SHELL SEMS PROJECT

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Quarterly Report No. 3

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CONTENTS

This is the third in a series of regular quarterly reports. SEMS is an acronym for Sandia National Laboratories' Seafloor Earthquake Measurement System, a fully self-contained remote seismic station.

This report is the result of work performed under Funds-in-Agreement No. DE-FI04-83AL24280, between the Department of Energy and the Shell Development Company. Supporting studies have been funded by the Minerals Management Service of the Department of Interior.

1.0 Current Status

References [1] and [2] describe work prior to this quarter. Reference [3] provides the terms of the DOE/SHELL agreement.

The Shell SEMS was assembled, tested, deployed, and monitored once during this quarter. The deployment was successfully completed on May 14. On June 7 the unit was monitored and found to be operating properly. The data recovered at that time are currently being studied, and the software necessary for reducing it is being updated to reflect the specific hardware and software that were installed on this SEMS.

A 13 minute video tape of the installation of the SHELL SEMS has been made [4] and distributed. It describes the final assembly operations and shows the major events that occurred on the day of deployment.

Alonzo Lopez (phone AC 505/844-8783 or 844-6500) was named the project engineer for the SEMS program after James Hickerson was assigned other responsibilities. Al has been the lead electrical engineer for SEMS development for the last four years and has been a key member of the project team since he joined it almost six years ago. Al will be the principal technical contact for all SEMS activities.

2.0 Plans for Next Quarter

In late July or early August the Shell SEMS will be visited and monitored again. At that time, adjustments in trigger threshold for the seismometer will be made and the internal clock will be reset. We expect to have the major portion of the data reduction software complete by then and will be ready to provide routine analyses of the data recovered. A third visit to the unit is planned for mid-September, or immediately after a major seismic event, should that occur first.

We are currently studying the possibility of measuring the tilt of the seismic probe in the sediment. In Section 3.5 we describe a method by which we would set off a small explosive charge in the water over the SEMS and then analyze the resulting response of the SEMS probe to gain information regarding its tilt. If such an approach is feasible, the necessary field work will be done during this next quarter.

A development report covering the design and installation of the SHELL SEMS is in preparation and will be completed in draft form during this next quarter. It will provide full documentation of the unit, its features, design specifications, and method of deployment.

3.0 Summary of Accomplishments

3.1 Hardware Assembly (in Albuquerque). During this quarter assembly and testing was completed on the following:

* the SHELL SEMS
* a backup SEMS electronics system
* the Command and Recording System and transducer
* a backup Command and Recording System

3.2 Immersion Test. On April 1 the SHELL SEMS was transported to the Sandia Test Pond facility for immersion testing. At 2:00 p.m. that day it was submerged in 50 feet of water and began a test series that involved checking its acoustic telemetry system, the operation of its basic seismic functions and memory, the operation of its recovery float circuits, and its overall seaworthiness.

The immersion test was also a test of the Command and Recording System that is used to communicate with the SEMS from a surface ship. The Command and Recording System performs the functions of acoustically communicating with the SEMS via its own transducer, recording the data that is transmitted from the SEMS and, in addition, is able to command a number of adjustments in the SEMS operating software such as trigger threshold and data transmission rate. This electronics package is as sophisticated and complex as the SEMS itself and was built specifically for use with the SHELL SEMS.

On April 2 the unit was recovered briefly in order to adjust the position of its acoustic telemetry system transducer. Following this, it was submerged again to a depth of 45 feet and remained there until 10:00 a.m. on April 4, at which time it was recovered and returned to the assembly building.

During the immersion test, all onboard electronic functions were checked on numerous occasions and found to be operating correctly. Some difficulty was experienced with acoustic reflections from the nearby side walls of the pond that made communication with the SEMS difficult at times. This was not due to any fault of the unit itself and was overcome by adjusting the position of the Command and Recording System transducer that was suspended from a raft floating overhead in the pond.

Extensive testing of the Command and Recording System, both in the lab and at the pond facility, showed it to be functioning properly and ready for service.

Upon return to the assembly building, the SEMS was disassembled and inspected for evidence of leakage or malfunctions. One electrical connector was found to have leaked water through the first of its two O-ring seals. It was also observed that this connector had not been properly tightened during assembly, and a procedural change was made to ensure that this would not occur during the final assembly prior to deployment. It was also decided to adjust the position of the SEMS transducer to a higher location to improve its response and prevent its broadcast and receive pattern from being disturbed by the surrounding framework.

3.3 Final Assembly. Final assembly of the SHELL SEMS was performed at the MARFAB plant in Torrance, California. At that time, the actual battery package was installed and the unit was prepared for the deployment operation that was to follow. Special deployment tools were also fabricated at MARFAB and procedures for using MARFAB's submersible, "DELTA", were discussed and agreed upon.

During assembly of the lithium battery packs, it was found that a design error had been made. Not enough cushioning spacers had been provided between the layers of batteries. This resulted in a crushed wiring harness that caused short circuits when the the pressure vessels were assembled for the first time. This problem had gone undetected during earlier tests because it was not possible to assemble and use the actual lithium battery packs for power sources. These packs had to be shipped as they were received from the manufacturer in order to meet federal regulations on lithium battery transportation.

The assembly problem was overcome by installing low density foam spacers between battery layers. Unfortunately, this modification required additional volume inside the pressure vessels, and left us with insufficient space for all the batteries that were originally planned for. One layer of batteries had to be deleted from each pressure vessel, resulting in a final battery count of 147 packs, down from the 189 packs that were originally planned for. This will reduce the overall life of the unit from approximately five years to about four years. On the other hand, there is no question that the overall reliability of the unit was substantially improved by this modification.

While at MARFAB discussions were held with Douglas Privitt, operator of the submersible "DELTA", as to the procedures and handling equipment needed for the installation of the seismic probe. The design of an insertion tool was arrived at, and it was then fabricated at MARFAB. This tool was termed the 'installation handle' or 'probe handle' and was used to force the probe into the drilled hole. The "DELTA" crew removed this handle after using it to emplace the probe.

While on board ship a tethering arrangement was prepared that linked the SEMS with the equipment needed for drilling the hole for the seismic probe, allowing the two to be lowered together in a fixed orientation. This consisted of a 10-foot length of polypropylene rope inside a rigid PVC tube that was fastened to each unit. The crew of the "DELTA" separated the tether from the SEMS after the hole was drilled by removing a pin at the attachment point.

Reference [4] shows the actual useage of the probe handle and the tethering arrangement, as well as the removal of the pin holding the tether to the SEMS frame.

3.4 Deployment. GEOMAREX of La Jolla, CA was our prime contractor for conducting the deployment of the SEMS on Shell property in the Beta Field. Their subcontractors were GEOCUBIC of Ventura, CA, for services of the ship "GLORITA", and MARFAB of Torrance, CA, for the submersible, "DELTA".

The site for the SEMS was jointly selected by Sandia and Shell California Production, represented by Thomas Szytel. Shell California provided the deployment team with the map:

> "Cultural Resource Evaluation, Bathymetry, Intrafield Piping", prepared by MESA, Inc.

showing the location of platforms and of underwater piping and electrical cables. The map was further marked to show those areas in which Sandia and its contractors were allowed to operate as well as the target site for the SEMS. This site was surveyed by SHELL after installation and the actual location was found to be:

X = 1,429,712 feet
Y = 521,906 feet

California Lambert System coordinates. This site is also identified by

LAT 33° 35' 13" North

LONG 118° 07' 22" West

Reference [5] is an updated version of the Cultural Resource Evaluation map mentioned above that shows all this information and gives the surveyed location of the SEMS as installed.

After arriving at the site, the submersible was launched and reconnoitered the bottom to check for possible hazards, the conditions of the soil, and water visibility. Once it was ascertained that all were satisfactory, GEOMAREX used their Vibracorer (registered trademark) to recover a 12-foot core of the sediments. This was subsequently packaged and shipped to Shell Development Company in care of Dr. Raul Husid (ref. [6]).

The SEMS and the Vibracorer were next put over the side and tethered together by a diver in the water. They were then lowered to the bottom.

It was our intention to next drill a 5 to 6-foot deep hole with the Vibracorer, leaving behind a 5-inch diameter casing. The probe would then be inserted in the cased hole by the submarine, the probe handle removed, and the casing extracted. A fabrication error, however, prevented the modified Vibracorer from leaving the casing in the hole after it was drilled. After several unsuccessful attempts, the crew of the submersible was finally able to insert the probe into an uncased hole, and successfully removed the installation handle and filled the hole. This job was completed at approximately 12:30 a.m. on June 15.

The Command and Recording System located onboard the "GLORITA" was used to interrogate the unit before we departed the installation site, and it was ascertained that the unit was healthy and functioning properly.

3.5 Probe Orientation. In spite of measures taken to ensure that the Vibracorer would drill a vertical hole for the probe, video pictures taken of the final installation prior to removing the probe handle indicate that a tilt of several degrees exists in the final installation. This will cause some cross coupling of signals between the X, Y, and Z transducers. While we believe that this angle and the resultant cross coupling of signals are small, we cannot measure the angle accurately from the video picture because of the lack of a horizontal plane of reference.

In order to arrive at a measurement of the tilt of the probe, we are currently investigating a calibration of the unit by a signal of known orientation. It appears possible, by knowing the soil strength properties, to arrive at the orientation of the probe by setting off a small explosive charge in the water directly above the SEMS. A measurement of the response of each sensor can then be compared with an analysis of the predicted response as a function of tilt. By this means we can possibly determine the true tilt of the probe and use this information to correct all data recovered in the future.

We are pursuing this activity now, and if it appears feasible, we will probably perform the calibration during our next visit to the SEMS in late July or early August.

3.6 Results of the First Data Retrieval. On June 7 the unit was visited and monitored from a 40-foot boat. All functions were found to be operating properly. A total of 4831 events had been detected by the SEMS, for an average of 201 events per day since the system was installed. An average of five of the strongest of these events were transferred to the magnetic bubble memory each day for permanent storage.

After using the Command and Recording System to review the contents of the memory while on site, it was decided to retrieve 8 of the 56 events that were currently stored in memory for further analysis. These were transferred from the SEMS and recorded on magnetic tape.

Our analysis of the data collected thus far shows that none of the events recorded and stored by the SEMS are of earthquake origins. It appears that one of the offshore platforms is causing most of the triggering pulses that have been detected thus far. Over 100 times per day a piece of equipment operates for about 20 seconds at 25 Hz, creating a signal level of 0.00285 g at the SEMS. All the events recovered had this signature. Between these events the average background level was 0.00008 g. All other events recorded by the SEMS were of this magnitude or smaller, indicating that equipment noise may be the relevant and controlling background noise condition.

It is apparent from our analysis of the data and background noise levels that :

1. The system is healthy and operating according to specifications.
2. The system sensitivity is approximately what we had predicted on the basis of estimated background noises from electronics and from wave conditions.
3. The trigger threshold needs to be raised in order to reduce the number of unnecessary triggers of the system that use power from the batteries.
4. Raising the trigger level will in no way degrade the performance of the system because the background noise that must be suppressed is still an order of magnitude below data levels of interest.

We are currently modifying our data reduction software to deal efficiently with the hardware and software that were specifically installed in the SHELL SEMS. When we have completed that and a new algorithm for setting the onboard clock to WWV time, we will interrogate the SEMS again. At that time, we will also remotely adjust the trigger level of the SEMS to a value that is more in keeping with the existing background in order to conserve system power without sacrificing strong motion earthquake sensitivity. We should be ready for this operation in August.

4.0 References

1. Geotechnical Engineering Division 6252, "SHELL SEMS Project, October - December 1984, Quarterly Report No. 1", Sandia National Laboratories.

2. Geo Systems Division 6256, "SHELL SEMS Project, January - March 1985, Quarterly Report No. 2", Sandia National Laboratories.

3. Agreement Between United States of America and Shell Development Company, DE-FI04-83AL24280, February 6, 1984. Amendment No. 1, October 24, 1984.

4. Geo Systems Division 6256, video tape entitled, "Sandia Seafloor Earthquake Measurement System: Beta Field Installation", June 1985, Sandia National Laboratories.

5. Coastal Production Division, drawing 008-85-365, "SEMS Location Plan", 5-24-85, Shell California Production Inc.

6. Letter, Andre' Rossfelder, GEOMAREX, to Raul Husid, Shell Development Company, letter of transmission for the 5-inch diameter core that was taken during the SEMS deployment and shipped to Shell, June 12, 1985.

5.0 Distribution

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