Development of I-SPIDER: a towed platform for video survey and instrument placement

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***Abstract*–The I-SPIDER or Integrated Scientific Platform for Instrument Deployment and Emergency Recovery, is a battery-powered camera and light platform tethered by a fiber optic cable to a surface support vessel. It was designed by the Mississippi Mineral Resources Institute at the University of Mississippi with assistance from engineers at the National Institute for Undersea Science and Technology. In addition to cameras and lights, the I-SPIDER is capable of integrating additional payloads over serial, ethernet, and fiber optic interfaces. It typically carries a scanning sonar that is used to navigate relative to seafloor equipment and bubble plumes. A tracking system with equipment mounted to the ship and I-SPIDER is used for absolute positioning. Along with the navigation sensors, a motorized release mechanism allows precise placement of instruments on the seafloor. The I-SPIDER has been utilized on several recent cruises; notable achievements are discussed in this paper.**

***Keywords*—seafloor video; instrument deployment**

I. Background

The I-SPIDER, or Integrated Scientific Platform for Instrument Deployment and Emergency Recovery, is a battery-powered camera and light platform tethered by a fiber optic cable to a surface support vessel. It was designed by the Mississippi Mineral Resources Institute (MMRI) at the University of Mississippi with assistance from engineers at the National Institute for Undersea Science and Technology. MMRI, through its centers The Center for Marine Resources and Environmental Technology and the Seabed Technology Research Center has been actively involved in marine research the northern Gulf of Mexico for over 20 years. Much of this time has been spent at an area of actively bubbling seeps and ongoing methane gas hydrate evolution in the Mississippi Canyon region [1], [2]. This site, within the MC118 lease block, is at a depth of nearly 900 meters.

Over the course of research activity at MC118, many towed, free swimming, and moored sensors have been employed. Navigation is critical, with equipment operating in close proximity to natural targets and previously placed sensors. Much of the equipment is tracked using a LinkQuest Ultra Short Baseline (USBL) system which uses shipboard hardware to interrogate transponders mounted on various sensor systems and interpret the range and direction to each transponder. Several variations of lander systems have been developed at MMRI as well [3], [4], [5]. Most of this moored equipment depends on Benthos mechanical releases that, when sent an acoustic command, drop sacrificial weights allowing the equipment to float to the surface for recovery.

A specialized ROV called the Station Service Device (SSD) is owned and operated by MMRI. It was designed specifically for working on the seafloor observatory at MC118 [6], [7], [8], [9]. The SSD was recently upgraded to work at depths up to 2000 meters [10], greatly expanding its potential operational area. During ascent and descent this vehicle resides within a cage that contains its batteries. The cage is tethered to the ship by a 3000-meter steel-jacketed cable containing three optical fibers. By adding threaded fiber optic connectors to the SSD and cable termination, tethered payloads can be switched quickly without requiring the oil-compensated terminations used previously.

MMRI has been continually improving their ability to survey and place sensors on the seafloor with greater control. An evolving design centered around a fiber optic multiplexer, USBL transponder, and a modified Benthos release unit, has become the I-SPIDER. The I-SPIDER was designed and built in 2012, and its first cruise was in March of 2013.

II. Hardware

The primary sensors aboard the I-SPIDER platform are its video cameras. Typically, four of these are DeepSea Power and Light wide-angle cameras mounted on four of the eight

Figure 1. The I-SPIDER.

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articulated arms and spaced to provide 360 degrees of video coverage around the platform. The other arms carry LED arrays also produced by DeepSea Power and Light. One camera and light pair is usually pointed downwards, and another is often directed towards the latch of the release mechanism. Cameras and lights can be swapped and reconfigured between missions to provide the necessary coverage for a given mission.

In addition to its six video cameras, the I-SPIDER has several core features to set it apart from typical towed camera platforms. Its navigation sensors include a TrackLink USBL transponder; an OceanServer compass, attitude, and depth unit; and a Benthos altimeter. These components facilitate precise deployment of moorings, landers, and other seafloor equipment using a high capacity Benthos mechanical release system modified to be triggered electrically rather than acoustically. While the release itself is rated to 2200kg, a lever arm is used for additional capacity. Additionally, the I-SPIDER can support serial, ethernet, and fiber payloads. A Kongsberg scanning sonar, frequently used as a payload, can be installed either upright or inverted – extending from the bottom of the frame. A sliding mount is used when the sonar is inverted so that it can be retracted before lowering the I-SPIDER onto the deck after recovery. The system is powered by parallel 24V gel-cell batteries within DeepSea Power and Light oil-filled housings.

The control station for I-SPIDER is essentially contained within a large Pelican case. This case contains video monitoring and recording equipment, a laptop to control functions and display status, two monitors in its lid, 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 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.

Figure 2. Control station for the I-SPIDER and SSD.

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.

Engineers at the National Institute for Undersea Science and Technology designed a switchboard incorporating a microcontroller and serial interface for controlling power and video relays. A control GUI was written to interface with this hardware. Both Focal multiplexers (the main multiplexer and the optional secondary) support three video feeds. If only one multiplexer is in use, a main and an alternate camera angle are assigned to each video channel. The control board can switch the sources of each channel independently. Communication between the switchboard and a surface computer is provided over one of the RS-232 serial ports of the main multiplexer.

III. Operation

While on deck, the I-SPIDER can be configured for various payloads. It has been frequently reconfigured between dives depending on individual mission goals. The lights and cameras, mounted on articulated arms, are oriented to provide adequate coverage of targets. The I-SPIDER is deployed using the ship's stern A-frame. Currently, the fiber-optic cable used to communicate with the I-SPIDER and SSD is stored on a drum compatible with the main winch aboard the UNOLS research vessel *Pelican*, operated by the Louisiana Universities Marine Consortium. For convenience, the USBL equipment has been integrated into the hull of the *Pelican* as well.

Upon nearing the bottom, the altimeter response is monitored closely. The lights are turned on, having been left off to conserve battery. The I-SPIDER's altitude above the seafloor requires frequent adjustments of the main winch, but this has proved a smoother operation than one might imagine. Adjustments can be anticipated based on known regional bathymetry and whether distance between the ship and the I-SPIDER is widening or closing. The position is tracked using the USBL system, and the position of the I-SPIDER relative to the ship and the bathymetry basemap is displayed on a Hypack survey window.

During the mission, interaction with the I-SPIDER subsystems is provided through a control GUI. This program displays status of the batteries, altimeter, Ocean Server module, and the release. It is used to switch two sets of lights and an auxiliary 24V output. Additionally, it can select between the main or alternate display of each of the three video feeds. If a secondary multiplexer is being used by the I-SPIDER then all six feeds can be displayed at once, but this option is not available when using the secondary fiber channel for an external payload. As the batteries run down, the lights are the first subsystem to be affected. When using a self-powered payload connected directly to the secondary fiber channel (such as the SSD), the I-SPIDER can suffer a complete power failure without hindering communication to the payload.

IV. Field Use

Between March and July of 2013, the I-SPIDER completed its first ten missions during three cruises. During these missions the I-SPIDER was used by itself for video reconnaissance. It was also used to deploy instrument packages weighing roughly 100 kg in water. In air, this same load was 1000 kg, with the full load suspended from the I-SPIDER release during deployment with the ship's A-frame. Three different payloads were integrated testing, in turn, all three communications protocols, serial, ethernet, and optical fiber. These payloads were respectively, a scanning sonar, a multibeam lander, and the SSD ROV.

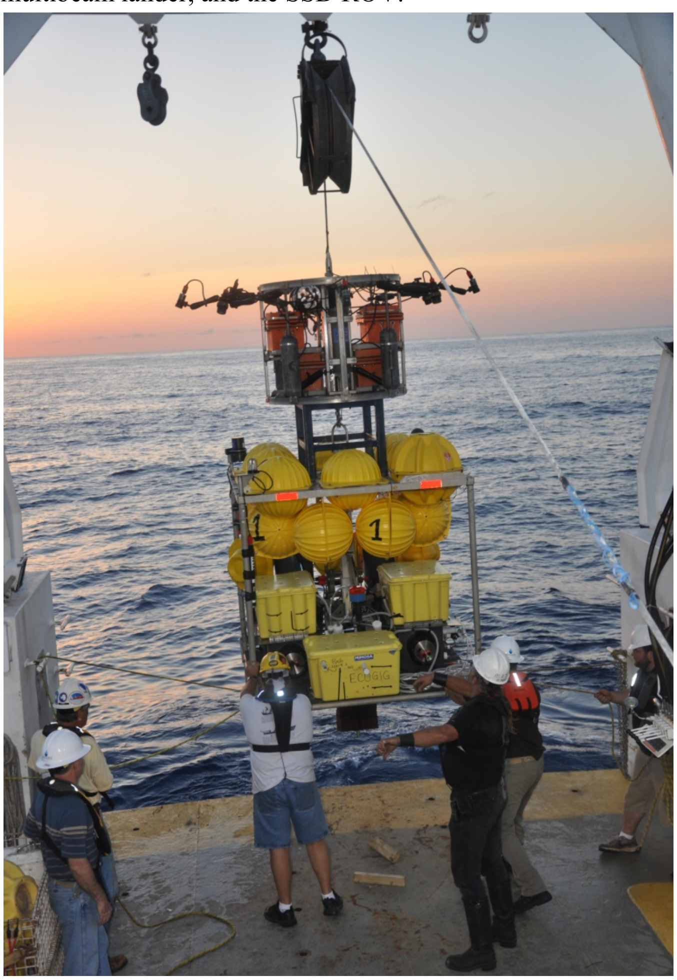

Figure 3. I-SPIDER carrying ECOGIG lander

Several recent cruises involving the I-SPIDER and SSD were a part of ECOGIG, a Gulf of Mexico Research Initiative funded project lead by the University of Mississippi. Among other studies, this project involves the placement and servicing of seafloor landers outfitted with chemical sensors, water sampling systems, current meters, and in-situ experiments [11]. To accomplish research goals, these landers must be placed close to natural oil seeps and microbial communities. The I-SPIDER can perform reconnaissance over a region of interest and then place a lander within meters of a selected target. Its navigation system aids in closing on a target region while the cameras provide real-time feedback on the lander deployment area. Upon reaching the target position, the release is triggered, dropping the lander within two meters of the seafloor.

On its first cruise the I-SPIDER was tasked with reconnaissance of a study area and the subsequent deployment of two landers therein. This area is within Green Canyon block 600 at a depth of nearly 1200 meters. The site is in the vicinity of oil and gas plumes visible in multibeam sonar imagery [12]. At the surface, an oil sheen and strong hydrocarbon odor are present. As an initial test mission, the I-SPIDER deployed a short term mooring used to calibrate the USBL tracking system. Upon releasing the mooring, the system was towed around the area for a quick survey revealing active plumes and biological activity. After this initial test, another survey was performed. The two landers were deployed in the following missions. The first (Lander 4) was placed adjacent to an active plume, visible in Fig. 4. The second (Lander 3) was deployed 50 meters from the first and right next to a bacterial mat.

Later the I-SPIDER and SSD returned to Green Canyon 600 for the placement of an additional lander and the servicing of its scientific payloads. On its fifth mission, the I-SPIDER deployed the refurbished Lander 1 next to a plume. The I-SPIDER was then mounted atop the SSD cage to function as a transparent link between the SSD's vehicle multiplexer and topside multiplexer. The multi-view monitor displayed both

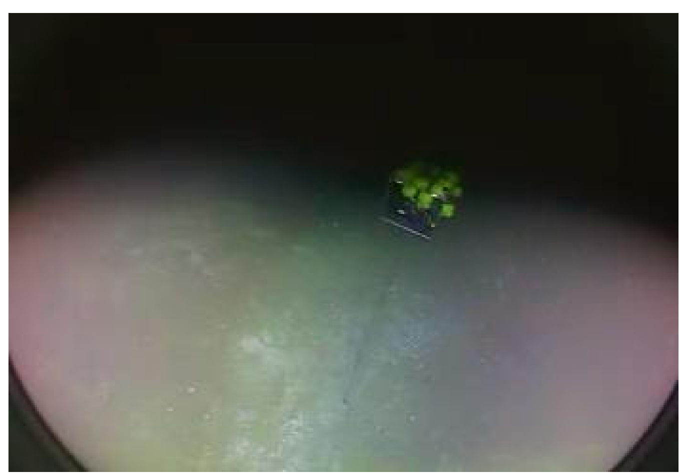

Figure 4. Lander 4 deployment near bubble plume.

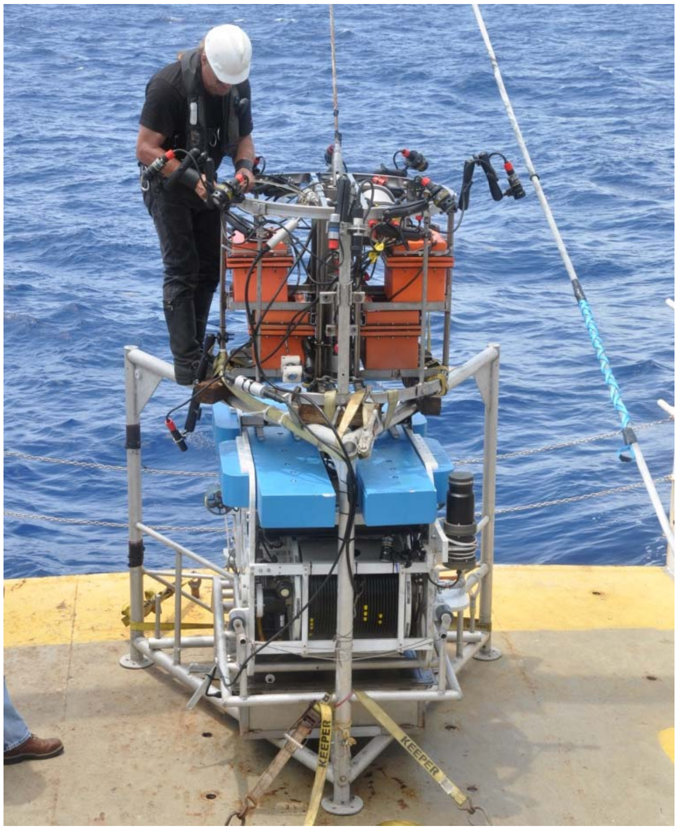

Figure 5. I-SPIDER installed on SSD frame

the first-person feeds from the SSD and the third-person overviews from the I-SPIDER. The additional angles were valuable in the operation of the SSD, providing a greater sense of position and surroundings to the operators. Several cameras were directed to external components of the SSD and its cage that could otherwise not be seen by the SSD cameras. One camera and light pair was directed straight up from the cage to monitor the tether cable. Another was focused on the latch mechanism that locks the SSD into its cage during ascent – a component that has been troublesome in the past.

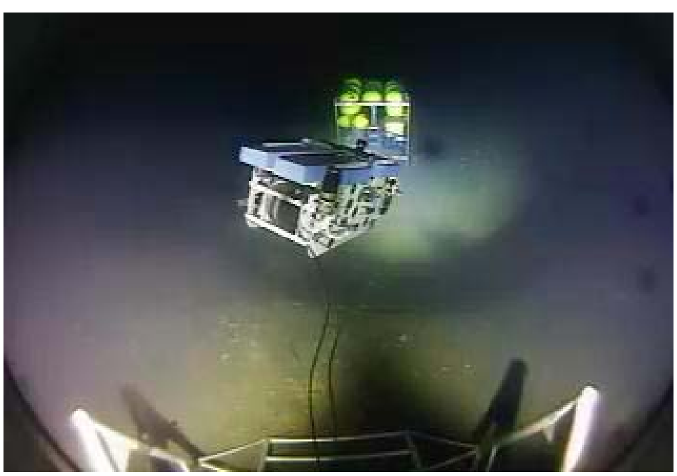

Figure 6. I-SPIDER providing overview of SSD operation

Most recently, MMRI researchers visited their familiar site MC118 for studies of gas seeps. This work was funded by the DoE National Energy Technology Laboratory (NETL) and the Bureau of Ocean Energy Management (BOEM) and involved collaboration with the Center for Applied Isotope Studies at the University of Georgia and the Marine Science Institute at the University of California at Santa Barbara. The first task completed was the placement of a lander near a bubble plume. This lander was designed and built by MMRI and outfitted with a bubble-monitoring scanning sonar system by Kevin Martin at the University of Southern Mississippi.

Ira Leifer at UCSB developed a lander consisting of two vertically-oriented multibeam sonar systems and a compass mounted on a rotator to allow horizontal scanning of the sonars. The I-SPIDER was integrated with the UCSB multibeam sonar frame, and the combined system was lowered down near an active plume. The system was then gently placed on the seafloor for several minutes as real time data and control of the sonar system were provided through the I-SPIDER gigabit ethernet payload port.

V. Summary

The I-SPIDER has proven itself as an ideal tool for seafloor reconnaissance, precision deployment of seafloor equipment, and a versatile platform for managing tethered payloads. It was initially built in 2012 and was immediately placed into service in 2013 with only a single test dive. So far it has been used to survey areas of seafloor to assist in locating superior locations for instrument deployment, and it has been used to locate already deployed seafloor instruments. The I-SPIDER has also deployed landers onto the seafloor with greater precision than was achievable during previous operations. Finally is has integrated with other instrument packages to monitor ROV operations and integrate sonar systems for both mobile survey and short term tethered lander operation. With its multitude of cameras and lights it has already recorded tens of hours of geological and biological activity in the deep Gulf of Mexico.

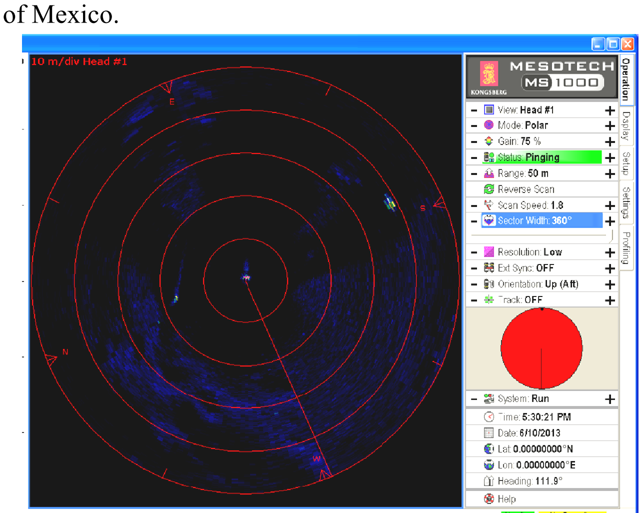

Figure 7. Sonar display with deployed lander (S) and a plume (N).

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