



GO / NO-GO REPORT

DEMONSTRATION OF AN ULTRASONIC METHOD FOR 3-D VISUALIZATION OF SHALLOW BURIED UNDERWATER OBJECTS

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LIST OF ACRONYMS AND ABBREVIATIONS

BFSD	Benthic Flux Sampling Device
BRAC	Base Realignment and Closure
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DoD	Department of Defense
EOD	Explosive Ordnance Disposal
ERDC	Engineer Research and Development Center
ESRI	Environmental Systems Research Institute
ESTCP	Environmental Security Technology Certification Program
FUDS	Formerly Used Defense Sites
MEC	Munitions and Explosives of Concern
RMS	Root Mean Square
ROV	Remotely Operated Vehicles
SERDP	Strategic Environmental Research and Development Program
SPAWAR	Space and Naval Warfare Systems Command
UCLA	University of California Los Angeles
UXO	Unexploded Ordnance

1.0 INTRODUCTION

1.1 BACKGROUND

Many former and active DoD ranges and installations have MEC in the underwater environment posing a potential, current, or future hazard. The Army Corps of Engineers has evaluated formerly used defense sites and found that there are more than 10 million acres potentially containing MEC in underwater environments, at approximately 400 sites, and the U.S. Navy and Marine Corps have identified 20 offshore range sites containing MEC. Relatively little is known about underwater sites which cover a broad spectrum of environments including estuarine, near-coastal and offshore, as well as freshwater. Virtually any munitions in the historical inventory may be found at these sites.

The development of technologies to address detection and identification of MEC in underwater environments is significantly behind those used at terrestrial sites. There have been a number of technologies developed and tested for underwater MEC wide-area detection, including some 15 projects under the SERDP and ESTCP programs. However, the wide-area assessment of underwater MEC continues to be hampered by the lack of technology which can readily discriminate MEC from clutter or non-MEC items which have become buried and are not readily visible. While side scan sonar, laser line scanners, and magnetometry can provide wide-area coverage, the data does not provide sufficient diagnostic information for MEC identification among the significant amount of buried clutter. Before remediation planning can begin debris fields must be classified as hazardous (MEC containing) or non-hazardous (debris only). This is traditionally done by examining historic data, visual identification of objects sitting proud of the sediment, and by digging up shallow buried potential munitions/MEC at spot locations identified as high probability within the wide-area surveillance field.

Often after wide-area underwater surveys debris fields are identified and several high potential objects pinpointed within the field, video spot surveys can provide local imagery for positive “heads-up” identification of high potential objects, but shallow buried or partially buried objects are difficult to assess. Currently, spot surveys of these buried objects must be treated as assumed MEC and require expensive, hazardous removal, identification, and disposal by Navy trained and certified underwater EOD teams. Traditional removal and identification of buried objects by trained EOD disposal teams is slow, expensive, and for benign objects unnecessary. Undisturbed identification of these buried objects either by a single diver using a hand held sensor, in shallow water by pole, or by ROV would greatly speed up spot identification, paving the way for more cost effective remediation and cleanup planning.

The proposed use of an ultrasonic 3-D visualization system for the undisturbed characterization and identification of submerged shallow buried objects will serve to eliminate the costly digging and removal of objects for spot identification.

1.2 OBJECTIVE OF THE GO/NO-GO

This go/no-go test will examine the capability of an ultrasonic 3-D visualization system to provide the undisturbed characterization and identification of submerged shallow-buried objects.

Analysis of a location by this system would provide a visual image of individual buried UXO not visible on the surface.

1.3 REGULATORY DRIVERS

The regulatory issues affecting the MEC problem are most frequently associated with the BRAC and FUDS processes involving the transfer of DoD property to other government agencies or to the civilian sector. When the transfer of responsibility to other government agencies or to the civilian sector takes place, the DoD lands fall under the compliance requirements of the Superfund statutes. Section 2908 of the 1993 Public Law 103-160 requires adherence to CERCLA provisions. The basic issues center upon the assumption of liability for ordnance contamination on the previously DoD-controlled sites.

2.0 TECHNOLOGY

2.1 TECHNOLOGY DESCRIPTION

The 3-D Ultrasonic system was originally developed at UCLA's School of Civil and Environmental Engineering by Dr. Scott Brandenburg. The goal was to study the potential of using p-wave reflection imaging for geotechnical engineering. The demonstration system was adapted for underwater use by SPAWAR Systems Center, Pacific.

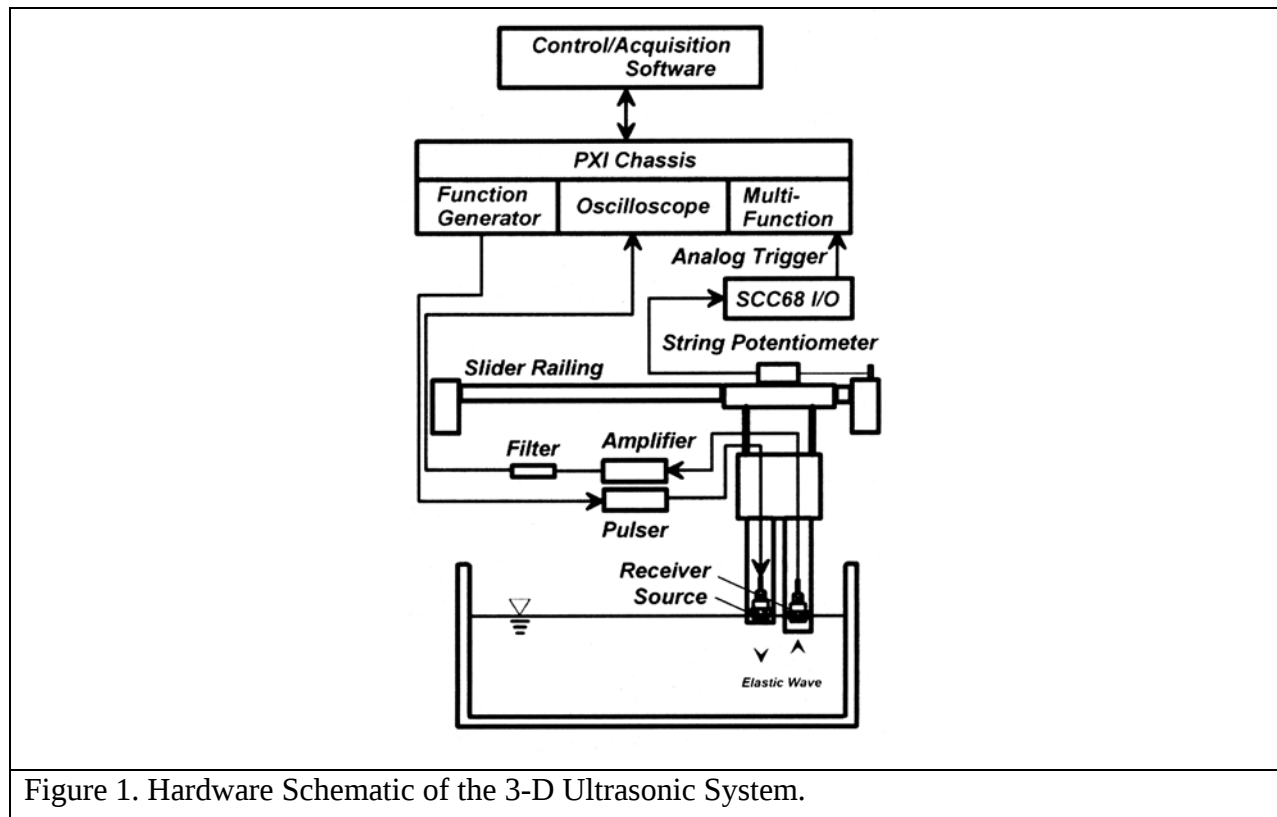


Figure 1. Hardware Schematic of the 3-D Ultrasonic System.

The ultrasonic system components are off-the-shelf hardware consisting of two ultrasonic transducers, source pulser, receiver amplifier, receiver analog filter, terminal block, data acquisition cards mounded in a PXI chassis, a laptop computer running the control and data processing software, and the underwater delivery vehicle with the X-Y positioning system. The vehicle is the BFSD with the X-Y positioning system attached. It is composed of an X-Y gantry system operated by underwater servo motors controlled by the operator's computer. The BFSD vehicle was originally developed under ESTCP project ER-9712 a complete description of the vehicle can be found in the January 2008 ESTCP final report for that project. For this project the flux sampling equipment was removed and replaced by the X-Y positioning system.



Figure 2 BFSD Vehicle, on the left shown with detachable wheels for maneuvering on land, on the right is a test deployment off a pier. The vehicle contains lights and a video camera for accurate positioning underwater.

3.0 PERFORMANCE OBJECTIVES

There are five performance objectives for this go/no-go test they are listed in Table 1.

Table 1. Performance Objectives

Performance Objective	Acceptance Criteria	Current Status	Ultimate Target	Probability of Reaching Ultimate Target
Detection Depth	0.5 m	0.5 m	>0.5 m	high
Scan Time	20 min	60 min	15 min	high
Render Time	5 min to object rendering	2 min	>5 min	high
Software User Interface bugs	0%	0%	0%	high
Object Recognition	100% identification	Qualitative Objective 100%	100%	high

3.1 OBJECTIVE: DETECTION DEPTH

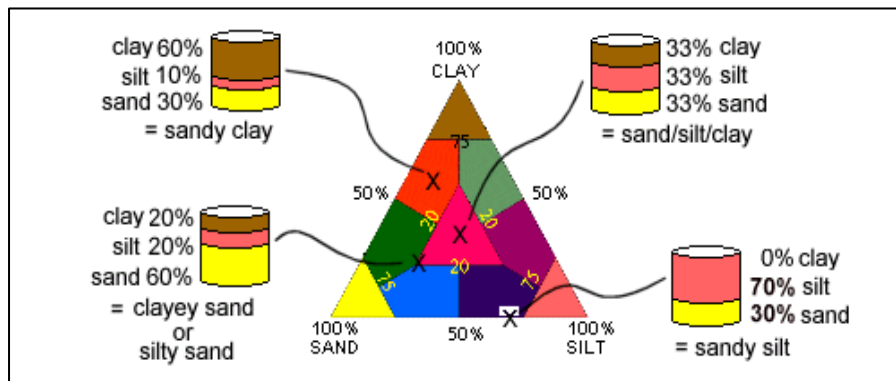
The goal of this performance objective is to determine the ability of the system to generate a useful sonar return signal at the target depth.

3.1.1 Metric

Evaluate the strength of the ping return signal to determine if it is above the noise floor of the of the system.

3.1.2 Data Requirements

Fix the transducer and receiver over each of the four buckets filled to the top with each of the standardized sediment types (Figure 3). Place the system in continuous ping and return mode. Evaluate the 5000 count discrete RMS average of signal return displayed in the user interface and compare it to the no-signal level 0.1 msec before the signal return.



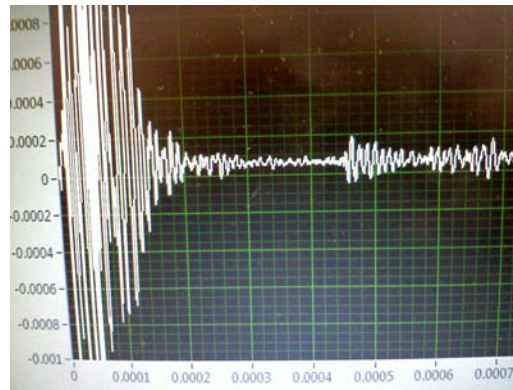


Figure 3. Target depth testing was done with the transducers placed over buckets filled with each of the four sediment types (top picture). Ping returns were noted on the user interface oscilloscope screen (bottom picture) at the appropriate signal travel time (X axis) for that depth.

3.1.3 Success Criteria

The objective will be met if the signal-to-noise ratio is above 0.1. Where the signal-to-noise is the square of the root mean square of the signal amplitude (A_{signal}) divided by root mean square of the noise amplitude (A_{noise}).

$$\text{SNR} = \frac{P_{\text{signal}}}{P_{\text{noise}}} = \left(\frac{A_{\text{signal}}}{A_{\text{noise}}} \right)^2,$$

3.1.4 Performance Assessment

The signal-to-noise ratio was above 0.1 for all four sediment types at a depth of 0.5 m.

3.2 OBJECTIVE: SCAN TIME

This objective will evaluate the length of time of time it takes the system to cover a 1m^2 area. The test was setup by placing the system over a tank of water containing know objects (Figure 4). The system was set to scan a full 1m^2 area and the render times were noted and recorded.

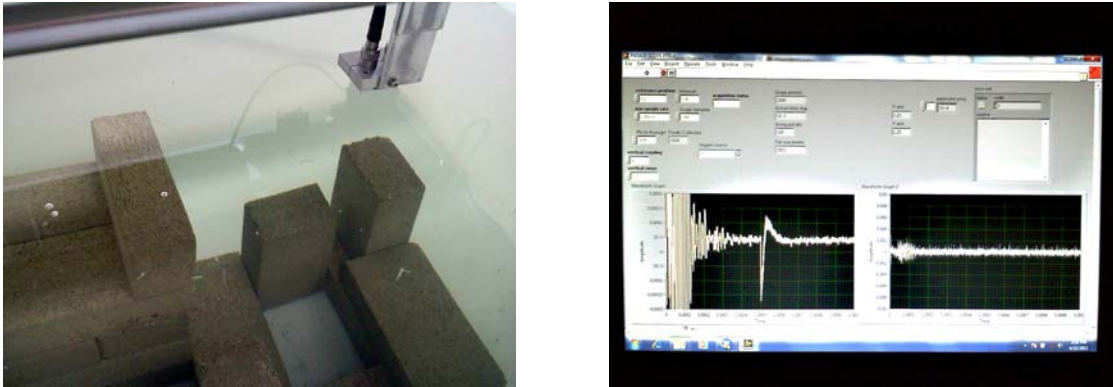


Figure 4. Water tank testing for software scan time and render time checkout. Bricks at known depths and shapes were used to thoroughly check the control and acquisition software. The photo on the right is one of the operator windows showing the oscilloscope ping return and system status indicators. The left photo shows the water filled test tank.

3.2.1 Metric

The metric is the length of time it takes the system to cover 1m^2 using a scanning step size of 3 mm.

3.2.2 Data Requirements

Length of time required for the scan as recorded in the data log.

3.2.3 Success Criteria

A scan time of 20 minutes or less.

3.2.4 Performance Assessment

Scan time for a 1m^2 area was 19.3 minutes.

3.3 OBJECTIVE: RENDER TIME

This objective will evaluate the length of time it takes the software to process the data once the surface scan is complete. The test was setup by placing the system over a tank of water containing known objects (Figure 4). The system was set to scan a full 1m² area and the start and stop times were noted and recorded.

3.3.1 Metric

The metric is the length of time it takes to process a 1m² area data set.

3.3.2 Data Requirements

The data required is the length of time to process the data as measured by a digital watch.

3.3.3 Success Criteria

A rendering time of 5 minutes or less will be considered a success.

3.3.4 Performance Assessment

The rendering time for a 1m² area data set using a PC with a dual core processor and 8 GB of RAM averages 2.2 minutes.

3.4 OBJECTIVE: SOFTWARE USER INTERFACE BUGS

This objective will evaluate the number of user interface errors there are in the software. The test was setup by placing the system over a tank of water containing know objects (Figure 4). The system was set to scan a full 1m² area. Software bugs were noted by the test team and corrected by the software development team.

3.4.1 Metric

The metric is the number of software bugs identified and not corrected during the QA/QC of the software before delivery to the users.

3.4.2 Data Requirements

Evaluation of all the user interface controls and outputs

3.4.3 Success Criteria

100% error free, all identified bugs have been corrected.

3.4.4 Performance Assessment

Three software bugs were identified during the QA/QC of the software. Software modifications were completed to address these errors and the new version of software passed QA/QC without any errors.

3.5 OBJECTIVE: OBJECT RECOGNITION

This objective will evaluate the ability of the system to create identifiable three dimensional models of objects buried in the sample sediment as seen in Figure 5.



Figure 5. Object recognition testing. Left, the test tank filled with sandy clay to a total depth of 1.2m. the Danforth anchor was placed at a depth of 0.5m and the 60mm mortar was placed at a depth of 0.25m. Left, photo showing the transducers submerged in the water traversing the sediment surface.

3.5.1 Metric

This metric is the identification of a 60mm mortar round and 5 lb Danforth anchor scanned at an average depth of 0.5m in sandy clay and a 60mm mortar buried in sandy clay at a depth of 0.25m.

3.5.2 Data Requirements

U3D format data file of the object.

3.5.3 Success Criteria

The data model looks like the object.

3.5.4 Performance Assessment

The two items were rendered and identified. All users were able to correctly identify the objects from the 3D Adobe Acrobat Reader files created by the software. The results can be seen in Appendix A.

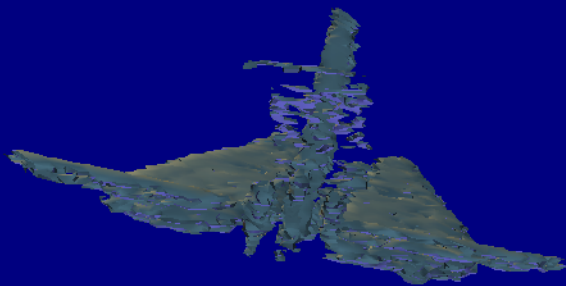
4.0 CONCLUSION

The go/no-go milestone has been met. The system has exceeded all five of the go/no-go criteria. It is recommended that the project proceed to bench scale testing.

APPENDICES

Appendix A: Output of the Object Recognition Test

The software produces a 3D object file (U3D format) that is readable by Adobe Acrobat's 3D viewer. The following two pages contain the files.





Appendix B: Points of Contact

POINT OF CONTACT Name	ORGANIZATION Name Address	Phone Fax E-mail	Role in Project
Mike Putnam	SPAWAR Systems Center, Pacific Code 71752 San Diego, CA 92152	Mike.putnam@navy.mil 619-553-2926	Project Manager
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Scott Brandenburg	UCLA 5731D Boelter Hall Department of Civil and Environmental Engineering University of California Los Angeles, CA 90095	sjbrandenberg@ucla.edu 310-825-9891	System Provider