Deepwater Synthetic Aperture Sonar and the Search for MH370

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***Abstract*— From October 2014 through June 2015, Phoenix International Holdings, Inc. (Phoenix) and Hydrospheric Solutions, Inc. (Hydrospheric) worked together aboard M/V GO Phoenix supporting an international effort in the search for Malaysia Airlines Flight 370 (MH370). Using the SLH ProSAS-60, a 6,000 meter rated towed synthetic aperture sonar (SAS) system, developed by SL Hydrospheric, LLC, the Phoenix-Hydrospheric Team collected and analyzed over 150 terabytes of SAS data while surveying 13,295 square kilometers of seafloor. With this SAS technology, Australian Transport Safety Bureau (ATSB) representatives were provided highly detailed imagery with up to 10 centimeter x 10 centimeter resolution – even at the outer edges of the system's 2.0 km swath width. This degree of image resolution allowed ATSB investigators the ability to quickly and effectively "rule out" areas of seafloor scanned with the ProSAS-60. While the wreckage was not located, Phoenix and Hydrospheric personnel worked for over nine months in challenging conditions while successfully surveying assigned areas. Both Phoenix and Hydrospheric are deeply honored to have participated in this search and are eager for the day when the wreckage is located and the mystery of MH370 is solved.**

Keywords—MH370, ProSAS, Phoenix International Holdings, Inc., Hydrospheric Solutions, LLC, ATSB

I. INTRODUCTION

The disappearance of Malaysia Airlines Flight 370 (MH370) on March 8th, 2014 resulted in the tragic loss of 239 passengers and crew. With no wreckage to guide the search, investigators narrowed the search area by relying on data obtained from electronic signals between the aircraft and ground stations, relayed via a geo-synchronous satellite positioned high above the Indian Ocean. This ultimately led the Australian Transport Safety Bureau (ATSB) to define a 60,000 square km search area in the Southern Indian Ocean along a curved line associated with the last electronic signal relayed from the satellite, a line that has become known as the 7th arc.

Phoenix teamed with Hydrospheric Solutions, Inc. (Hydrospheric) and their 6,000 meter rated SLH ProSAS-60 (SLH PS-60) subsea survey system and joined an international effort to help search this large area. Working under a contract with DRB-HICOM Defence Technologies Sdn Bhd (DEFTECH) on behalf of the Government of Malaysia Phoenix and Hydrospheric personnel mobilized in Singapore in September 2014, loaded equipment aboard M/V GO Phoenix, and got underway for the search area. On 5 October 2014, M/V GO Phoenix entered the search area and Phoenix and Hydrospheric personnel commenced SLH PS-60 search operations.

II. SAS TECHNOLOGY AND SLH PROSAS-60

Prior to discussing the specifics of the MH370 search, an overview of SAS and the SLH PS-60 (see Fig. 1) is required. SAS technology operates by using acoustic pings to illuminate the same spot on the seafloor several times, thus producing a highly detailed image. By coherent reorganization of the data from these pings, an image is produced with constant along-track resolution at all ranges. At maximum range the resolution can be orders of magnitude better than that of conventional side scan sonar.

Fig. 1. ProSAS 60 Sensor Platform

The SLH PS-60 collects data from receive arrays over the course of up to 70 pings (user configurable). The receive arrays consist of 24 elements on a 13.5 cm pitch and, due to the fact the vehicle is moving, the theoretical resolution, along and across track, is one-half that, or 6.75 cm. The stated resolution of the SLH PS-60, however, is 10 cm due to beam pattern sidelobe effects and other minor data influences. This resolution was regularly seen all the way to maximum range of 1,000 meters, where small, hard objects would occupy one 10 cm x 10 cm pixel. The SLH PS-60 uses this SAS technology to support seafloor survey operations to depths of 6,000 meters.

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The system is composed of the sensor platform, subsea cabling, and topside processing and display equipment. The neutrally buoyant sensor platform provides a framework to hold the SAS transmit and receive arrays and electronics, Kearfott T16 Inertial Navigator System, Doppler Velocity Logger (DVL) Sensor and Sound Velocity Profiler. The synthetic aperture sonar array is mounted to the sides of the sensor platform. This array operates with a center frequency of 60 kHz and with an operational bandwidth of 15 kHz. The system is composed of three modular receivers, each with eight elements as described above. Additionally, there are separate transmit transducers and a titanium pressure vessel which houses control and telemetry electronics, power amplifiers, and the inertial navigator. Finally, the SLH PS-60 was fitted with a Kongsberg EM 2040 multibeam echosounder used as a gap-filling sonar.

Extending from the platform is a 50m neutrally buoyant tether that connects the sensor platform to a 2,000 lb. depressor weight. The depressor weight is attached to a 10,000 meter armored umbilical with fiber optics and power conductors. This umbilical, or tow cable, serves as a conduit for the power and SAS data flowing from the sensor platform to the surface.

Topside, aboard the tow vessel, is the SLH PS-60 data processing and display capability. This includes a series of powerful computers and flat screen monitors – all housed within a conex box known as the "Data Acquisition Shack." From this location (see Fig. 2), ProSAS 60 operators review the SAS imagery in real time, and also fly the vehicle and navigate the sensor platform along the subsea terrain such that the vehicle maintains an altitude of roughly 150 meters over the bottom. Flying the sensor platform involves adjusting vessel speed and paying out and hauling in tow cable. Navigating the vehicle is accomplished by comparing the subsea terrain with the layback calculated position of the sensor platform and ensuring the platform is safely positioned above the bottom, especially as the vehicle approaches changes in the subsea terrain. All data coming into the Data Acquisition Shack is processed, reviewed, and stored to support subsequent retrieval, review, and customer delivery.

Fig. 2. ProSAS 60 Data Acquisition

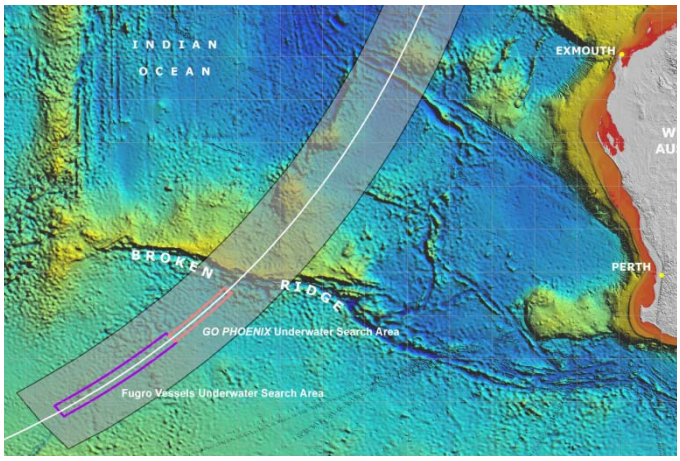

Fig. 3. MH370 Search Area

III. MH370 Search Operations

From 5 October 2014 until 19 June 2015, Phoenix and Hydrospheric personnel, working aboard M/V GO Phoenix, used the SLH PS-60 to search over 13,000 square km of seafloor. Fig. 3 shows the overall search area. From the start, the Phoenix – Hydrospheric search effort aboard GO Phoenix relied heavily on teamwork. That teamwork concept began with the equipment provided to accomplish the search. Hydrospheric provided the SLH PS-60 sensor platform equipment used to process and display the data. Phoenix provided the 10,000 meter tow cable, the traction winch, and a specifically engineered and manufactured over-boarding sheave for routing the tow cable up and over the stern of M/V GO Phoenix.

Teamwork was also evident in the personnel used to staff the watch-stations associated with the search. For each 12 hour rotation, Hydrospheric provided a pilot, co-pilot, and navigator for the vehicle, as well as a data management technician to review and process the data. During ProSAS operations, the pilot, co-pilot and navigator, all positioned within the data acquisition shack, would keep the sensor platform positioned roughly 150 meters above the seafloor while reviewing real-time data and cataloging files. The Hydrospheric data management technician – working in the ship's navigation room, directly beneath the ship's bridge – would process the SAS data, take needed file size reduction measures to make the data manageable, and methodically store the data with standardized file names.

Phoenix watch-station duties included an individual responsible for navigation, data reviewing, and customer liaison. This person worked alongside the Hydrospheric data management technician and, among other things, would regularly calculate the layback position of the sensor platform and relay that information to the Hydrospheric personnel piloting the vehicle. This Phoenix watch-stander was also responsible for reviewing incoming SAS search data for potential targets, and then package and deliver the SAS data to the ATSB. As the Prime contractor Phoenix was duly responsible for regular and timely communications with the ATSB representative onboard GO Phoenix. The Phoenix watch-stander also served as the primary liaison with the

Master of M/V GO Phoenix and other related shipboard activities. With this 24/7 team structure in place, Phoenix and Hydrospheric personnel went about the business of searching for MH370.

Search operations were conducted on a regular and repeating schedule. Throughout the search operation, Fremantle in Western Australia served as the base of operations for provisioning, refueling, and crew changes. The distance from Fremantle to the assigned search area was approximately 1,500 nautical miles and involved a ship transit time of just over five days.

To assist in describing the search operation, what follows was the typical schedule of a single MH370 search "swing" (a term used to define the time between Fremantle port visits):

- Day 1 – 5: Depart Fremantle, transit to the search area.
- Day 5 – 25: Conduct search operations.
- Day 25 – 30: Depart search area, transit to Fremantle.
- Day 30 – 32: In Fremantle preparing for next swing.

In total, from October 2014 through June 2015, Phoenix and Hydrospheric personnel working aboard M/V GO Phoenix completed 8 swings totaling 257 days in support of MH370 search operations.

Search operations aboard M/V GO Phoenix were conducted in a standardized and very methodical manner. As the ship approached the search area, Phoenix, Hydrospheric, and ATSB personnel reviewed the previously completed search lines and plotted the next search line. Once M/V GO Phoenix was steady on the search line course but still 10 kilometers away from the next area to be searched, and at a speed of roughly 2 knots, Phoenix and Hydrospheric personnel would deploy the SLH PS-60 sensor platform (including the 50 meters of neutrally buoyant tether and the 2,000 lb. depressor). The tow cable was then gradually payed out, via the over-boarding sheave, until nearly 10,000 feet of tow cable was deployed. Roughly 5 hours later, depending on the depth (depth of water ranged between 3,800 and 5,000 meters), the SLH PS-60 sensor platform arrived at its search height of 150 meters off the seafloor.

As described earlier, the Hydrospheric watch-standers stationed within the data acquisition shack would pilot the sensor platform by hauling in and paying out the tow cable to maintain the desired height above the bottom. This was accomplished by monitoring center beam data provided by the Kongsberg multi-beam echo sounder (MBES) and the purpose built Teledyne RDI 150 kHz DVL mounted to the sensor platform. In addition, watch-standers also had access to recently collected bathymetry data from survey operations conducted by Fugro. These operations were funded by ATSB and took place from June – August 2014 for the benefit of future MH370 search efforts. This data allowed Hydrospheric personnel to essentially "look ahead" during search operations to ensure the sensor platform was safely maneuvered up or down in preparation for upcoming terrain changes, while maintaining optimal seafloor coverage and minimizing acoustic shadows. While this process worked well, occasionally the Fugro provided multi-beam data would mask sharp and narrow rises on the seafloor. As the sensor platform approached these areas, the Hydrospheric pilots would have to react quickly by recovering more and more tow cable as the sensor platform's height above the bottom rapidly decreased. While the ProSAS 60 sensor platform never touched the bottom during MH370 search operations, these instances served to re-enforce the need for constant vigilance on the part of the pilot and co-pilot.

As data arrived aboard GO Phoenix, the imagery was reviewed multiple times to ensure no potential targets were missed. Hydrospheric personnel in the Acquisition Shack would conduct an initial review as the search data streamed up the tow cable. The Hydrospheric data manager – positioned in the navigation room – would conduct a second review of all data. The Phoenix watch-stander would also review the search data and categorize any targets of interest. The last reviewer on the ship was the ATSB representative. This individual would review all identified targets and also review the entire data set to ensure nothing was missed.

If any targets of interest were identified, the Phoenix watch-stander would develop a target summary report and provide that document to the onboard ATSB representative for review. From there the ATSB representative would transmit it to the MH370 search operations center located in Canberra, Australia for further review. In addition, at the end of each swing, all search data amassed during the swing would be bundled onto individual hard drives and handed over to ATSB representatives for subsequent transport to the MH370 Search Operations Center. There the search data would undergo further review and ultimately final storage.

While the Phoenix – Hydrospheric subsea search did not identify MH370 wreckage, the SLH PS-60 performed exceptionally well. In fact, during this nine month operations period the SLH PS-60 sensor platform spent over 3,211 hours at depth collecting seafloor data and achieved an admirable record of nearly 97% uptime during the course of this long project. The operational track record amassed during the search for MH370 clearly shows the ProSAS 60 as a robust and highly capable deep water survey capability.

Not only is the ProSAS a proven robust deepwater survey tool, the search for MH370 also showcased the system's ability to provide clear and precise subsea imagery of the deep ocean seafloor. Hour after hour, during over 3,000 hours of data collection, the ProSAS provided vivid images of never before seen areas of the Southern Indian Ocean seafloor. Deep canyons, steep cliffs, wide open plains, and subsea mountain ranges were all captured with impressive clarity by the ProSAS 60. As the images below indicate (Fig. 4 and 5), we now have a better picture of what lies beneath the surface of the Southern Indian Ocean – an area of the world that was previously more unknown than the surface of the moon.

Fig. 4. Subsea Terrain in Search Area

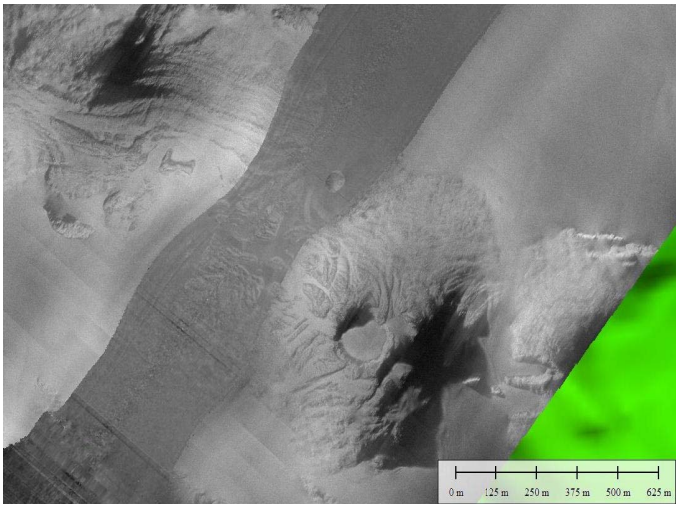

Fig. 5. Subsea Craters Within Search Area (1 km range and nadir gap filled by MBES)

IV. Conclusion

While the mystery of MH370 still remains unsolved as of the writing of this article, Phoenix and Hydrospheric are proud of our performance and contribution in support of this international search operation. We accomplished our task of searching our assigned area, we provided timely and accurate imagery of the seafloor, and we did it all in an efficient and safe manner. Operating in the deep ocean in a very remote part of the world – often during difficult weather conditions (see Fig. 6) – is a challenging task.

Fig. 6. Heavy Seas During MH370 Search Operations

For nine months Phoenix and Hydrospheric personnel met these challenges and provided MH370 investigators with the information they needed to conduct the search. We are honored to have played a role in this historic effort and we are eager to help continue the search and one day find MH370.

References

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