Proceedings OMAE03
22nd International Conference on Offshore Mechanics and Arctic Engineering
June 8-13, 2003, Cancun, Mexico

OMAE2003-37254

EXPANDING MISSIONS FOR SMALL UNMANNED UNDERSEA VEHICLES (UUVS)

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ABSTRACT

Small unmanned undersea vehicles (UUVs), those less than 150 pounds, have many advantages for field operations over the larger models. The increase in number and capabilities of these vehicles is opening doors for an ever expanding number of applications. Current and anticipated mission areas will be discussed, including hydrographic survey, mine countermeasure survey / classify / map, target reacquisition and identification, chemical detection and plume mapping, and harbor security. New trends in applicable technologies will be described and recommendations made for the further development and use of small UUVs.

NOMENCLATURE

ADCP: Acoustic Doppler Current Profiler
AMP: Adaptive Mission Planner
AUV: Autonomous Underwater Vehicle
DIDSON: Dual Frequency Identification Sonar
EOD: Explosive Ordnance Disposal
MCM: Mine Countermeasures
MIRIS: Mine Reacquisition and Identification Sonar
NSCT 1: Naval Special Clearance Team 1
NSW: Naval Special Warfare
REMUS: Remote Environmental Measuring UnitS
RI: Reacquire / Identify
SAHRV: Semi Autonomous Hydrographic Reconnaissance Vehicle
SCM: Survey / Classify / Map
SSC SD: Space and Naval Warfare Systems Center San Diego
UUV: Unmanned undersea vehicle
VSW: Very Shallow Water
WHOI: Woods Hole Oceanographic Institution

INTRODUCTION

There are currently several types of small unmanned undersea vehicles (UUVs) being produced and used in a variety of military, scientific, and commercial applications. For the purposes of this article, a small UUV is defined as one that is two-man portable: less than 150 pounds, and manageable without a crane or dedicated handling system. Such a UUV is very attractive for a number of applications due to the reduced logistics and ease of handling. The cost of such systems is also attractive, generally being under $300K for a fully capable system.

One of the primary small vehicles currently in use by the US Navy is the REMUS (Remote Environmental Measuring UnitS), developed by the Woods Hole Oceanographic Institution, described by Stokey, et. al [1]. REMUS is a low cost, light weight, autonomous underwater vehicle designed for operation using a Windows laptop computer. The system has successfully performed thousands of missions for a wide array of applications. At 7.5 inches in diameter and under 80 pounds, REMUS is a robust, compact system, able to survey areas and collect data with side scan sonar and other sensors. Standard sensors on the REMUS platform include: RD Instruments acoustic Doppler current profiler (ADCP), Marine Sonics side scan sonar, long and short-baseline navigation systems, and a light scattering sensor.

FIGURE 1-1: REMUS VEHICLE

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A second vehicle being investigated by the Navy is the CETUS II, a low-cost hover-capable UUV designed for survey, relocation and inspection/intervention operations; the vehicle development has been primarily funded by Lockheed Martin Perry Technologies. CETUS II is the smallest hover-capable UUV and may be launched and recovered from small boats requiring no special handling equipment. The CETUS II vehicle is 54 inches long with a maximum body width of 21 inches (27 inches at the fins) and is adequately sized to support compact minehunting sonars, underwater cameras, and magnetometers. Fully equipped with sensors and minehunting sonar, CETUS II weighs 125 lb. in air and may be trimmed for operations in fresh or salt water. Sensors currently implemented on the vehicle include*:* the University of Washington Applied Physics Laboratory's Mine Reacquisition and Identification Sonar (MIRIS), RD Instruments ADCP, video camera, fiber optic motion reference unit, Woods Hole long baseline navigation, and the Datasonics Advanced acoustic modem.

FIGURE 1-2: CETUS II VEHICLE

HYDROGRAPHIC SURVEY

Naval Special Warfare (NSW) has been tasked to conduct hydrographic reconnaissance in the Very Shallow Water (VSW) region. They require an organic capability to assess and monitor the extent of the sea mine threat including the location of and gaps between suspected mine fields. Specifically, NSW forces are required to locate shallow water mines and obstacles from 21 feet of water depth to the high water line. To successfully conduct the VSW/MCM search mission, NSW forces are required to clandestinely enter into the objective areas, conduct surface and underwater reconnaissance in the beach landing zone, clandestinely depart, and compile and forward a beach survey chart to the Task Force Commander. Use of a small UUV will allow these tasks to be performed in a clandestine manner without putting divers in the water. The Semi-Autonomous Hydrographic Reconnaissance Vehicle (SAHRV) MK14 Mod 0 is a variation of the REMUS vehicle and will be used for this purpose.

The SAHRV MK 14 Mod 0 system is comprised of the vehicle and auxiliary equipment needed to support mission operations, maintenance, storage, and transportation. The primary components of the system include (WHOI [2]):

- Vehicle- semi-autonomous (untethered) self-propelled device
- Transponders- acoustic transmit / receive units that allow the vehicle to determine its position via triangulation
- Ranger- used to track position of vehicle in real-time, and / or send selected commands such as "abort mission" or "come home"
- Precision Lightweight GPS Receiver (PLGR II)- used to place SAHRV transponders
- Rocky Unlimited laptop computer- used to program missions, analyze data, view operational status, and archive collected data on writeable compact disks (CD-RW)
- Power / Data Interface Box- used to speed transfer of data between the vehicle and laptop computer and to provide external power to the vehicle during programming and battery charging
- Transportation containers- two equally sized polyethylene shipping / storage containers; one with an integral cradle for securing the vehicle, the second for protection and transport of SAHRV auxiliary equipment. Two addition containers are provided with the system for protection of the transponders, Ranger, laptop, PLGR II, and other associated gear during transit to and from the area of operation.

In a typical hydrographic reconnaissance operation, a laptop computer is used to program the SAHRV vehicle prior to the planned search. A typical search program will include transiting to the area of interest, performing a ladder search pattern, and returning to the pickup point. Once programming is complete, the vehicle and transponders are transited to the area of operation, and the transponders are placed to provide the navigation network. The vehicle is then launched, performing the programmed search pattern and collecting data. Once the mission is complete, the vehicle is recovered, and the collected data is downloaded and analyzed.

VERY SHALLOW WATER MINE COUNTER-MEASURES (VSW MCM)

The Program Executive Officer, Littoral Mine Warfare (PEO LMW) initiated the UUV program on 15 August 2000. The VSW MCM Unmanned Underwater Vehicle (UUV) System for Search-Classify-Map (S-C-M), will combine the current and demonstrated capabilities of UUVs into a system that will determine the location of bottom and tethered mine-like objects in specific lanes through the very shallow water zone. This system will utilize integrated sensors and navigation technology. The operators will be members of the Naval Special Clearance Team 1 (NSCT1) UUV Platoon, and the UUV System will interface with small craft and Command, Control, Communication, and Computer Interface (C^4I)

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equipment for precise navigation and mapping of target locations. The UUV System will be launched to map the potential minefields and possible mines in the VSW zone for avoidance, or later clearance by other MCM assets. After working in its assigned area, the system will return to a recovery point and the mission data collected will be downloaded for transmission back to the VSW MCM Commander and to other operational commanders.

The next phase of the VSW MCM program will be the evaluation of systems for the reacquisition and identification (RI) of those targets found by the SCM system. During this mission, the vehicles will be directed to locations of targets previously found by the SCM or other systems, with the intent of obtaining sufficiently detailed information for positive identification as a mine or non-mine. Space and Naval Warfare Systems Center San Diego (SSC SD) is evaluating sensors and platforms to perform this mission. Initial system tests will include the use of high frequency side scan and optical cameras on the REMUS and the CETUS II platforms. A preliminary operational capability is planned for NSCT1 in 2004.

ANTI-TERRORISM / FORCE PROTECTION

The US Navy Explosive Ordnance Disposal (EOD) Mobile Unit 7 is currently evaluating the use of REMUS UUVs for anti-terrorism / force Protection applications. Three primary mission areas are being examined: hull search, berthing area search, and small area survey. The driving force in these missions is the need to gather and disseminate information in a timely manner. They are currently operating two REMUS UUVs: one with a 900 kHz side scan sonar, and one with a 1.2 MHz side scan sonar. Over the course of the two-year program, these systems will be operated in a variety of operational environments with tactics developed for use by the EOD community.

Other platforms are also being developed for use in harbor security and force protection applications. The CETUS II is currently being outfitted with a high frequency (2.4 MHz) side scan sonar and altitude sensors designed for close-in conformal inspection of ship hulls. The system is described further by Trimble [3].

CHEMICAL DETECTION AND PLUME MAPPING

The Office of Naval Research (ONR) Chemical Sensing in the Marine Environment (CSME) program targets the development of novel means to detect and locate unexploded ordnance in marine environments. A REMUS UUV has been used for chemical plume mapping, as described by Fletcher [4]. In support of a plume tracking demonstration this year, two main efforts are underway, described further by Arrieta in [5].

First of these is the integration of a chemical sensor onto the REMUS vehicle. An integration specification is being developed to facilitate the installation of this type of sensor onto the vehicle. The integration follows a modular approach by placing an additional body section between the doppler profiler module and the nose cone, thereby eliminating the need to penetrate the pressure vessel. The new sensors will make use of the sensor input interface already provided on the REMUS for the optical backscatter sensor and fluorometer.

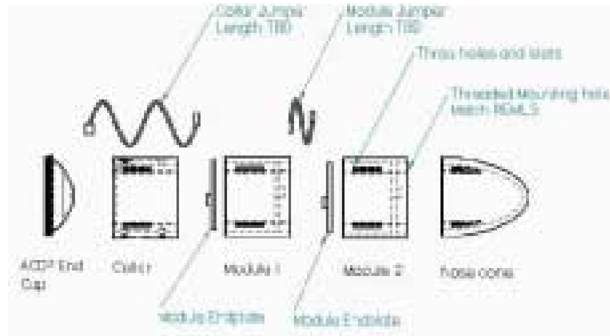

FIGURE 1-3: REMUS SENSOR MODULE

The second effort is an Adaptive Mission Planning (AMP) capability so that the UUV can rapidly respond to odor detection events and changes in the fluid environment (e.g., flow direction). An AMP with the desired capabilities has been designed and tested in simulation by Dr Jay Farrell at the University of California, Riverside. The AMP, a separate "brain" that has the ability to take control of the vehicle and provide it with external navigation and control commands, is installed on the SSC SD REMUS UUV. During normal operations, the standard REMUS vehicle executes a pre-programmed mission, navigating to pre-determined waypoints and water depths and/or altitudes above the bottom. However, for certain missions such as plume tracking, the vehicle is able to adaptively modify its plan based on inputs received during the mission from vehicle sensors. To accomplish this, it implements search strategies in an intelligent manner as dictated by the mission circumstances without human intervention. Throughout the mission, the UUV combines the sensed flow and concentration information to construct a map of likely source or plume locations. The AMP allows the vehicle to break away from the pre-programmed missions. During recent demonstrations, the vehicle has used both bathymetry and chemical concentration as the driving input , as shown in Figure 1-4.

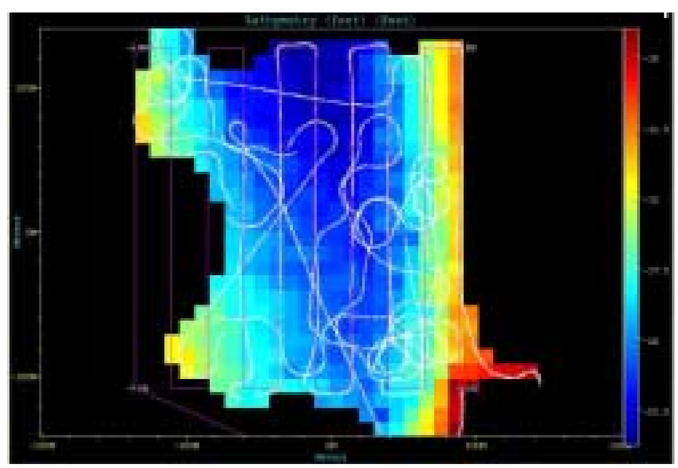

FIGURE 1-4: AMP PATH

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ENABLING TECHNOLOGIES

A number of emerging technologies are contributing to the new mission capabilities of small UUVs. These include the development of new sensors, navigation equipment, and communications.

The development of small, inexpensive side scan sonars has opened the door for the survey applications described above. The small size and light weight of sonars such as those by Marine Sonics, used on the REMUS vehicles, allow for the collection and extraction of data by field personnel using only a laptop computer. The use of forward-looking imaging sonars, such as the University of Washington Applied Physics Laboratory's MIRIS and DIDSON (Dual Frequency Identification Sonar), described by Belcher [6], will enable vehicles to collect photo-quality data in conditions not suited for optical imaging. Future development of these and other sonars will continue to expand the range of missions open to these systems.

Small size GPS antennas and processors are also providing greater capability to the UUV. By combining GPS information with inertial and / or dead reckoning data, it is not always necessary to lay out a transponder field for vehicle navigation. This is a major advantage for operations where the need is for the operators to remain well away from the vehicle operational range.

As many of the missions such as harbor defense require real-time data transmission, the development of high bandwidth communications is increasingly important. Use of acoustic modems allows for real-time transmission of data without the need for a hard-wire tether or for exposing the vehicle on the surface. A real-time communication capability also permits the re-direction of the system to accommodate evolving mission scenarios.

Other sensors such as the chemical sensors described above are also contributing to the wide range of missions being performed by these systems. The keys for use on the small vehicles are both small size and low power consumption. As more sensors are developed taking advantage of micro electronics, more applications for these vehicles will evolve

SUMMARY AND CONCLUSIONS

With the dramatic advances in UUV technology, the future applications for such vehicles are only limited by the imagination. Whether launched individually by hand from a small boat or as a swarm of many vehicles deployed from an aircraft, ship or another larger UUV, their impact on future Navy missions will be dramatic. One can envision a helicopter crossing the inlet to a harbor that has been mined, dropping a large number of UUVs as it goes. Once in the water these vehicles gather in groups around a central communications vehicle that provides accurate GPS location and communicates between its squad. Using preprogrammed routines, the vehicles, each with their own simpler navigation system, begin to search the harbor, communicating as they go. Periodic updates are provided back to the communication buoy for relay to the Fleet operators. Once the minefield has been mapped, the targets can be prioritized, and the same vehicles, or another squadron of expendable neutralization vehicles, can be sent to reacquire the targets. At a given time the neutralization charges are detonated and the mines destroyed. These are but a few of the expanding missions for small UUVs.

Whether for high speed hydrographic surveys, MCM or protection of ports and harbors, UUVs are beginning to play an ever increasing role within the U.S. Navy and other organizations tasked with dealing with such missions.

ACKNOWLEDGMENTS

The authors wish to thank the information and contributions provided by the following users of the systems described:

Explosive Ordnance Unit Mobile Unit 7
Navy Special Clearance Team 1
Navy Special Warfare Group 3
Space and Naval Warfare Systems Center UUV Lab

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