Utilizing Autonomous Underwater Vehicles for Seafloor Mapping, Target Identification, and Predictive Model Testing

Dawn Lavoie
Naval Research Laboratory
Stennis Space Center, MS 39529-5004
phone: (228)688-4659 fax: (228) 688-5752 email: dawn.lavoie@nrlssc.navy.mil

Kevin Briggs
Naval Research Laboratory
Stennis Space Center, MS 39529-5004
Phone: (228)688-5310 fax: (228)688-5752 email: kevin.briggs@nrlssc.nav.mil
Award #: N0001498WX30251

LONG-TERM GOALS

Our long term goals are: (1) to develop/improve inversion techniques for normal-incidence sediment classification systems and remotely determine sediment physical and geoacoustic properties and (2) to determine mechanisms responsible for scattering of high-frequency energy.

OBJECTIVES

Our objectives are to identify mine burial mechanisms in shallow water environments subject to tidal and wave-induced currents and to test existing predictive burial models with AUV-acquired environmental parameters. These objectives are pursued jointly with the University of South Florida (USF) and Florida Atlantic University (FAU) so as to provide the site characterization and AUV components necessary for the experiment. We must remotely classify sediments for mine burial prediction sing the 2-12 kHz chirp subbottom profiler and predict acoustic reverberation using the chirp sidescan system. These systems can be used to image buried (or proud) inert mines. By collecting ground-truth data with divers together with the remote sediment classification data we can test existing predictive mine burial models. Use of an instrumented mine analogue to monitor the results of hydrodynamic stress on the seabed is an essential portion of the model validation effort.

APPROACH

We designed and constructed a mine analogue instrumented with sensors for detecting motion, orientation and scour for deployment during the late winter experiment in February-March 1998. The plan was to deploy the instrumented mine along with inert cylindrical and bomb-shaped mines in the surveyed area off Indian Rocks Beach, Florida. Diver cores collected from the experiment site before and after significant storm events were to be used to ground truth remote acoustic data collected by FAU. USF was to monitor current velocity and direction and seafloor bedform formation and migration. We also planned to measure seafloor roughness for the purpose of providing, with the aid of other measured sediment properties, predictions of seafloor scattering strength. Such predictions would allow calculation of probabilities of discrimination of targets from baseline seafloor reverberation.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**

4. TITLE AND SUBTITLE **Utilizing Autonomous Underwater Vehicles for Seafloor Mapping, Target Identification, and Predictive Model Testing**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory,Stennis Space Center,MS,39529**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002252.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

WORK COMPLETED

Although a February-March cruise off Indian Rocks Beach was conducted by USF and FAU, a short lead time from the date of acquisition of funds (late January) to the date of the experiment (mid-February) precluded construction of the mine analogue in time for deployment. Instead, we provided several inert mines for deployment during the winter experiment and planned a post-winter sampling of the site aboard a ship of opportunity. We intended to deploy the completed mine analogue during the sampling cruise to establish baseline hydrodynamic forcing variables. Comparison of predictions using mine burial models for severe stress from storms and baseline stress (tides) would be used to validate existing burial models.

Post-winter sampling was performed aboard the R/V Seward Johnson in late August 1998. With small boat support from USF we visited two buried mine sites and collected cores, in-situ permeability, mine photographs and stereo photographs of the seafloor roughness. Due to difficulty in obtaining bids on the fabrication and machining of the aluminum casing, the mine analogue was not available for deployment during the cruise.

Core and data analysis have only started. We have measured sediment sound speed and attenuation on diver cores. In-situ and laboratory permeability measurements made on site have been processed. Although we have many high-quality digital photographs of the buried mines, we have yet to develop and analyze the stereo photographs of the sea floor. Predictions from impact, WISSP, SPMBP and scour models were made from data collected during winter and post-winter cruises. In order to run the models, some model parameters which have not been analyzed yet were determined from pre-experimental site surveys in previous years (Stephens *et al*., 1997).

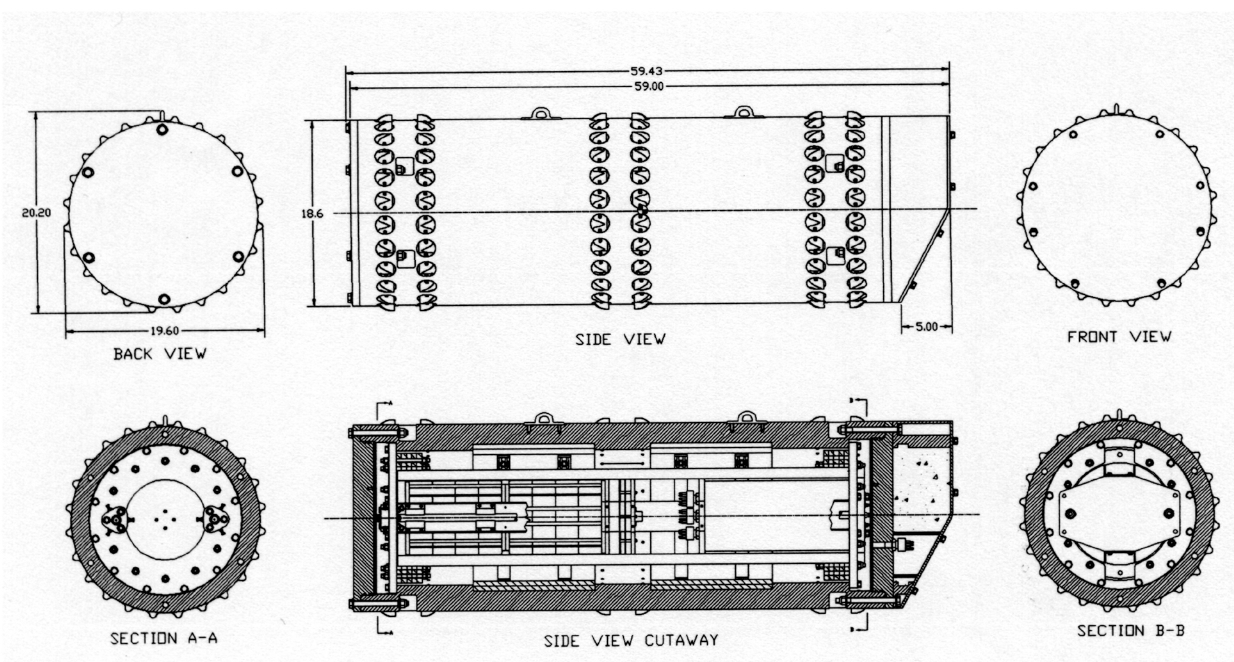

Figure 1. Instrumented mine analogue designed to record in situ motion, orientation, and scour.

RESULTS

Diver observations and cores collected from the site where three inert mines were deployed within 20 m of each other indicated that fine-to-medium sand had winnowed away leaving a very coarse shell lag in which two of the mines were buried. USF-provided side scan imagery indicated that the mines were deployed in the finer substrate before winnowing left only one mine in the finer substrate and the other two buried in the shell lag. Photographs (Figs. 2 and 3) demonstrate that two of the cylindrical Mk52 mines have nearly buried in the interim (March-August). A projectile-shaped mine has completely buried in the shell lag after five months. Sediment to the south was fine to medium sand in which a cylindrical mine was partially buried. The salient characteristics of the two mine types are given in Table 1.

Table 1. Physical parameters of the two types of inert mines deployed.

	Mine A Cylindrical	Mine B Projectile
Mass–Air (kg)	612	227
Mass–Water (kg)	354	170
Overall Length (m)	1.524	1.676
Max diameter (m)	.48	.292
Length of Taper or Base (m)	0	.396
Min Taper distance (m)	.48	.076
Axial Drag Coefficient (m)	Unspecified	Unspecified
External Surface Area (m^2)	2.660	Unspecified
Volume of Mine (m^3)	0.276	Unspecified

Figure 2. Nearly buried cylindrical mine in shell lag. Two sea urchins with attached shells are the dark objects in the foreground.

Figure 3. Cylindrical mine nearly buried in fine-medium sand. Dark objects are sea urchins.

With the aid of S4 current meter data provided by USF for the periods 17 February-9 March and 25 April-28 July, we are able to employ impact burial, scour, liquefaction, and sand ridge migration models to make predictions for the cylindrical (Mk52) and projectile mines. Table 2 gives the parameters needed to make predictions for scour and liquefaction models. Over the range of hydrodynamic stresses measured during the experiment DRAMBUIE predicts that 30-cm deep scour pits develop at each end and the middle of the mine resulting in less than 65% burial of the cylindrical mine, Sakai predicts that liquefaction is a viable mechanism for burial in this area during storms, but GESMA predicts that maximum burial by liquefaction is only 31% (Table 3).

Table 2. Measured values of parameters required for calculation of DRAMBUIE, Sakai and GESMA model predictions.

Water Density (kg/m^3)	1026
Water Depth (m)	4.2
Current Velocity (m/s)	1.0
Time Period (h)	24
Sediment Porosity	0.4
Sub-Bottom Depth (cm)	95
Specific Gravity (g/cm^3)	2.5
Bulk Density (kg/m^3)	2070
Permeability (m/s)	6.765×10^{-7}
Shear Modulus (N/m^2)	4.1×10^{6}
Poisson’s Ratio	.499
Sediment Sound Speed (m/s)	1772
Sound Speed Attenuation (dB/λ)	0.1

Table 3. Wind wave environmental parameters and scour and liquefaction model results.

Wave Characteristics				DRAMBUIE	Sakai	GESMA
Height		Period	Length	Burial Depth	Burial Depth	Burial Depth
ft	m	sec	m	m	m	%
3.2	1.0	4	68	0.3	0.2	31
4.9	1.5	6	113	0.3	0.3	31
5.2	1.6	7	135	0.3	0.4	31
6.2	1.2	8	156	0.3	0.3	31
7.5	2.3	7	135	0.3	0.6	31
9.8	3.0	8	156	0.3	0.7	31
10.5	3.2	9	177	0.3	0.8	31

Because sand wave migration and impact burial are not viable mechanisms in this environment, these models were not employed to obtain predictions for mine burial.

IMPACT/APPLICATION

The mine burial experiment results indicate that small-scale sediment transport (winnowing), as opposed to the migration of sand waves, can be a significant process in burying mines. Burial of the mines, although more effective for bomb-shaped mines, probably occurs through scour around the mine. Mine burial models are not especially sensitive to the environmental forcing present in this particular, though rather typical, shallow-water shelf regime. Clearly, more experiments like this are necessary, although with more frequent monitoring of environmental variables and mine burial in order to understand how mines bury in sands and identify potential modeling improvements. Use of an instrumented mine analogue like the one developed in this project would be ideal for monitoring burial.

TRANSITIONS

Upon completion of analysis our geoacoustic ground-truth data will be utilized by FAU (Steve Schock) in interpreting the normal-incidence and side-scan data from the chirp sonar. The instrumented mine analogue will be used by the NRL 6.2 Mine Burial Processes project in FY99 (Mike Richardson and Dan Lott) in experiments at Duck, NC.

RELATED PROJECTS

1 – The 1998 post-winter survey was accomplished aboard the R/V Seward Johnson during the NRL 6.1 Sediment Geoacoustics project cruise. This cruise was also supported by the NRL 6.1 ISSAMS project (Herb Eppert, manager).

2 – Results from modeling the mine burial constitute a valuable database for the NRL 6.2 Mine Burial Processes project (Mike Richardson and Dan Lott, principal investigators).

REFERENCES

Stephens, K.P., D.L. Lavoie, K.B. Briggs, Y. Furukawa and M.D. Richardson. 1997. Geotechnical and geoacoustic properties of sediments off south Florida: Boca Raton, Indian Rocks Beach, lower Tampa Bay, and the lower Florida Keys. Naval Research Laboratory, Stennis Space Center, MS. NRL/MR/7431--97-8042, 310p.