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U.S. NAVAL OCEANOGRAPHY AND THE ROLE OF AUVs

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INTRODUCTION

The Department of Defense Hydrographic Initiative published in 1991, envisioned the use of autonomous underwater vehicles (AUV) for extended ocean survey operations. The preferred AUV will be a low maintenance, low cost, easy to handle survey tool acting as a force multiplier to existing survey assets. The Navy is pursuing this vision through the efforts of the Office of Naval Research (ONR), the Naval Research Laboratory (NRL), and the Naval Meteorology and Oceanography Command (NAVMETOCCOM) through the Naval Oceanographic Office (NAVOCEANO).

CONCEPT OF OPERATIONS

The Concept of Operations for Naval Oceanography involves both large and small vehicles. There is no clear difference in size between the two, but for the sake of this discussion, large vehicles will be defined as being longer than 10 feet, weighing more than 1000 pounds, and having a range of more than 100 miles. This artificial demarcation highlights the true difference between large and small vehicles, that is operational capabilities.

The important issue is that the larger size gives the capability for 1) more endurance (i.e. more batteries), 2) better navigation (ring-laser gyros) and ballasting, and 3) the flexibility to easily interchange a wide variety of payloads. With this accurate internal navigation, a large AUV can be within 200-meters accuracy after surveying 50 nmi. This allows the vehicle to update navigation using GPS or coregistration with a predeployed target. This approach is particularly useful for a long-range mission (like a mine warfare Q-route). The ability of the larger vehicles to adjust ballast is also important, allowing the vehicle to hover over a target, or adjust

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to changing water masses. However, the downside of the larger vehicles includes cost, difficulty of launch/recovery and logistics.

Smaller AUVs lend themselves to a different approach to survey applications. Operators can easily handle several of the smaller vehicles from a much smaller support platform, thus expanding area coverage, lowering costs, and increasing speed of survey completion. In the long term, technological advances should enable the smaller vehicles to have extended range and improved navigation. Battery improvements will soon give the smaller vehicles improvements in range (up to 12-hour missions). The reduction in size and cost of inertial navigation systems promises capabilities approaching that of larger vehicles.

For survey missions of 12-hours or less, smaller vehicles are excellent. The only weakness is navigational control. Without a high precision inertial navigation system or periodic Differential GPS updates, these vehicles must use a transponder navigation net. Ease of transponder placement and the new technique of tying an RF beacon to each transponder allows the support craft to monitor survey progress and vehicle status, thus increasing survey options.

All sizes of AUVs have proven themselves as productive participants of environmental data collection operations. To say that one vehicle will meet all survey scenarios would be untrue. However, a suite of these vehicles, using common data processing techniques, will provide the Navy with a valuable means of augmenting current survey systems (ships, aircraft, and remote data collection systems) at a very reasonable cost.

DEVELOPMENT EFFORTS

The Navy's early environmental AUV surveys were based on available DOLPHIN AUVs which were originally engineered by International Submarine Engineering of Canada. NRL used these platforms to pioneer efforts targeted at developing military oceanographic survey capabilities for NAVOCEANO.

Concurrently, ONR was sponsoring several smaller AUVs. These systems were easier to handle than the larger NRL AUV, but lacked long-range data collection requirements. The Navy's interest in smaller AUVs continues, realizing that specific missions require vehicles tailored to specific operational requirements. ONR conducted its second annual demonstration exercise with NAVOCEANO during November 1998 to demonstrate the capabilities of those academic vehicles currently under evaluation.

This ONR/NAVOCEANO technology demonstration partnership continues to be a resounding success. NAVOCEANO chartered the Texas A&M research vessel RV GYRE to be staged off the Mississippi Gulf Coast as the AUV support platform, while ONR sponsored participating AUV teams from Massachusetts Institute of Technology, Florida Atlantic University, Woods Hole Oceanography Institute, and Naval Postgraduate School.

NAVOCEANO brought another important operational aspect to the exercise, through the selection of performance standards and testing methods. The evaluation process was based on International Hydrographic Office (IHO) shallowwater survey techniques. Each team was provided a copy of the IHO survey specifications as a benchmark to NAVOCEANO's standard survey requirements. NAVOCEANO also embarked on board GYRE a team of surveyors and engineers who were tasked with evaluating specific operational areas.

The test sites were selected off the coast of Gulfport, Miss. and a ground-truth survey of these two 0.25 x 1 mile sites was conducted by NAVOCEANO prior to the event. Depths in one area varied from 4-5 meters, while in the other from 10-15 meters. NAVOCEANO surveyors also positioned two mine-like targets within the same area. Current velocities in both areas ranged from 1 to 2 knots.

EXERCISE PARTICIPANTS

ONR invited those academic institutions with relatively mature initiatives to participate in the Unmanned Underwater Vehicle (UUV) demonstration program. Since the Navy requires seafloor and water column information, the AUVs were outfitted with relevant sensors for measurement.

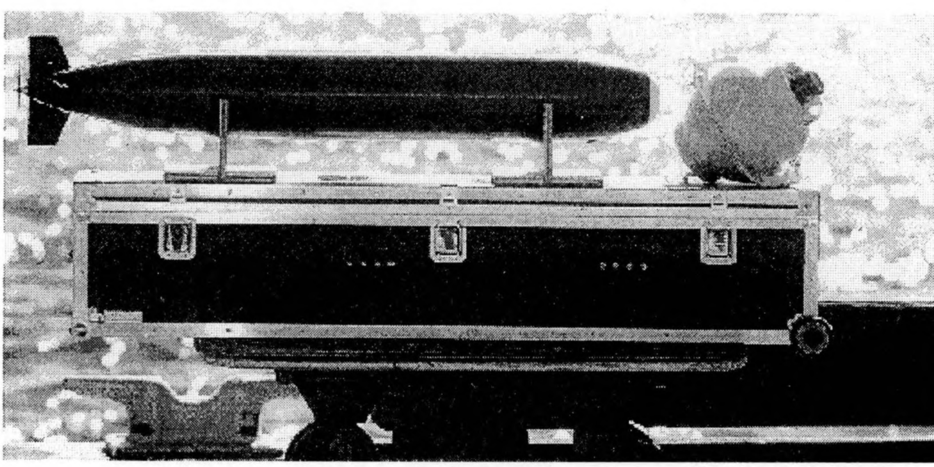

FIG. 1.- WHOI's REMUS

Woods Hole Oceanographic Institution developed its Remote Environmental Measuring Units (REMUS) to conduct surveys in coastal oceans, bays and estuaries. REMUS was 53 inches long, 7.5 inches in diameter, and weighed 68 pounds on deck. The host program, capable of running in a Windows 3.1 or 95 environment, was initiated using a laptop computer and was connected to the vehicle via a RD-232 link. REMUS sensor packages were designed to be relatively modular. This technique included the use of a 600 kHz side-scan, a 1.2MHz Acoustic Doppler Current Profiler (ADCP), and a conductivity, temperature, and density (CTD) sensor. Positioning was achieved using at least two transponders oriented in the direction of the survey. The WHOI mission-planning tool was comprehensive and easy to use.

The Massachusetts Institute of Technology's Sea Grant Laboratory Odyssey was 82 inches long, 22 inches in diameter, and weighed 360 pounds on deck. Its primary navigation was with Differential GPS (DGPS) positioned transponders. The Odyssey hosted a side-scan and CTD. All data logging was synchronized to GPS. Launch and recovery required an overhead crane, but no diver support (an important feature for the Navy) due to the wire-mounted quick-release shackle. This AUV hosted the only deep water (6000+ meters) measuring capability of the exercise.

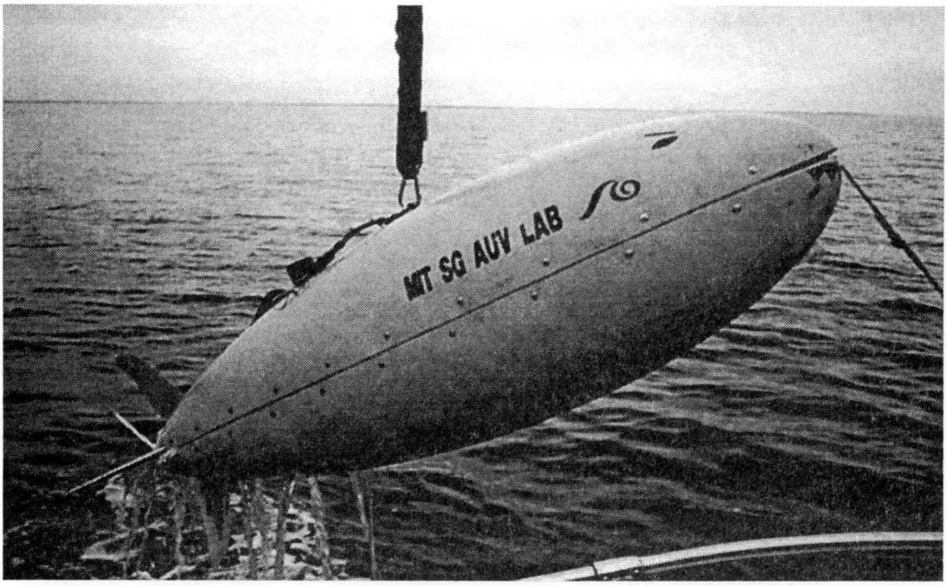

FIG. 2.- MIT's Odyssey.

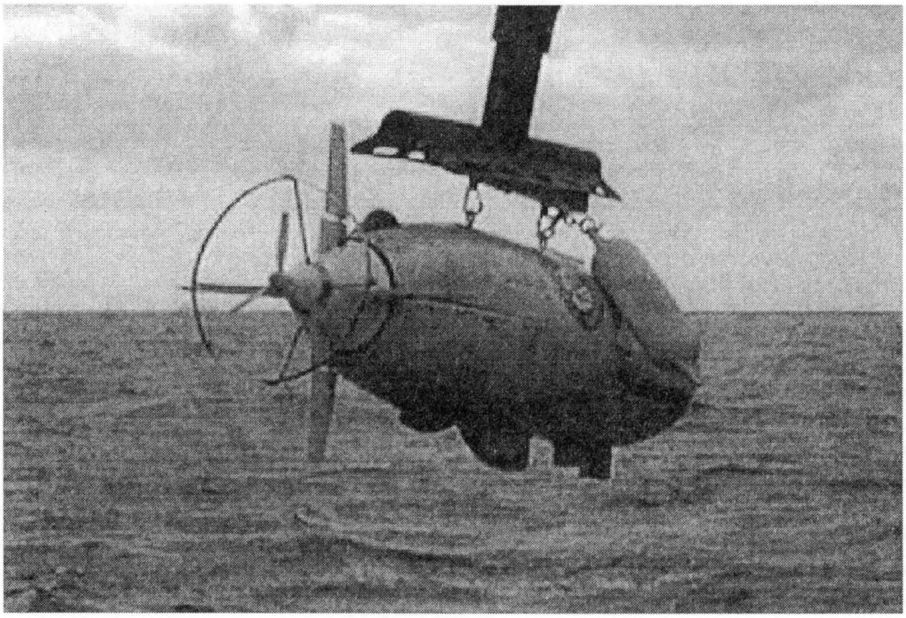

FIG. 3.- FAU's Ocean Explorer.

Florida Atlantic University's Ocean Explorer (OE) was 7–10 feet long, 21 inches in diameter, and weighed over 900 pounds in the water. The OE offered some unique capabilities, such as a modular approach toward interchanging the aft propulsion/battery section with a variety of payloads and control systems. Onboard sensors included a side- scan (100/390 kHz), an ADCP (1.2 MHz) and a CTD. Vehicle commands and waypoints were transferred to the vehicle computer which charted the mission. FAU navigational emphasis focused on GPS/DGPS data to update their onboard navigational system. Their most successful approach used a vehicle pop-up antenna with a GPS receiver. The FAU team was able to achieve short-range communications with the vehicle during operations via acoustic modem.

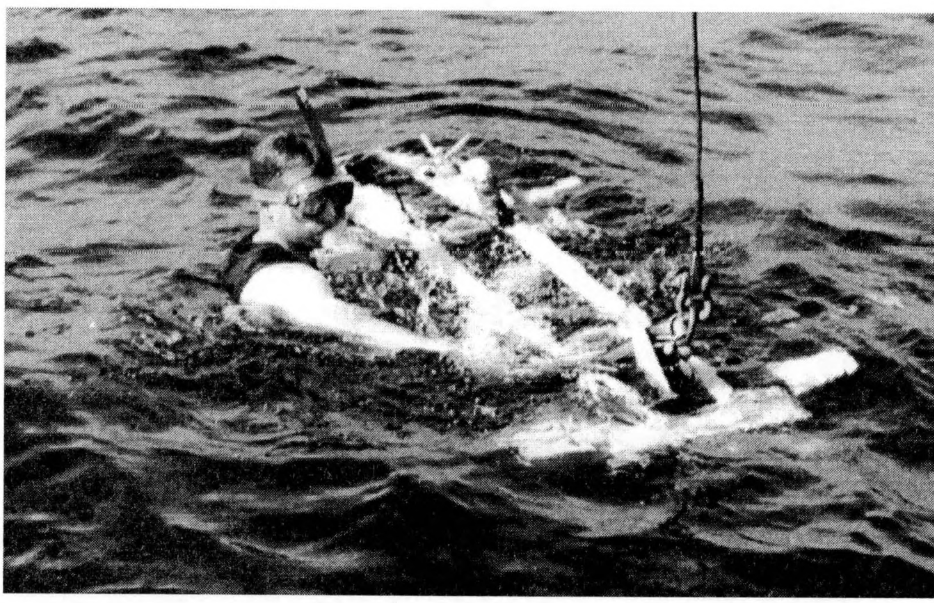

FIG. 4.- NPS' Phoenix.

Naval Postgraduate School's Phoenix was 7 feet long, 1.5 feet in breadth, and weighed approximately 450 pounds. Its source of navigation was magnetic compass, Precision Nav, and an inertial navigation system. The Phoenix batteries powered a twin screw system with a ¼ hp brushless DC motor on each shaft for a three-hour period. It hosted a wide array of sensors which included an ADCP, altimeter, doppler, sonar, short baseline acoustic positioning system, Turbo Probe Speed Sensor, Depth Cell, and Sistron and Donner motion package. The Phoenix has typically been used as a research tool in a protective environment, though proved itself very capable of completing assigned missions in varying seascapes.

While all four contestants effectively operated and provided data showing target features, a major success was the sharing of information and experiences among the team members. Each was looking forward to another "workshop."

THE NEXT STEPS

Taking advantage of local interest in AUVs and technology transfer, NAVMETOCCOM has recently entered into a cooperative agreement with the University of Southern Mississippi (USM) and Meridian Sciences Corporation to transition a larger and more capable AUV inherited from the Draper Laboratory. This spring modifications to the large AUV will be completed and tests conducted in the Gulf of Mexico prior to deployment on actual operations. Simulated Q-route tracks will be run and the system will be equipped with side scan sonar, optical, and navigational systems. Characteristics of the vehicle are:

CHARACTERISTICS/CAPABILITIES

Length/Diameter: 27 ft./44 in. Navigation: INS/GPS/OAS
Power: 900 "D" Cells. Weight: 10,190 lbs.
Depth: 1000 ft. Range (3 kts): 300 nm.
Propulsion: Prop/ Thrusters Speed: 0-4 kt. Sensors: SLS, Video, etc.

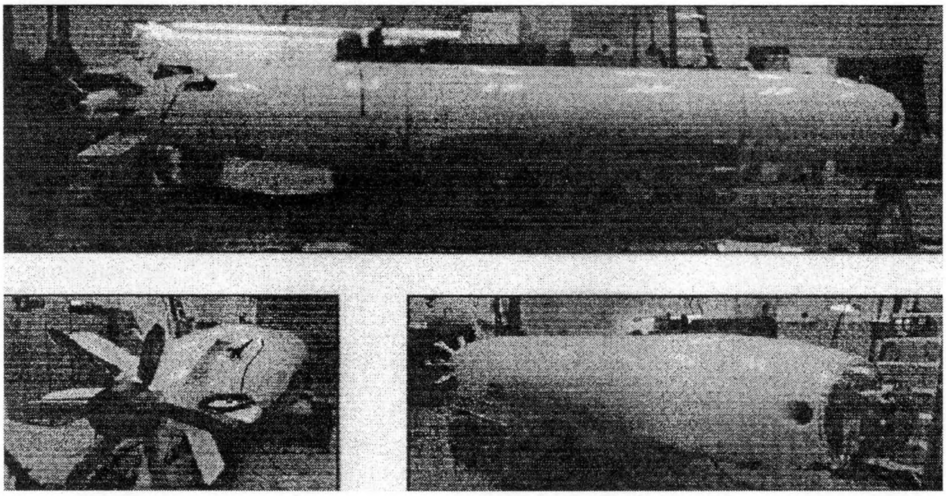

FIG. 5.-DRAPER AUV.

USM's Institute of Marine Science has taken several steps for AUV transitions. With the help of NAVOCEANO, USM has acquired a proven AUV handling platform, the Navy's modified LCU, IX-508. NAVOCEANO plans to work in partnership with USM to test and operate the AUVs off of the Gulf Coast. NAVOCEANO is also using an existing structure at the John C. Stennis Space Center, Mississippi to house what will be an oceanographic AUV operational center.

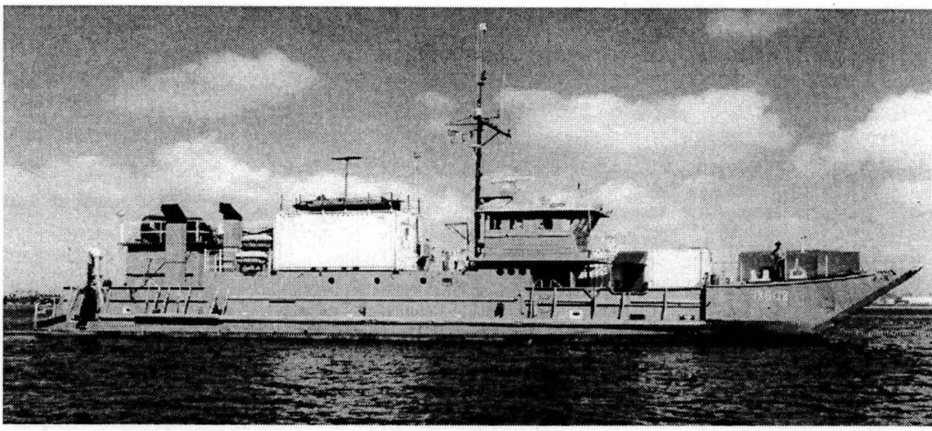

FIG. 6.- IX-508.

The development of an AUV test range off of the Mississippi coast is also being investigated. The intent is to model a range for use in the laboratory as well as to provide a reliable arena through which to test instrumentation. Its accuracy is anticipated to allow the calibration of various sensors related to AUVs and other disciplines.

ONR and NAVOCEANO have scheduled a third AUV demonstration exercise to be held off of the Mississippi Coast in early November 1999. New target areas are being planned for this event that will establish the Mississippi Coast as a premier test range for AUVs and other underwater instrumentation. ONR anticipates that additional participants and observers from related industries will join the 1998 AUV participants.

ONR's long-term vision includes a host of AUVs recharging their energy cells and downloading data at docking pads throughout a survey area. The ONR/NAVOCEANO partnership is providing an accelerated path to conducting operational military surveys for the U.S. Navy.

CONCLUSIONS

Navy's mission extends from the shore to the oceans' depths. Smaller AUVs have their greatest cost efficiencies operating independently from survey ships. Long-range vehicles enable the host platform to continue its survey mission while the AUV can either expand the survey area, or survey a unique region. Preferred capabilities around which Navy envisions its long-range AUV to be built include a minimum speed of five knots; modularized sensors meeting IHO requirements; and an approximate range of 300 nmi. Mission specific AUVs, while having a shorter range, will host the same high-resolution sensors. The challenge is to house these capabilities affordably and provide accurate navigation and high quality environmental data.

From an industry viewpoint, Meridian Sciences envisions opportunities in several commercial applications. AUV technology is currently evolving to meet a host of commercial demands. Current exercises in: docking, pipeline or navigable waterways surveys, repairing breaks or spotting new navigational hazards, may steer AUV's long-term goals. Certainly the ocean-engineering industry has not reached such capability, but the establishment of a robust industrial customer base will only accelerate and mature developments.

References

[1] BUNCE, John A.; "Results of the U.S. Naval Oceanographic Office's AUV Assessment Survey," Proceedings of the Underwater Technology '98 Symposium, Tokyo, Japan, 22-26 April 1998, p. 115-120.