16]. During trials in 1994, the Kaiko achieved a new depth record for ROVs when it reached a depth of 35,797 feet in the Marianas Trench. Thus, it does not appear that there are limitations of technology in the area of tethered vehicles. Systems can of course be made smaller and more efficient, but sufficient technology is available today to work in the ocean deep. Perry Tritech, although they have not delivered a full depth capable vehicle (other than the mothballed British TUMS system), advertise their TRITON line of vehicles to be capable of 20,000-foot operation with only the upgrading of the depth capability of their pressure bottles [13,19]. Getting to 20,000- and possibly 30,000-foot depths is only a design problem today, assuming you can pay for the system. Table 3 lists the available deep-ocean-capable tethered vehicles.

Autonomous Underwater Vehicles

The systems that will conduct long-term in-situ investigations in the future are the autonomous (or semi-autonomous) underwater vehicles (AUVs). Autonomous is often a controversial term since many of the vehicles are controlled via fiber optic or acoustic control paths. However, the general direction of this class of systems is toward full autonomy. Autonomy is the direction that must be followed if the exploration of the oceans is to begin to resemble the exploration of space. Like the ROVs, the AUVs are also coming of age. The most prominent and capable AUVS have been funded by the military: advanced unmanned search system (AUSS) and MT '88 for example. The AUSS was developed by the NCCOSC RDTE Division and has recorded over 100 successful launch and recoveries and reached a test depth of 12,000 feet. It is presently being transitioned to the U.S. Navy's Supervisor of Salvage where it will become operational under Navy contract to Oceaneering Technologies Inc. (OTI). The Russian MT '88, along with its predecessor vehicles, had been operational for some time, although it was only recently that the technology was declassified and unveiled to the world. Since that time, the MT '88 has been used to survey two sites where former Soviet submarines had sunk, the Komsomolets off Norway in 6,500 feet of water and the Yankee-class SSBN in the Atlantic in over 18,000 feet of water [20].

Although lacking the sophistication of hardware that exists in other countries, the Russians developed a less sophisticated, yet highly reliable vehicle that has been used with great success. Two sister MT '88 vehicles are also operational [21]. Many other vehicles have been developed such as the Epaulard in France and other recently unveiled systems from Russia. These systems add to the viability of this class of vehicles to perform meaningful work.

AUVs can do what the tethered ROVs cannot: eliminate the physical attachment of the vehicle to the ship, or in possible future scenarios, the coast or dock. They do, unfortunately, suffer from the requirement to carry all their energy with them. Increased efficiency in the onboard systems will help with this problem, but, without the development of cheaper sources with higher energy density, the full benefit of these systems will not be realized. This is the singular stumbling block to seeing AUVs reach their full potential. To achieve a level of ocean research and exploitation such as that envisioned by President Kennedy and many others, the AUV must reach the same capability level for long-term exploration as its outer space analogues of satellites and robotic probes. Table 4 lists the status of developed AUVs.

Future Requirements

The levels of sophistication and capability reached by undersea vehicles in the future will depend on technology, but that will not be the limiting factor to them reaching their full potential. The most significant limitation to exploiting the wealth of the ocean and unveiling its secrets is funding. Without the capital to fund ships to take vehicles to sea, or to mass produce autonomous ocean probes, ocean exploration will continue to stagnate. In the U.S., UUV technology was basically developed in the Navy laboratories, transitioned to industry, and exploited by the offshore oil community. With the infusion of commercial funding, and the resulting increase in the number of operational systems, it was only a matter of time until vehicle reliability increased and cost came down. Low-cost vehicles, essentially those with costs below $100,000 U.S., are now common place and used by universities, government agencies, police and fire departments to name a few. Russia's fleet of vehicles was developed through government and military funding and Canadian firms are heavily subsidized. Probably the most dramatic turn-around in undersea technology has been in Japan. A nation of islands that requires an intimate understanding of the seas that surround it, Japan has provided an infusion of funds to not only develop its technology base, but to develop the ships and equipment to perform useful work [22]. The Advanced Robotic Technology Research Association (ARTRA) is a good example of such support. The Shinkai 6500, the KAIKO, and the wonderfully engineered support ship Yokosuka are a tribute to Japan's ability to plan and succeed. And, Japan now has an 11,000-meter manned submersible in the planning stages.

For the U.S. Navy, the concern has recently shifted from the deep ocean to the littoral zone. Navy operations, such as the Gulf War, have once again drawn attention to the devastating potential of mine warfare, an area where the odds are heavily in favor of the mine. Previous UUV programs such as the AUSS and ATV have culminated and no new deep ocean vehicles are being planned. The Navy's attention has been directed to such new systems as the Mine Search System, the Submarine Off-board Mine Search System (SOMSS), and the Semi-Autonomous Undersea Vehicle (SAUV) [23]. Although the present direction of the U.S. Navy is toward solving shallow water problems, the technologies that are being investigated will ultimately have an affect on the future of underwater exploration. The goal to make quieter, more efficient, affordable systems with better navigation ability and increased on-board intelligence will help strengthen the technology base. Presently, the Navy is holding up funding on the UUV programs while the overall approach is reassessed to ensure that they are being conducted in a financially efficient manner without duplication of effort. Although the thrust toward financial efficiency by the U.S. Navy is good, its effect on the level of research in the future does pose some concern. The goal of the U.S. government to reduce spending in defense programs and to reduce the overall national debt will probably result in a negative impact on funding to conduct such programs.

The world of explorers and entrepreneurs still exists, much to the delight of those who have experienced a career in the fields of ocean engineering and vehicle development. The continued high visibility exploits of Bob Ballard and his team of explorers at Woods Hole Oceanographic Institution (WHOI) advertises to the world the benefits that can be gained from applying this technology. Others, such as Graham Hawkes, are trying to do the previously unachievable: sending a vehicle and then a human to the deepest depths of the ocean in a small, lightweight, high technology vehicle [2]. His goal of applying the latest in ceramic pressure hulls, fiber-optic communications and the integration of the most advanced human factors, hydrodynamic and related technology in the Jules Verne Explorer and Deep Flight vehicles shows that vision is not dead. Unfortunately, his effort also suffers from the same problem that plagues all aspects of ocean research - financing.

Conclusions

If the future is to hold a place for ocean research and exploration, a significant change must be made in the way such research and exploration is being financed. It will be necessary to have a dramatic change at the national level, one where a program for the oceans is established and funded in a fashion similar to the space program.

It is also unlikely that the potential of the oceans will be realized if each country follows its own path of exploration, for its own gain. Once the boundaries of the EEZs are crossed, international cooperation is essential. By combining efforts and leveraging critical resources, both financial and material, a significant increase in work will be achieved. There is a trend in that direction now and it must be followed with enthusiasm. The UJNR is one example of international cooperation where such concepts can be discussed and promoted.

The deep ocean applications of UUVs will be realized by following a new paradigm, one of international cooperation and government-backed funding. The limitation is not in developing technology or advanced systems, it is in getting these systems to sea. Not to recover downed airliners, or solve insurance claims, but to discover the mysteries of the ocean. President Kennedy's challenge to get to the moon was heeded, and his team succeeded within 8 years. It is time to meet the challenge of inner space. It has been over 30 years since President Kennedy defined his goal to investigate the world's oceans. In his words, "It is time to change this, to use to the full our powerful new instruments of oceanic exploration, to drive back the frontiers of the unknown in the waters which encircle our globe."

References

[1] Dewaard, E. John and Dewaard, Nancy. History of NASA. Exeter Books, 1984.

[2] Ashley, Steven. Voyage to the bottom of the sea. Mechanical Engineering Magazine, Vol 115/No 12, December 1993.

[3] McGraw Hill Encyclopedia of Science and Technology, 7th Edition, 1992.

[4] The 1989 Information Please Almanac. Houghton Mifflin Company, 1989.

[5] Haux, Gerhard. Subsea Manned Engineering. Best Publishing Company, 1982.

[6] Von Braun, Wernher and Ordway III, Frederick I. History of Rocketry & Space Travel. Thomas Y. Crowell Company, 1969.

[7] Herring, Peter J. and Clarke, Malcolm R. Deep Oceans. Praeger Publishers, 1971.

[8] Earle, Sylvia A. Ocean Everest - An Idea Whose Time Has Come. Marine Technology Society Journal, Vol. 24, No. 2, June 1990.

[9] Silva, Armand J. UTILIZATION OF THE EEZ: Challenge for the Future. Proceedings of the US/Japan Cooperative Program in Natural Resources, October 30-31, 1992.

[10] Undersea Vehicles Directory - 1990-91. Busby Associates, Inc. February 1990.

[11] Burns, Richard F. Eastport International: "Smoking Guns" and Deep Ocean Recovery. Sea Technology, December 1991.

[12] Cooper, Keith. Search and Salvage Operations in 17,251 Feet of Water. ROV '92 Conference Proceedings, Marine Technology Society, 1992.

[13] Given, Deam. ROV Review 1993-94. Windate Enterprises, Inc., August 1992.

[14] Hardy, Kevin. Return to the Titanic: The Third Manned Mission. Sea Technology, December 1991.

[15] CURV III Makes Deepwater ROV Dive Record. Subnotes, Windate Enterprises, Inc., Vol. 10, No. 2, September/October 1990.

[16] Tsuchiya, T., Watanabe, K., and Suzuki, K. Results of Sea Trial of 10,000m Class ROV "Kaiko." MTS '93 Conference Proceedings, Marine Technology Society, 1993.

[17] Mullen, C., Dean, D., and Higgins, M. SAA Flight 295 Wreckage Recovery Pushes ROV Frontier to New Depths. Sea Technology, February 1989.

[18] Eastport Sets Ocean Recovery Record. Military Robotics.
L and B Limited. April 1, 1992.

[19] Wernli, R.L., personal communication.

[20] Given, Deam. Underwater Technology in the USSR. Oceanus, Vol. 34, No. 1, Spring 1991.

[21] Wernli, R.L., personal communication.

[22] Okamura, Kenji. Ocean Technology in Japan: Recent Advances, Future Needs and International Collaboration. Marine Technology Society Journal, Vol. 24, No. 1, March 1990.

[23] Special Report - U.S. Navy's UUV Programs. Underwater News and Technology. Technology Systems Corp. Vol. 1, No. 2. September/October, 1993.

TABLE 1

STATUS OF TOWED VEHICLES WITH GREATER THAN 10,000-FOOT CAPABILITY

VEHICLE	DEVELOPER	DESIGN DEPTH	MAX DEPTH ACHIEVED
OCEAN EXPLORER 6000	OCEANEERING TECHNOLOGIES INC., U.S.	25,000 FT	13,800 FT (LUCONA OPERATION)
DEEP OCEAN SEARCH SYSTEM	OCEANEERING TECHNOLOGIES INC., U.S.	26,000 FT	20,000 FT (TEST OPS)
ORION	OCEANEERING TECHNOLOGIES INC., U.S.	20,000 FT	17,251 FT (WAKE ISLAND OPS)
ARGO	WOODS HOLE OCEANOGRAPHIC INST., U.S.	20,000 FT	12,500 FT (TITANIC)
DEEP TOW (FISH 4, 5 & 6)	MARINE PHYSICAL LABORATORY, U.S.	23,000 FT	23,300 FT
FOSS #1	WOODS HOLE OCEANOGRAPHIC INST., FOR STENNIS SPACE CTR., U.S.	20,000 FT	18,000 FT (PACIFIC OPS)
FOSS #2	WOODS HOLE OCEANOGRAPHIC INST., FOR STENNIS SPACE CTR., U.S.	20,000 FT	UNDER DEVELOPMENT
FISH 103	INTERSHELF, RUSSIA	20,000 FT	UNKNOWN
ORANI	KRYLOV INST., RUSSIA	20,000 FT	UNKNOWN
DEEP TOW	JAMSTEC, JAPAN	21,325 FT	21,677 FT
SAR	IFREMER, FRANCE	20,000 FT	20,000 FT (TEST DIVE)
TOBI	INSTITUTE OF OCEANOGRAPHIC SCIENCES, DEACON LAB, U.K.	20,000 FT	16,700 FT (NORTH ATLANTIC)
MAK-1	YUZHMORGEOLOGIYZ, RUSSIA	20,000 FT	UNKNOWN
URAN-1	KRYLOV INST., RUSSIA	20,000 FT	UNKNOWN
NPA-6000	ST. PETERSBURG MARIN ENG. BUREAU, RUSSIA	20,000 FT	UNKNOWN
RELIEF 6000-100	CENTER OF OCEAN ENG. LTD, BULGARIA	20,000 FT	4,920 FT (BLACK SEA)
RELIEF 4000	CENTER OF OCEAN ENG. LTD, BULGARIA	13,120 FT	UNKNOWN

TABLE 2

STATUS OF MANNED VEHICLES WITH GREATER THAN 10,000-FOOT CAPABILITY

VEHICLE	DEVELOPER	DESIGN DEPTH	MAX DEPTH ACHIEVED
11,000 METER MANNED	JAPAN	36,080 FT	UNDER DEVELOPMENT
SHINKAI 6500	JAMSTEC, JAPAN	21,325 FT	21,414 FT (JAPAN TRENCH)
NAUTILE	IFREMER, FRANCE	20,000 FT	20,000 FT (PUERTO RICAN TRENCH
SEA CLIFF	U.S. NAVY	20,000 FT	20,000 FT
MIR 1 & 2	SHIRSHOV INSTITUTE, RUSSIA	20,000 FT	13,000 FT (TITANIC), MAX TEST DEPTH UNKNOWN
RIFT CLASS	SHIRSHOV INSTITUTE, RUSSIA	20,000 FT	2 UNDER CONSTRUCTION
RUS	ST. PETERSBURG MARIN ENG. BUREAU, RUSSIA	20,000 FT	UNKNOWN
ALVIN	WOODS HOLE OCEANO-GRAPHIC INST., U.S.	14,760 FT	14,760 FT
TURTLE	U.S. NAVY	10,000 FT	10,000 FT
CYANA	IFREMER, FRANCE	10,000 FT	10,000 FT

TABLE 3

STATUS OF ROVs WITH GREATER THAN 10,000-FOOT CAPABILITY

VEHICLE	DEVELOPER	DESIGN DEPTH	MAX DEPTH ACHIEVED
KAIKO	MITSUI/MITSUBISHI/ KAWASAKI/JAMSTEC, JAPAN	36,089 FT	35,791 FT (MARIANAS TRENCH)
ATV	NCCOSC RDTE DIV, U.S.	20,000 FT	20,600 FT (PACIFIC)
CURV	OCEANEERING TECH- NOLOGIES INC., U.S.	20,000 FT	20,105 FT (PUERTO RICAN TRENCH
MAGELLAN 825	OCEANEERING TECH- NOLOGIES INC., U.S.	26,000 FT	20,000 FT (PUERTO RICAN TRENCH
MAGELLAN 725	OCEANEERING TECH- NOLOGIES INC., U.S.	25,000 FT	17,800 FT
MAGELLAN 680	OCEANEERING TECH- NOLOGIES INC., U.S.	20,000 FT	COMMERCIAL VERSION OF CURV, NONE BUILT TO DATE
GEMINI	OCEANEERING TECH- NOLOGIES INC., U.S.	20,000 FT	14,800 (AIRCRAFT RECOVERY)
JASON/MEDEA	WOODS HOLE OCEAN- OGRAPHIC INST., U.S.	20,000 FT	13,000 FT
HYSUB 5000	INTERNATIONAL SUB- MARINE ENGINEERING, CANADA	16,400 FT	15,088 FT
DOLPHIN 3K	MITSUI/JAMSTEC, JAPAN	11,247 FT	11,247 FT (SIKOKU BASIN)
TRITON	PERRY TRITEC, U.S.	20,000 FT	NONE BUILT TO THIS DEPTH YET
ROV 6000	IFREMER, FRANCE	20,000 FT	UNDER DEVELOPMENT (LAUNCH 1996)

TABLE 4

STATUS OF AUVs WITH GREATER THAN 10,000-FOOT CAPABILITY

VEHICLE	DEVELOPER	DESIGN DEPTH	MAX DEPTH ACHIEVED
AUSS	NCCOSC RDTE DIV, U.S.	20,000 FT	12,000 FT
MT-88 (SEA LION)	INSTITUTE OF MARINE TECHNOLOGY PROBLEMS, RUSSIA	20,000 FT	18,000 FT
EPAULARD	ECA, FRANCE	20,000 FT	20,000 FT (DECOMMISIONED)
YANTAR	GIDROPRIBOR RES. INST. RUSSIA	20,000 FT	UNKNOWN
DEEP REMOTELY OPERATED VEHICLE	STATE MARINE TECH. UNIV., RUSSIA	20,000 FT	UNKNOWN
ANPA-6000	ST. PETERSBURG MARIN ENG. BUREAU, RUSSIA	20,000 FT	UNKNOWN
ARUS	TECNOMARE, ITALY	20,000 FT	UNKNOWN
ABE	WOODS HOLE OCEANO-OGRAPHIC INST., U.S.	20,000 FT	5,250 FT
ODYSSEY	MASSACHUSETTS INST. OF TECHNOLOGY, U.S.	20,000 FT	UNDER DEVELOPMENT
PLA 2	C.E.A./IFREMER, FRANCE	20,000 FT	SHALLOW (DECOMMISIONED)
PTEROA 250	UNIV. OF TOKYO, JAPAN	20,000 FT	UNDER DEVELOPMENT
DEMONSTRATION TEST VEHICLE (DTV)	INSTITUTE OF OCEAN-OGRAPHIC SCIENCES, DEACON LABS, U.K.	20,000 FT	UNDER DEVELOPMENT
DOGGIE	INSTITUTE OF OCEAN-OGRAPHIC SCIENCES, DEACON LABS, U.K.	20,000 FT	PLANNING STAGES
DOLPHIN	INSTITUTE OF OCEAN-OGRAPHIC SCIENCES, DEACON LABS, U.K.	20,000 FT	PLANNING STAGES