Advanced Sensors ACTD Demonstration; FY1998 Summary Report

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LONG TERM GOAL

This effort, succeeding the "VSW Integrated Sensors" effort conducted in FY 1997, supported the long term goal of developing a clandestine mine surveillance, reconnaissance, and detection capability that uses several sensors to provide knowledge of the full dimensions of the mine threat. Technologies developed by the Office of Naval Research include the Toroidal Volume Search Sonar (TVSS), the Synthetic Aperture Sonar (SAS), and the Electro-Optic Identification (EOID) Sensor, with associated signal and image processing and display. These Advanced Sensors, when deployed in a low observable system, will provide the Navy with a capability to conduct low observable or clandestine mine reconnaissance against volume and bottom mines from deep water through very shallow water at a rate ten times that currently available to the Fleet. Furthermore, use of the Advanced Sensors will provide the rapid mine identification capability needed if joint forces are to exploit gaps in enemy defenses (minefields) as envisioned in the concept of Operational Maneuver From the Sea (OMFTS)(1). Since the sensors were ready for field demonstration, they were included in the Joint Countermine Advanced Concept Technology Demonstration (JCM ACTD) conducted during the Maritime Combined Operations Testing (MARCOT) Unified Spirit 1998 NATO Exercises which took place in May-June 1998 in Newfoundland, Canada.

OBJECTIVES

The objective of the Advanced Sensors ACTD was to demonstrate within the Joint Countermine ACTD the unique ability of these sensors to conduct clandestine mine reconnaissance against bottom and volume mines from deep water through very shallow water, and to identify the mines for avoidance or neutralization. Demonstration of these sensor packages was to show a capability for the tactical commanders to execute rapid, safe mine reconnaissance and mine hunting in water depths as shallow as 25 feet against all mine types, using systems which could be organic to the Fleet. This is a greater capability than was demonstrated with the Remote Minehunting Operational Prototype (RMOP), which was equipped with an AN/AQS-14 side scan sonar and a SeaBat forward-looking sonar. The Advanced Sensors packages also provided greater speed, endurance, and sensor performance than the Near Term Mine Reconnaissance System (NMRS). This demonstration was also to provide critical input into the specifications for the RMS Version-4, a later variant of the Remote Minehunting System (RMS), earlier versions of which are already being tested by the Fleet.

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APPROACH

The approach was to integrate the Advanced Sensors into two tow bodies that would be towed by a Remotely Operated Vehicle (ROV), the *Dolphin*. Mr. Steve Castelin conducted the systems engineering of the overall Advanced Sensors hardware and software. A winch system was fabricated and installed in the keel of the *Dolphin* ROV, allowing the deployment and retrieval of the tow body. Mr. Randy Ledman directed this work. The tactical control system previously developed as part of the RMS demonstration was modified for use by the *Advanced Sensors Program*. Mr. Doug Freeman developed the display subsystem with displays for all three sensors. The system overlaid navigational data (from GPS) with target detections to give the ROV operator a tactical view of the search area.

Two different sensor packages were to be demonstrated at MARCOT. This reflected the fact that the mine threat and the means for mine detection differ markedly depending on what depth of water is being surveyed.

For water deeper than 200 feet, the principal threat is moored mines in the water volume. The sensor of choice in this situation is the TVSS, designed for mine detection in the water column at long range. Coupled with the TVSS was the Embedded Computer, developed by Mr. Gary Bills, whose function is to process all sensor data within the tow body and form a [processed] data stream that can be transmitted by the radio link in the ROV to the command ship. The Deep Water (DW) package was developed by Mr. Bob Manning. Dr. Jan Crane developed the tow bodies for both packages.

For very shallow water, closer in to the beach, the areas to be searched become smaller and mine density is likely to increase. At the same time, it is still important to identify all the mines, since the very shallow water areas selected for search are those over which large numbers of amphibious assault craft will proceed during the assault. Often these mines are alternately buried and exposed, as wave forces tending to bury and expose mines are more prominent in shallow water. The sensors selected for the very shallow water suite are relatively short range, but possess high capabilities for buried mine detection, false alarm rejection and mine identification. They are the dual-frequency SAS and the EOID sensor. The sonar performs target detection and classification, while the EOID sensor was to be used for identification. Mr. Jim Christoff prepared the SAS and Mr. Mike Cooper prepared the EOID sensor for integration into the Very Shallow Water (VSW) package. Mr. Phil Bernstein supervised the overall integration of the VSW package.

WORK COMPLETED

We refurbished the *Dolphin ROV* and equipped it with cameras to monitor system operation, high and low data rate radio transmitter/receivers, and a keel winch for variable tow cable length. We successfully tested topside communications between the sensor display subsystem (Elliot) and the vehicle. We then installed the tow cable. We fabricated two spare tow cable assemblies.

The TVSS had been successfully tested in 1994 and was tested and repaired as necessary for incorporation into the Deep Water (DW) package. The DW tow body was developed and tested at sea in FY 97. The TVSS and the GEM Embedded Computer were integrated into the deep water tow body. We calculated and prepared a table of tow body trailback versus depth so that target latitude/longitude could be calculated for display and reporting. We installed an altimeter for assistance in motion control. The GEM computer was equipped with software to process TVSS data in real time and send the processed data to the surface via the RF data link.

After completing development of the DW package we integrated it with the Dolphin and tested it successfully in the Gulf of Mexico.

Simultaneously we developed the VSW package. The tow body was configured differently, with shorter wings, in order to cope with increased hydrodynamic forces characteristic of very shallow water. As in the case of the DW sensor, all control surfaces were active, i.e., they were equipped with computer-controlled actuators which responded to input from motion and attitude measurement sensors in such a way as to keep the vehicle stable. This was critical to adequate performance of the imaging sensors in the package. We first verified the autopilot code by use of models of vehicle performance and subsequently refined it using sea test data. We added ribbon fairing to the tow cable to reduce strum-induced roll in the tow body.

At the request (and with the funding) of the Joint Program Office (JPO) we equipped the SAS with a second side. We then developed real time motion compensation and beamforming algorithms that we implemented on the GEM for the ACTD. We successfully demonstrated the low frequency 3-inch by 3-inch real-time beamformer and the high frequency 1-inch by 1-inch real-time beamformer using previously collected real data as input. Three separate CAD/CAC algorithm suites for detection and classification of mine-like objects, developed at CSS, Lockheed-Martin, and Draper, were completed, documented, tuned on existing data bases, and implemented on the GEM computer. We demonstrated that the GEM computer could beamform the SAS data at its highest resolution and run all three sets of algorithms on the image data in real time to produce the best possible probability of detection/probability of classification on mine-like targets.

The EOID sensor was refurbished by the contractor (Raytheon) and modified so that image data could be sent by radio to the surface processing/display subsystem. After tank testing in the CSS Laser Applications Laboratory we integrated the sensor into the VSW package.

CSS tested all elements of the integrated ACTD system prior to shipment. Both the DW and VSW systems were tested separately during the first part of May and shipped to Stephenville for

participation in the testing/demonstration activities conducted during MARCOT. The objective of that effort was:

- To demonstrate the usefulness for minehunting of the Advanced Sensors as deployed in a tow body towed from an ROV.

- To facilitate Fleet assessment of the technologies.

- To determine whether use of the technologies in the exercise can provide insight into needed improvements and further research.

Mine Countermeasures Squadron Two (COMCMRON TWO) provided tasking for use of the Advanced Sensors. The Advanced Sensors were supported by the *R/V Knorr*, which had been engaged by ONR to serve as a simulated combatant. During the exercises the Advanced Sensors would, upon receipt of tasking, proceed to designated areas and conduct minehunting search operations. Because of the peculiar bottom topography of St. George’s Bay, the VSW system was not used at MARCOT. (In September, 1998 the VSW package was successfully used to survey the Swissair crash site off Nova Scotia.) ONR/Detachment Stephenville furnished the results of the searches to COMCMRON TWO on the USS Inchon[(2)].

RESULTS

The Advanced Sensors DW package collected a large amount of data on moored mine-like objects in the MARCOT exercise area. We demonstrated that the Advanced Sensors could in fact be operated from an ROV-towed vehicle in a mined area. Even when search speed had to be slowed to 5 knots due to the presence of obstructions such as fishing gear and crab pot lines, the search missions were conducted at a rate four times that of current MCM ships.

We learned the following lessons in the MARCOT tests:

- False contacts (those that are mine-like but not mines) were between 1 and 3 per square nautical mile. In fishing grounds, biologics caused a much larger number of non-mine sonar contacts. When minehunting in waters with a great deal of biologic activity, searching the same area two or more times and correlating the results can significantly reduce the number of false contacts. **Improved automatic target recognition algorithms are needed for the TVSS to better distinguish truly mine-like targets from natural agglomerations of material, debris, or biologics.**
- Large populations of crab/lobster pots and their associated lines and buoys became entangled with the equipment, impeding progress. We learned that searching parallel to the surface currents reduced entanglements very substantially. In addition, we added a simple crab line diverter to the tow cable for the final mission and no entanglements occurred.
- Obstacles at sea should be anticipated. Many areas susceptible to mining are close to human fishing, agricultural, industrial, and transportation activity, all of which has the potential to leave a residue of objects and debris in the water. Systems must be designed whose performance is insensitive to the presence of these objects.
- A negative sound velocity gradient created sonar shadow zones and limited the near surface sonar range. Minehunting in waters with a well-defined thermal layer may require multiple searches at differing depths to obtain full column coverage.

IMPACT/APPLICATIONS

We demonstrated by this effort that new ONR technology for unmanned minehunting can provide high area search rates and be organically incorporated into Fleet combatants. The Toroidal Volume Search Sonar's (TVSS) unique capability to search long ranges (and depths) proved to meet the Fleet's need for rapid area search. The way is open to steadily extend the capabilities of the Advanced Sensors, to incorporate a magnetic detection/classification capability, and to improve the weight/volume/power characteristics of the sensors for increasing flexibility of operational use.

TRANSITIONS

In the area of surface minehunting, the Advanced Sensors are being studied for incorporation into the AN/WLD-1, RMS (V4) system. In the area of airborne minehunting, PMS 210 has plans to integrate a variant of the EOID sensor with helicopter towed imaging sonar. Both of these transitions are being considered for the near (1-2 year) future.

RELATED PROJECTS

Coastal Benthic Optical Properties (COBOP)
Streak Tube Imaging LIDAR (STIL)
SIDE LOOKING SONAR (SLS)
BROADBAND SONARS; SAS

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