CoBOP: Electro-Optic Identification
Laser Line Scan Sensors

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LONG TERM GOALS

The goal of the Electro-Optic Identification Sensors Project[1] is to develop and demonstrate high resolution underwater electro-optic (EO) imaging sensors, and associated image processing/analysis methods, for rapid visual identification of mines and mine-like contacts (MLCs). Identification of MLCs is a pressing Fleet need. During MCM operations, sonar contacts are classified as mine-like if they are sufficiently similar to signatures of mines. Each contact classified as mine-like must be identified as a mine or not a mine. During MCM operations in littoral areas, tens or even hundreds of MLCs must be identified. This time consuming identification process is currently performed by EOD divers or ROVs, and is the rate limiting step in many MCM operations. A method to provide rapid visual identification of MLCs would dramatically speed up such operations. Figure 1 illustrates the capabilities of Electro-Optic Identification (EOID) sensors for positive determination of the presence of a mine or minefield.

OBJECTIVES

We are at a transition point for the EOID Sensors project. The first generation EOID Sensor was developed by this project to support Surface MCM (SMCM), and is based upon Laser Line Scan (LLS) technology. LLS technology has consistently produced the best underwater image quality of any underwater imaging technology demonstrated to date. The EOID Sensor was successfully demonstrated to the Fleet at Combined Task Force Exercise 96 (CJTFEX96)[2]. More recently, it was very successfully deployed for object identification in Operation Persistence, the investigation of the Swiss Air 111 crash off Peggy’s Cove, Nova Scotia. The successful demonstration of the capabilities of the EOID Sensor at CJTFEX96 has lead to fleet recommendations to field EOID Sensors to support both Air MCM (AMCM) and SMCM as soon as possible[3,4]. These transitions are now planned. In these roles, EOID will be a key element in implementation of Fleet plans for the development of a robust organic MCM capability.

With these planned transitions, it can be anticipated that the next decade will be very exciting for EOID. Since this will be the Fleet’s first experience with high resolution underwater optical imagery, we can anticipate that there will be evolutions in the tactics for EOID deployments as the Fleet gains experience with the capabilities of the systems. We can also anticipate that the fleet will deploy EOID systems for currently unanticipated missions. Finally, we can expect that pre-planned product improvement (P3I) opportunities will exist. Accordingly, the role of S&T is changing to addressing S&T issues which 1) impact the success of the transitions, and 2) impact “next generation” EOID sensors which are candidates for P3I or other missions.

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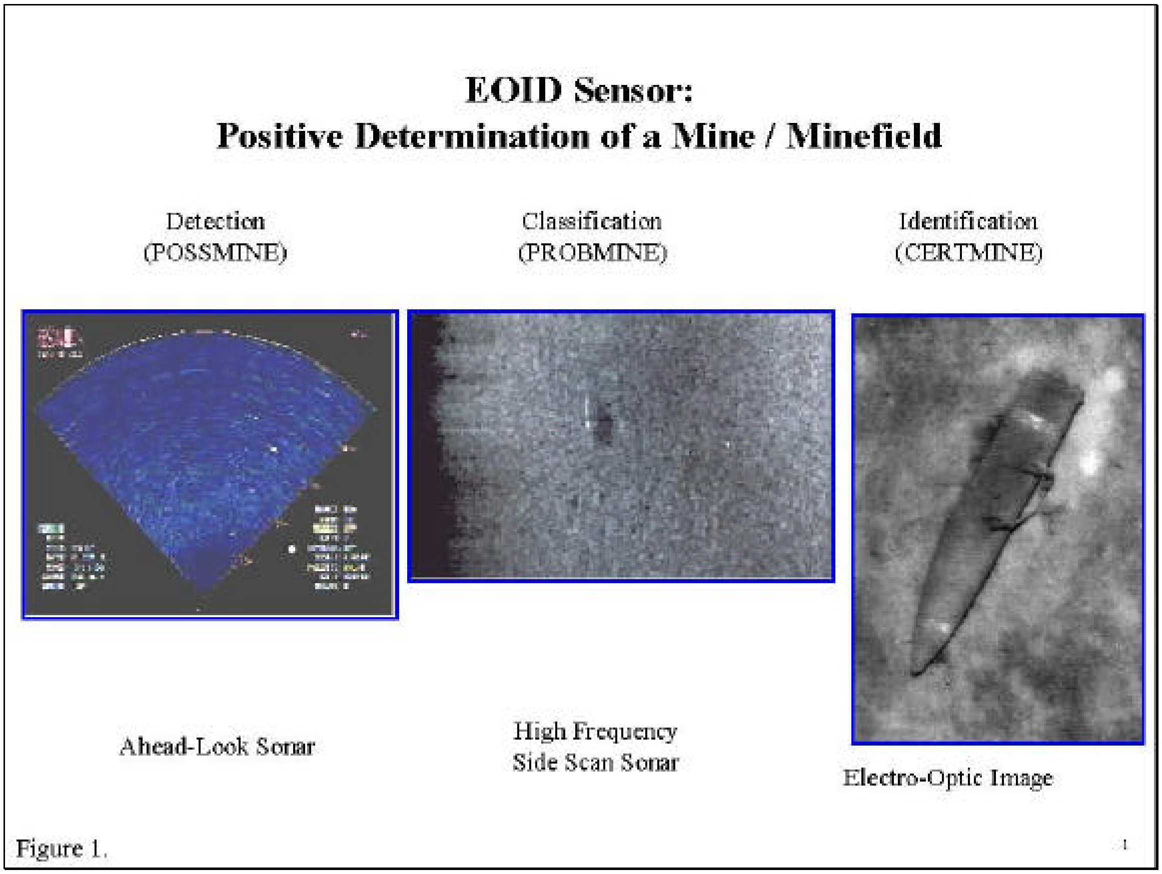


EOID Sensor:
Positive Determination of a Mine / Minefield

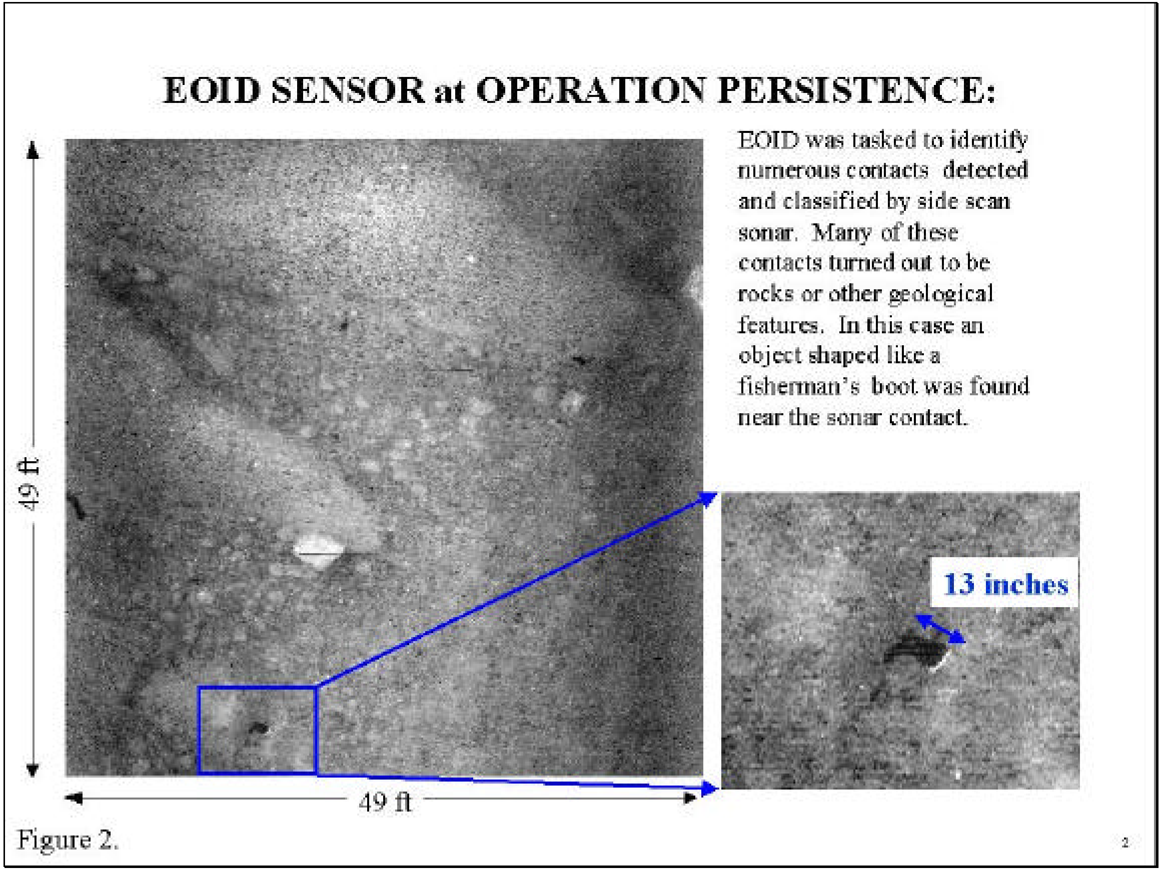
Figure 1.

APPROACH

The approach is to identify and understand the limitations of current and planned EOID sensors and systems that will impact operational performance of these sensors and systems in the fleet. Whenever possible, data acquired with existing LLS (and other) sensors is used to identify and resolve associated issues. Modeling is used as a complementary tool. Additional image data in different environments is acquired when feasible, in order to extend our database of underwater EO imagery. This includes use of the EOID Sensor and a prototype multiple channel laser line scan (MLLS) sensor.

Near real-time image processing, enhancement, and display of the image data is required to adequately support AMCM and SMCM. For both systems, large amounts of image data must be searched for mine-like contacts. Then the processed and enhanced images of only the mine-like contacts must be presented to an operator for target identification. For AMCM, this down-selection of the data to a small number of mine-like contacts for the operator to identify is important because the tow speeds are too fast for an operator to effectively deal with all the imagery. For SMCM in the Remote Minehunting System, this down-selection of the data is critical because the slow speed of the data link precludes transmission of any but a bare minimum of imagery.

The automatic selection of optically mine-like targets from background clutter is a challenging problem. One promising method of dealing with this problem is to exploit spectral information through use of a multiple channel LLS sensor. A key objective of the project is to investigate pay-offs associated with expanding the bandwidth of LLS systems to include spectral information. The MLLS sensor is being used for these investigations. It has been deployed in fluorescence, polarization, and color imaging modes. These investigations are key components of the selection of technology for potential P3I upgrades of EOID sensors in the RMS and AQS-20X programs.



EOID SENSOR at OPERATION PERSISTENCE:

EOID was tasked to identify numerous contacts detected and classified by side scan sonar. Many of these contacts turned out to be rocks or other geological features. In this case an object shaped like a fisherman's boot was found near the sonar contact.

Figure 2.

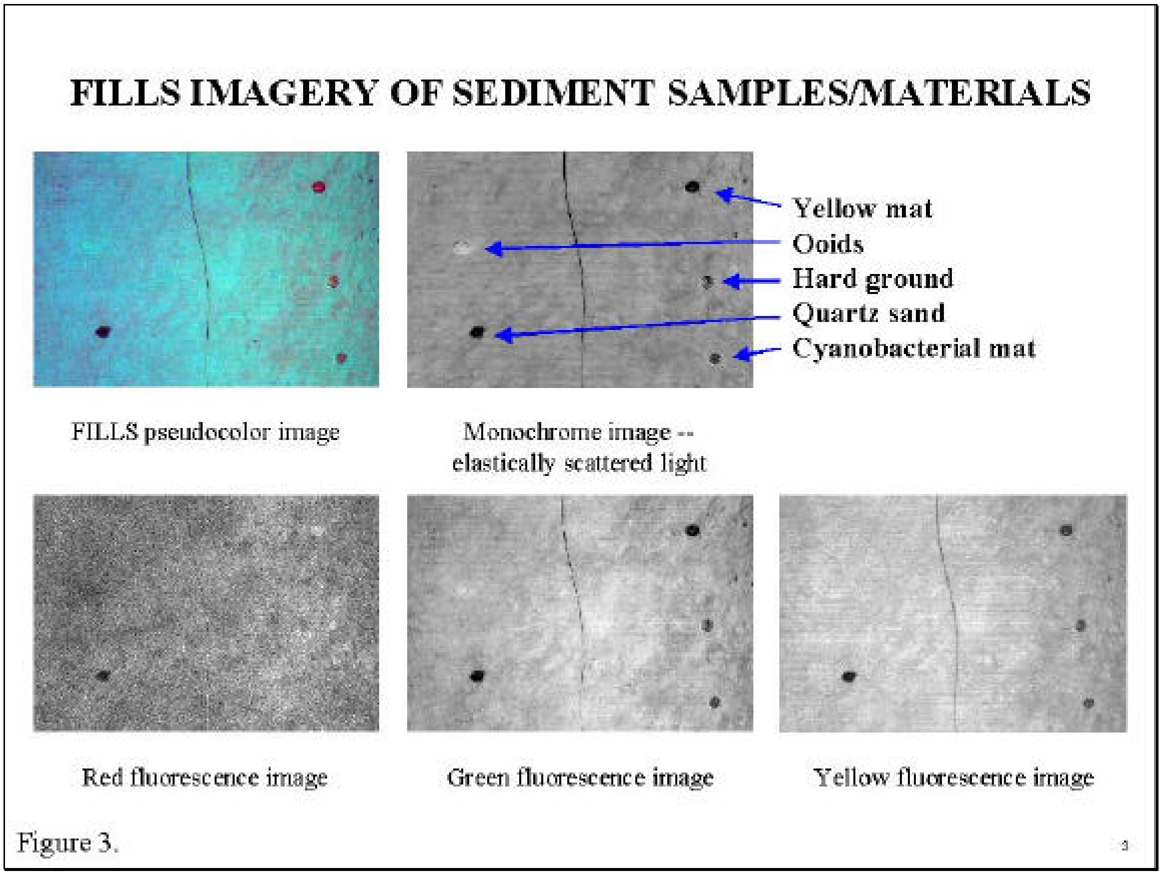
WORK COMPLETED / RESULTS

A test procedure for quantitatively evaluating the impact of environmental noise sources on underwater electro-optic imaging systems has been formulated[5]. Using this straightforward test procedure one can quantitatively determine the detrimental impacts of backscatter noise, blur/glow/forward scatter noise, and ambient light field noise. When the imagery degrades to the point where target identification can no longer be made, it is possible to clearly identify the origin of this degradation (e.g., backscatter or forward scatter noise). Improved systems that address the identified limiting factor(s) can then be designed. This testing protocol will allow other underwater imaging sensors (e.g., laser range gated, and streak tube imaging lidar) to be similarly evaluated.

Several algorithms for processing and enhancing monochromatic LLS imagery have been developed[6,7,8,9]. These routines correct for channel to channel variations in the signal strength, compensate for the extended slant range on each side of the scan lines, and enhance low contrast objects obscured in low signal strength regions. Initially these algorithms required operator intervention for good results. They have been refined to be fully automated and adaptive. Additionally, initial steps have been taken toward implementation of automated object detection algorithms.

At Operation Persistence the sea floor was rich with geological features which sonar operators classified as potential targets of interest. EOID was tasked to identify these sonar contacts. The EOID image processing and enhancement algorithms were key to the success of the EOID Sensor deployment. Figure 2 shows a portion of the EOID imagery acquired near one of the sonar contacts.

The prototype MLLS sensor, in its Fluorescence Imaging Laser Line Scan (FILLS) configuration [10,11,12,13], was deployed at the CoBOP Lee Stocking Island (LSI) test site during the May 1998 field test[14,15]. FILLS imagery was obtained of coral reefs, sediments, sea grasses, and various other targets including mine-like objects.



FILLS IMAGERY OF SEDIMENT SAMPLES/MATERIALS

FILLS pseudocolor image

Monochrome image -- elastically scattered light

Red fluorescence image

Green fluorescence image

Yellow fluorescence image

Figure 3.

During this deployment it was clearly demonstrated that the type of sediment strongly influences the background fluorescence signal. Figure 3 shows a FILLS image where samples of five different sediment types were inserted into the natural calcium carbonate sediment at the LSI test site. Four of the five sediment samples could easily be distinguished from the carbonate background by their fluorescence signatures. It is not surprising that the ooids, formed by spontaneous precipitation of calcium carbonate, exhibit little contrast with the carbonate background.

FILLS IMAGERY OF SEA GRASS

FILLS pseudocolor image

Monochrome image -- elastically scattered light

Red fluorescence image

Green fluorescence image

Yellow fluorescence image

Figure 4.

Figure 4 shows a FILLS image of sea grass. In the elastic scatter image the sea grass appears dark, since it absorbs the 488 nm light more strongly than the carbonate sediment. The sea grass also appears dark in the green (514 ± 20 nm) and yellow (570 ± 40 nm) fluorescence images, because the sediment fluoresces more strongly than the sea grass in these bands. The surprise was in the red (680 ± 20 nm) fluorescence band. The general expectation was that strong fluorescence from the chlorophyll in the sea grass would cause the sea grass to appear brighter than the sediment. Instead the contrast is close to zero, apparently indicating comparable red fluorescence from the sediment and the sea grass.

The automated image enhancement routines have been extended to apply to the FILLS imagery acquired at CoBOP and other tests[16]. The signal characteristics of the fluorescence channels are quite different from those of the elastic scatter channel of monochrome LLS systems. Specifically, the background fluorescence signal (from the sediment) is generally very weak, but there are typically certain items (e.g., coral heads) which have very intense fluorescence signals. The challenge is to enhance the weak background fluorescence signals without saturating the intense fluorescence signals. In the past this processing has required significant human intervention. Since the May 1998 LSI field test, a set of fully automatic routines has been designed and implemented. It was found necessary to develop two sets of automatic routines. The automatic processing / enhancement routines will allow a more rapid turn-around of the FILLS processed data at future CoBOP tests. Raytheon has developed, implemented, and exercised a technique for processing MLLS imagery which is promising for automatic target classification[17].

A database of approximately 100 LLS images of mine-like contacts, clutter, and backgrounds from a variety of tests in a variety of environments has been assembled. This data base is also available to qualified investigators[18] for development of image processing, image enhancement, and target detection algorithms. This data has been requested by a number of investigators, and results are beginning to appear[19]. This data has also been used to explore the resolution required for target identification [20].

IMPACT/APPLICATIONS

The demonstration of the EOID Sensor to the Fleet at CJTFEX96 allowed the Fleet to directly evaluate the impact of deployment of EOID Sensors on MCM operations. Fleet assessment was overwhelmingly positive, as expressed in Naval messages. The factor by which MCM operations would be accelerated through rapid visual identification with EOID Sensors was estimated in the first message. The second message includes the statement “(U) STRONGLY CONCUR WITH REF A RECOMMENDATION TO PROCEED WITH EOID PROGRAM AND FIELD EOID SYSTEMS ASAP” from COMINWARCOM.

TRANSITIONS

The Fleet plans to transition EOID Sensor technology to support AMCM and SMCM. For AMCM , EOID Sensor technology will be inserted into the AN/AQS-20X AMCM tow body. To support SMCM, EOID Sensor technology will be a part of the Remote Minehunting System (RMS).

The EOID Sensor transitioned to the JCM Advanced Sensors ACTD[21]. It has also transitioned to the Mobile Underwater Debris Survey System[22] (MUDSS) Program, sponsored by the Strategic Environmental Research and Development Program.

RELATED PROJECTS

This project is closely coordinated with the Coastal Benthic Optical Properties (CoBOP) DRI. This project is studying the optical signatures of backgrounds, clutter, and targets. These signatures are key to the development of the automatic target detection algorithms required to support AMCM and SMCM.

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