Oil & Natural Gas Technology

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Quarterly Research Performance Progress Report

(Period ending 06/30/2013)

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Temporal Characterization of Hydrates System Dynamics beneath Seafloor Mounds: Integrating Time-Lapse Electrical Resistivity Methods and In Situ Observations of Multiple Oceanographic Parameters

Project Period: October 1, 2012 – June 30, 2015

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RESEARCH PERFORMANCE PROGRESS REPORT

Temporal Characterization of Hydrates System Dynamics beneath Seafloor Mounds: Integrating Time-Lapse Electrical Resistivity Methods and In Situ Observations of Multiple Oceanographic Parameters

ACCOMPLISHMENTS:

Major objectives of the project are to:
1) characterize, geophysically, the sub-bottom distribution of hydrate and its temporal variability and,
2) contemporaneously record relevant environmental parameters (temperature, pressure, salinity, turbidity, bottom currents and seafloor microseismicity) to investigate possible links of the variability to climate. In order to achieve these overall objectives, we have identified the following goals:

a) employ the Direct Current Resistivity (DCR) method as a geophysical indicator of hydrates,
b) identify hydrate formation mechanisms in seafloor mounds,
c) detect short-term changes within the hydrates system,
d) illuminate relationships/impacts of local oceanographic and microseismic parameters on the hydrates system and, indirectly, the benthic fauna,
e) monitor fluid/hydrate motion and seafloor instability that these changes might produce.

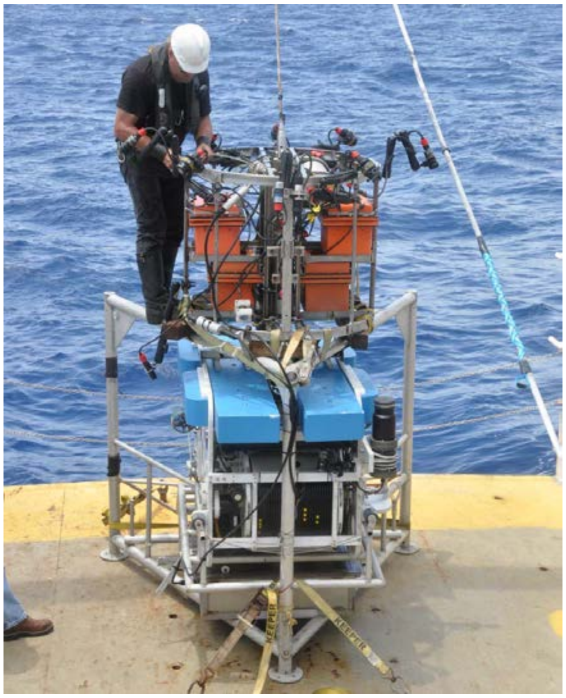
Accomplishments achieved in relation to these goals include the following (Quarter 1):

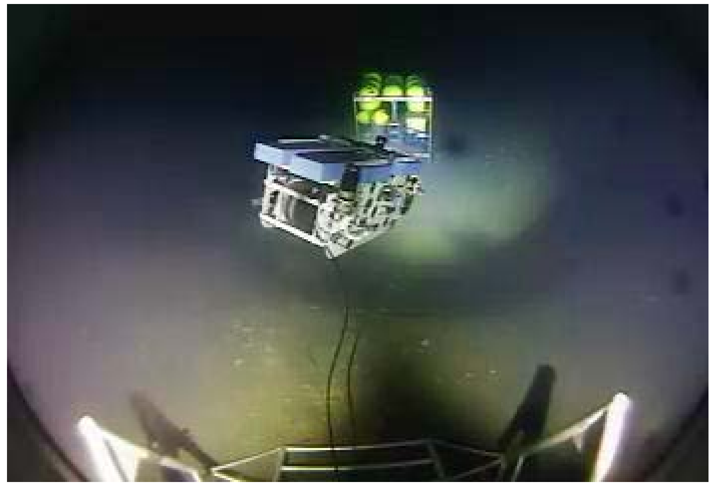
- Completion and acceptance of the Project Management Plan; successful “kick-off,”
- Successful completion and testing (at sea) of the SEA SPIDER, a new deployment and surveying system,
- Beginning of the assembly and evaluation of existing data from the research site at MC118,
- Renovation of the Direct Current Resistivity (DCR) cable in preparation for the September survey.

Accomplishments achieved in relation to these goals include the following (Quarter 2):

- We have used the I-SPIDER, the Integrated Scientific Platform for Instrument Deployment and Emergency Recovery, successfully on three successive cruises both surveying and deploying instruments;
- CMRET’s shop and SDI’s shop have coordinated effort to build the communications software that will enable us to have live communication with the DCR array while in survey mode;
- We have completed the consolidation of electronics into a single “topside system” that greatly increases our ability to control and monitor at-sea operations;
- We have installed Ultra-short Baseline (USBL) transponders in the hull of the R/V *Pelican* to maintain our exceptional navigation/locating capabilities while at sea;
- We have made significant progress in processing the 2012 multibeam data from MC118;
- We have established a processing protocol for the new polarity-preserving chirp data from MC118;
- We have begun to build the IPSO lander;
- We have made repairs to the damaged resistivity system resulting from the flooding event, summer 2012;
- We have determined what caused the instrument to flood;
- We have devised a solution to the flooding problem;
- We have begun work to devise a means whereby operation of the array can be accomplished autonomously while on the seafloor;
- We have scheduled two cruises for 2014 on the R/V Pelican: April 7-12 and October 3-6.

We have used the I-SPIDER successfully on three successive cruises both surveying and deploying instruments. This site reconnaissance-deployment system has been tested and its functions expanded dramatically on repeat occasions.





Left, MMRI Marine Systems Specialist, Lowe, installs the I-SPIDER on the SSD frame. Top, view of the SSD approaching an MMRI lander to service it.

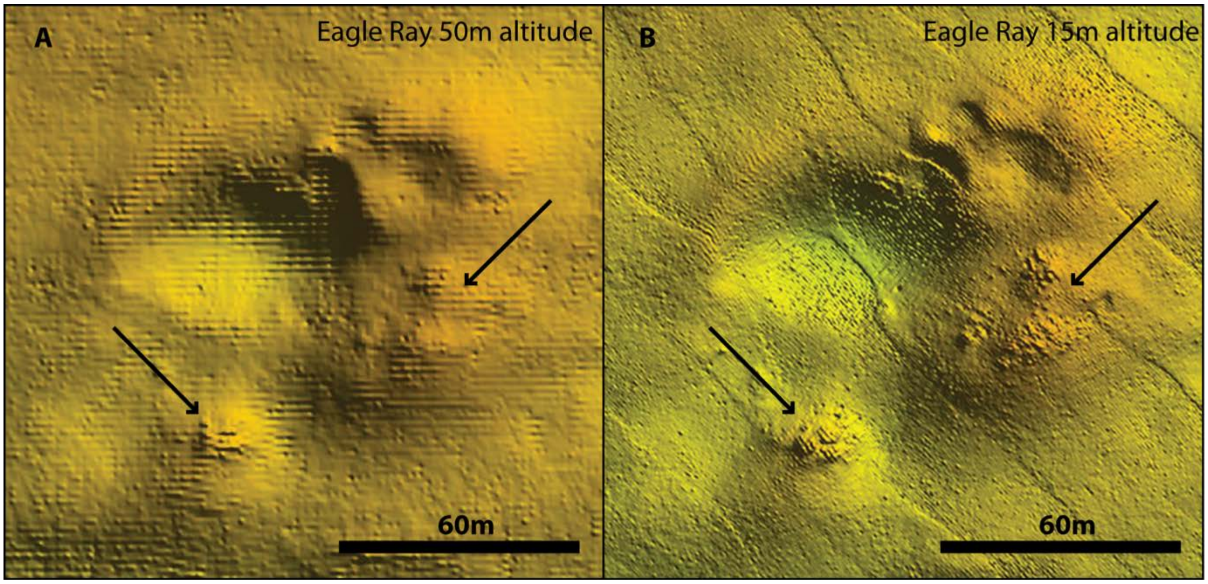
CMRET's shop and SDI's shop have coordinated effort to build the communications software that will enable us to have live communication with the DCR array while in survey mode. CMRET's shop and SDI's shop have coordinated effort on 4 occasions (3 via Skype and 1 visit by CMRET Marine Systems Specialist, Matt Lowe) to build the communications software that will enable us to have live communication with the DCR array while in survey mode. This effort is nearly complete and will greatly enhance our capability/efficiency at sea.

We have completed the consolidation of electronics into a single "topside system" that greatly increases our ability to control and monitor at-sea operations. The control station for survey and deployment vehicles is now consolidated within a large Pelican case that contains video monitoring and recording equipment, a laptop to control functions and display status, two monitors (in the lid of the Pelican case) and the multiplexers that manage fiber communication between the control station and the undersea equipment. Additional laptops are used for sonar control, acoustic tracking, and navigation. The topside control box was designed for use with both the I-SPIDER and Station Service Device (SSD), and has additional components to actuate the thrusters, hydraulics, and other SSD subsystems. Either the I-SPIDER or the SSD can be controlled by the same station with only minor adjustments. Additionally, the SSD has functioned as a fiber payload of the I-SPIDER, with the latter providing a third-person overview of SSD operations within the same control station. Although the tether cable contains three optical fibers, two of these are spares. "Coarse wave division multiplexing," a form of frequency division multiplexing, is used to merge multiple communications channels onto a single fiber. Each channel uses different uplink and downlink frequencies, and passive filters are used at each end of the tether to separate them. The I-SPIDER currently uses two such channels – with the first connecting to a Focal multiplexer (time division type) for video and serial communications. This secondary channel passes to a bulkhead connector on the main housing of the I-SPIDER and can be connected directly to a payload or to another multiplexer or media converter.

Control station for the I-SPIDER and SSD

We have installed USBL transponders in the hull of the R/V Pelican to maintain our exceptional navigation/locating capabilities while at sea. This design improvement will save about 6 hours in calibration time each time we go to sea and will enable us to move through surveys and change locations at much greater speeds than the previous system that limited our speed to 2knts because the transponders were attached to the side of the vessel. We have had the opportunity to make use of this improvement on 2 subsequent cruises of the Pelican and have found the navigation to be quite satisfactory.

We have made significant progress in processing the 2012 multibeam data from MC118.
Autonomous Underwater Vehicle (AUV) multibeam data, acquired in 2012, have been processed to produce high resolution bathymetry maps from MC118. Two datasets have been analyzed: 1) 50 m altitude survey (~1m resolution); 2) 15 m altitude survey (~.50 m resolution). The data have been cleaned, corrected for navigation errors, tide and other parameters, and displayed in morpho-bathymetric and backscatter maps for time lapse analysis with the 2005 AUV survey.
This processing will also provide bathymetry and the hardgrounds (from backscatter) at the research site as well as morphologic features that may translate to hazards, to seep sites or to benthic communities. This effort will continue into the next quarter.



Rock slabs on the seafloor as revealed in a A) 50m altitude AUV *Eagle Ray* survey with ~1.2m resolution and B) a 15m altitude survey (raw data ~.5m resolution).

We have established a processing protocol for the new polarity-preserving chirp data from MC118. Sub bottom profiles have been converted and processed for stratigraphic interpretation/analysis. Using a converter developed in-house, the files logged by the SBP in GeoAcoustics condensed format (.gcf) are merged with vehicle log files and exported in a variant of the SEG-Y (.sgy) geophysical data format. This allows additional processing to be carried out using standard seismic tools, thereby allowing for analysis of sediment elastic properties and, eventually, the creation of pseudo-3D volumes. The 3D representations can be combined with vehicle-derived bathymetry and backscatter measurements to derive a greater understanding of the seafloor structure. This process will allow selection of the most promising sites for the DCR deployment. A time-lapse analysis will be made comparing the 2005 and 2012 datasets.

We have begun to build the IPSO lander. The MMRI shop has completed the overall design of the IPSO lander and has begun building the new lander utilizing the technological experience gained from 15 years of working with landers and 6 years of custom-building them. Parts and instruments have been selected and some ordered for the oceanographic parameters evaluations. Specifications for battery packs are recently received from the Baylor group and design for the battery packs are in draft form.

We have made repairs to the damaged resistivity system resulting from the flooding event, summer 2012. The original assessment of the damage from the flooding was that only the four main circuit boards of the instrument needed to be replaced. The replacement circuit boards were acquired and installed in the first quarter of 2013. However, initial testing showed further problems, which were addressed in the second quarter of 2013. First, there were electrical shorts found within the electrode array between two of the 56 electrodes. These shorts were eliminated by re-terminating the array lead-in cable. Once, that fix was completed, a further short was found between one electrode and the instrument housing. The source of this short was found to be the core of one of the two array connecters that penetrate the housing. The short may have been caused by seawater forced into the backside of the connector, a result of the flooding. A new connector core has been ordered and when it arrives and is installed, the instrument should be back to working order.

We have determined what caused the instrument to flood

In the first quarter of 2013, measurements were made of the diameters and depths of the two O-rings grooves in the instrument housing end-cap to determine if they are sized correctly. These measurements indicated that the O-rings and the grooves in which they fit are sized correctly to seal the housing. However, the inside diameter of the O-ring groove on the face of the housing end-cap was found to be too small to provide sufficient tension on the O-ring to hold it in place during assembly of the housing. This O-ring seals against the top of the housing canister. The best explanation for the flooding of the instrument housing in 2012 is that the this O-ring slipped out of place during assembly and fell into a position that interfered with the seal of the second O-ring that seals against the inside of the housing canister.

We have devised a solution to the flooding problem

Our solution to the housing leakage problem requires two changes to the housing assembly process. In previous deployments that housing canister has been placed on the deck with the opening facing up, while the end-cap and instrument electronics were lowered down into the canister. This allowed the loosely fitting end-cap face O-ring to fall out of place. We plan to avoid this problem by reversing the assembly process. We will build a stand that will hold the end-cap on the deck with the electronics package facing up. The housing canister will then be lowered down onto the end-cap. In this configuration, gravity will hold the problem O-ring in place during assembly. Then, in the second change to the assembly procedure, we will add a fitting to the end-cap that will allow us to draw a vacuum on the housing after it is assembled. The housing will be assembled several hours before deployment. A vacuum will be drawn on the housing and checked periodically for seal. If the housing fails to hold the vacuum, it will be disassembled and the process repeated until a seal is achieved. We plan to test this new assembly procedure in pressure tank tests as soon as the repaired instrument is available in the third quarter of 2013.

We have begun work to devise a means whereby operation of the array can be accomplished autonomously while on the seafloor

During the second quarter of 2013 we entered into negotiations with AGI, Inc. to modify their existing instrument control software for autonomous operation on the seafloor. We are considering two options for this operation. The more complex option would require their control software to automatically begin execution each time a controlling PC was booted by a low-power timer computer. The controller program would then power-up the resistivity instrument, check its status, open a new recording file, and instruct the instrument to record a resistivity profile. When the profile is completed the controlling program would close the recording file, transfer the data from the resistivity instrument to the controlling PC, erase the data file on the instrument, power the instrument down, and power the controlling PC down. This process would be repeated for each profile. The advantages of this first approach would be that the controlling PC could also communicate to the surface via an acoustic modem and the relatively large storage capacity of the PC would mean that profiles could be acquired as often as desired, limited only by the available battery power.

The second approach would do away with the controlling PC between the low powered timer computer and the instrument. In this approach, the timer computer would power-up the resistivity instrument directly. The firmware on the instrument would be modified to execute a command file that records a profile, append the data onto the end of an existing file, and then power itself down. The advantage of this second approach would be that it would be simpler to implement, meaning there is less to go wrong. However, the data storage on the instrument is relatively small. Using this approach, the profile rate would be limited to approximately one repeat profile per day for the planned six-month deployment intervals.   We will decide which of the two approaches to take and implement the chosen approach in the third quarter of 2013.

We have scheduled two cruises for 2014 on the R/V Pelican: April 7-12 and October 3-6. This schedule will allow us six days to recover the lander following the initial 6-month deployment (September 23-28, 2013), evaluate the data-recovery, re-battery instruments and return the lander to the seafloor but in a different location. The October cruise is designed to recover the lander with instruments following another 6-month deployment and data-collecting cycle.

Milestone chart; Progress was made towards achieving Milestones A, B and C.

Milestone	**Planned Completion Date**	**Actual Completion Date**	**Verification Method**	**Progress/Deviation from Plan**
Milestone A: Target sites selection for IPSO deployment at MC118	9/15/2013		4 targets identified	
Milestone B: Successful testing of a new Integrated Portable Seafloor Observatory (IPSO).	9/15/2013		Successful onshore test of IPSO	
Milestone C: Successful deployment of Integrated Portable Seafloor Observatory (IPSO).	9/30/2013		Proper orientation and functioning of IPSO	
Milestone D: Recover data from MC118 with the IPSO	6/2014		IPSO recovered with data	
Milestone E: Complete analysis of temporal characterization of hydrates system dynamics at MC118	3/31/2015		Resistivity and temporal data produce reasonable temporal analysis	
Milestone F: Complete final report and submit to DOE	6/30/2015		Report accepted by COR	

PRODUCTS:

MMRI/CMRET scientists have, since 2005, studied, reprocessed, and analyzed geophysical datasets from thMC118 area. They have deployed instruments here since 2005 and have developed a variety of successful methods. These are being incorporated into the new lander and instrument array to be deployed in September, 2013.

An abstract was submitted and accepted for development into a full paper for the 2013 Transactions of the Gulf Coast Association of Geological Societies (GCAGS). This paper has been written, reviewed, revised and resubmitted (June). It is scheduled to be presented at the Annual Meeting of the GCAGS in New Orleans in October. Part of the paper includes innovative treatment of multibeam data from acquisition through post-processing and analyses. This constitutes another product, or cluster of products, in the form of maps of the research site. These will be used in all stages of the project from the planning of the cruises and selection of target sites for data-collection and potential deployment sites for the resistivity array. Products include:

- Lutken, C. B., D'Emidio, M., Macelloni, L., Lodi, M., Ingrassia, M., Pierdomenico, M., Asper, V., Woolsey, M., Jarnagin, R., Diercks, A., 2013, *Challenges in imaging the deep seabed: examples from Gulf of Mexico cold seeps,* Transactions of the Gulf Coast Association of Geological Societies, New Orleans, October 6-8.
- Post-processing of multibeam data acquired in 2012 from Woolsey Mound (MC118) is well underway. This dataset will be used along with previously acquired multibeam data to select

target sites for the resistivity active study as well as for sites at which to deploy the resistivity array.

- Papers have been submitted to Oceans 2013 in which participants are co-authors. These include processing and interpretation of multibeam data and the development of the I-SPIDER:
  - Lowe, P. M., M. Woolsey, R. Jarnagin, C. B. Lutken, B. Noakes, L. Overstreet, S. Tidwell, 2013, Development of I-SPIDER: a towed platform for video survey and instrument placement.
  - Woolsey, M., R. Jarnagin, K. Sleeper, L. Macelloni, M. D'Emidio, A.-R. Diercks, V. L. Asper, 2013, Integration of a Polarity-Preserving Chirp Subbottom Profiler into the NIUST AUV *Eagle Ray*.
- A paper evaluating the heat-flow study conducted by the Consortium at MC118 in March, 2012 has been written, reviewed by contributing authors, revised and re-revised. Lead author, Macelloni, is making final revisions before submission to the Journal of Geophysical Research. The tentative citation is: Macelloni, L., Lutken, C. B., Garg, S., Simonetti, A., D'Emidio, M., Wilson, R.M., Sleeper, K., Lapham, L., Lewis, T., Pizzi, M., Knapp, J., Knapp, C., Brooks, J. and McGee T.M., *Heat-flow regimes and the hydrate stability zone of Woolsey Mound (northern Gulf of Mexico): a transient, thermogenic, fault-contolled hydrate system.*

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS:

During this quarter, personnel from the University of Mississippi and from both subcontracting organizations, participated in the initial stages of the project. Their contributions are as follows:

Name: Carol Lutken
Project Role: PI, University of Mississippi
Nearest person month worked: 0 (1 week)
Contribution to Project: Lutken worked with D'Emidio to evaluate and clean data, readying them for site selection. She also executed all communications between participants and scheduled the next season's cruises.

Name: Marco D'Emidio
Project Role: Scientist, University of Mississippi
Nearest person month worked: 1 (five weeks)
Contribution to Project: D'Emidio has led the effort to assemble existing geophysical data from the project site. He has progressed with the post-processing efforts of the two new (2012) multibeam surveys from the Woolsey Mound area of MC118 and established the protocol for the polarity-preserving chirp data recovered from MC118 in late 2012.

Name: Matt Lowe
Project Role: Marine Systems Specialist, University of Mississippi
Nearest person month worked: 0 (1 week)
Contribution to Project: Lowe is the Chief of shop operations at MMRI/CMRET. During this quarter, he completed initial lander design for the IPSO, and has directed the at-sea activities involving the I-SPIDER, the primary means by which the DCR survey and IPSO placement and deploymentwill take place.

Name: Steven Tidwell
Project Role: Research Associate, University of Mississippi
Nearest person month worked: 0 (1 week)
Contribution to Project: Tidwell is the MMRI/CMRET shop technician with a degree in geological engineering and expertise in machining and electronics as well as computer software. During this quarter, he worked to convert existing lander components to those needed for the IPSO lander and began the redesign of an existing lander to accommodate the resistivity array. He has also machined pressure housings.

Name: John Dunbar
Project Role: Co-I, Baylor University
Nearest person month worked: 1 (3 weeks)
Contribution to Project: Dunbar has identified sources of failure in the DCR, corrected them and designed a new deployment strategy to prevent further deployment related failures. He has worked with Higley and AGI develop autonomous seafloor operation capability.

Name: Paul Higley
Project Role: Co-I, Specialty Devices, Inc.
Nearest person month worked: 0 (1 week)
Contribution to Project: Worked with AGI and with Dunbar to develop autonomous seafloor operation capability.

Name: Scott Sharpe
Project Role: Electronics specialist, Specialty Devices, Inc.
Nearest person month worked: 0 (1 week)
Contribution to Project: Worked with AGI and with Dunbar to AGI to develop autonomous seafloor operation as well as interfacing the control system to the DCR instrument.

IMPACT:

An application for patent has been made by the University of Mississippi's Office of Research and Sponsored programs for the I-SPIDER, Integrated Scientific Platform for Instrument Deployment and Emergency Recovery. The I-SPIDER has now been instrumental in the success of three successive cruises, successfully reconnoitering seafloor deployment sites, providing visuals on bubble streams and benthic communities, carrying instruments and landers to the optimal/selected site and releasing the payload on command. It has been used alone and in concert with other systems. Although not funded under this award, the I-SPIDER is a result of the ongoing at-sea activities of the MMRI and the need to have better visuals and seafloor information prior to making instrument deployments, recovering samples and executing surveys. This system is designed to reduce risk to equipment in a hazardous environment and to improve a researcher's chances of recovering data and to recover data from the precise location or environment targeted. It will be used in this project to emplace instruments/arrays in premier locations and to conduct surveys that include visual data matched precisely to location and to other datasets.

The survey and deployment efforts of the I- SPIDER and other instrumentation used in this project will be guided by the seafloor imagery in-hand. This is constantly improving as we reprocess existing data and add datasets to our arsenal. The better definition we are able to get of the seafloor, the better we will be able to guide these efforts. A beginning has been made to produce a new generation of imagery that will serve the goals of this project better than existing quality products.

The quality of seafloor imagery is a priority with our group. Government and hydrocarbon companies and their support industries rely upon seafloor imagery to site, survey, build, operate and decommission seafloor structures. With more detailed information from the seafloor and shallow subseafloor, including the hydrate stability zone (HSZ), these operators can achieve their goals in a safer and more efficient manner. They can also use the improved definition to focus on preferred sites, eliminate sites without characteristics that recommend others, saving needless expense and reducing risk. We have recently been contacted by the Navy to work with them and with BOEM on seafloor projects that require very precise locating capabilities and multiple sets of "eyes on the seafloor."

Students and interns have long been a vital part of our projects. The methods that we have developed and that we are developing are using, have been tested and some of them developed by students. We encourage these students to participate at all levels and expect at least one student to go to sea with us on every cruise in this project, as part of the scientific crew. We also hope to have a student/intern as part of our shop team.

The collaboration of our shop with another shop at the University of Mississippi in the electrical components of the I-SPIDER has made that project and system available to this project ahead of schedule. Because of this collaboration, we have gained access to their expertise in electronics and underwater systems and they have gained access to our expertise in mechanical design, machining and deployment and recovery techniques. We have published several papers on these subjects of shared development, as listed in the *Products* section of this report.

CHANGES/PROBLEMS:

Changes to this project were made prior to the execution of the contract. Since that time, there have not been major changes in approach, anticipated timing, or budget. Some changes that are currently being addressed are:

- The I-SPIDER (name change due to patent process) has now been operated successfully on three cruises as a survey and deployment tool performing excellently in both modes. The Station Service Device ROV will also be available as an option for use in concert with the I-SPIDER. Particularly for survey mode, we hope to accomplish the projects goals using the I- SPIDER, primarily because we will be able to monitor the survey, visually, as it is happening, thus avoiding hazards while acquiring the ability to match seafloor environment with resistivity anomalies.
- Dunbar has rebudgeted the time for which he will employ a student on this project. With a strong student "in-hand", he has altered his time-budget to allow the student to begin work in the third quarter of Year 1 of the project.

SPECIAL REPORTING REQUIREMENTS:

None noted.

BUDGETARY INFORMATION:

The expenses incurred during this quarter have been charged to both direct charges and cost-sharing. Subcontractors Higley and Dunbar have spent some of his funds but they have not been charged to UM yet so do not appear in the budget sheet. Please see the budget report spread sheet, below.

DOE Hydrates FY12 DE-FE0010141 Baseline Reporting by Quarter	**Budget Period 1**								**Budget Period 2**								**Budget Period 3**			
	Quarter 1 - Corrected		**Quarter 2**		**Quarter 3**		**Quarter 4**		**Quarter 1**		**Quarter 2**		**Quarter 3**		**Quarter 4**		**Quarter 1**		**Quarter 2**	
	1/1/13 - 3/31/13		**4/1/13 - 6/30/13**		**7/1/13 - 9/30/13**		**10/1/13 - 12/31/13**		**1/1/14 - 3/31/14**		**4/1/14 - 6/30/14**		**7/1/14 - 9/30/14**		**10/1/14 - 12/31/14**		**1/1/15 - 3/31/15**		**4/1/15 - 6/30/15**	
	Q1	**Cumulative Total**	**Q2**	**Cumulative Total**	**Q3**	**Cumulative Total**	**Q4**	**Cumulative Total**	**Q1**	**Cumulative Total**	**Q2**	**Cumulative Total**	**Q3**	**Cumulative Total**	**Q4**	**Cumulative Total**	**Q1**	**Cumulative Total**	**Q2**	**Cumulative Total**
Baseline Cost Plan																				
Federal Share	127,121	127,121	127,120	254,241	209,200	463,441	127,120	590,561												
Non-federal Share	36,912	36,912	36,912	73,824	36,912	110,736	36,912	147,648												
Total Planned	164,033	164,033	164,032	328,065	246,112	574,177	164,032	738,209												
Actual Incurred Cost																				
Federal Share	-	-	8,592	8,592																
Non-federal Share	22,599	22,599	5,770	28,369																
Total Planned	22,599	22,599	14,362	36,961																
Variance																				
Federal Share	127,121	127,121	118,528	245,649																
Non-federal Share	14,313	14,313	31,142	45,455																
Total Planned	141,434	141,434	149,670	291,104																