THE FUTURE OF MARINE SURVEY – APPLICATIONS FOR SUBMARINE CABLES

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Abstract: New advances in survey capabilities have been and are being developed for use in various global industries. While some of these technologies have been explored for use in the submarine cable industry, the development, advancement and adoption of other technologies have yet to be fully explored or implemented.

This paper gives a brief overview of the evolution of marine survey technologies. The paper will then explore modern survey technologies and their possible applications for the survey of submarine cables. These technologies include airborne LiDAR (Light Detection And Ranging), AUVs (Autonomous Underwater Vehicles), MBES (Multibeam Echo Sounder) backscatter, deep-tow SAS systems (synthetic aperture sonar), and drones / unmanned aerial vehicles (UAVs) with orthophoto or mounted laser capabilities.

1. 1980 – 2000: Survey Technology Overview

The first full-ocean depth capable survey equipment suitable for the surveying of submarine cable routes was commercially implemented in the early 1980's. The equipment consisted of a 9 kHz / 10 kHz vector side scan sonar tow fish system that simultaneously provided an acoustic intensity image in fixed swath widths and bathymetric data in a swath that was more than 3 x water depth. The bathymetric data was acquired by measuring the angle of incidence of seafloor reflections on the towed array using a phase measurement technique.

At the time (1980's through 1990's) and up to the advancement of modern multibeam echo sounders, this system was the latest state-of-the-art example of swath bathymetry/side scan sonar systems which had been pioneered by SeaMARC II and MRI (operated by the University of Hawaii) and later by the IZANAGI system (built by Seafloor Surveys International and operated by the University of Tokyo) [1].

Throughout the 1990's, this technology was used with great success to survey submarine cable systems such as PacRimEast, PacRimWest, APC, HAW-5, COLOMBUS-2, CANTAT-3, TPC-5, Kagoshima-Naha, Antillas-1, Alaska United, Southern Cross and Japan-US, among many others.

Figure 1: Deep-water swath bathymetry system being prepared for launching © Don Hussong

In the shallower waters less than approximately 1,000 meters, the survey technology implemented was similar. An integrated shallow water swath bathymetry and side scan sonar system with integrated CHIRP sub-bottom profiler offered a completely contained sensor system for surveying shallow water burial areas. At the time of its use, this system offered greater resolution and accuracy than could be provided by the earliest multibeam echo sounders due to the proximity of the sensor to the seafloor.

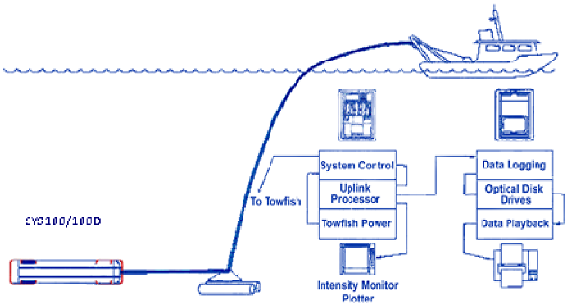

Figure 2: Shallow water swath bathymetry system vessel and tow configuration. Source: Don Hussong / Fugro

These integrated swath bathymetry and side scan sonar systems were implemented in the submarine cable industry up until 2009, but bathymetric and geophysical survey equipment started advancing in a new direction much earlier with the modernization, advancement and wide commercialization of the multibeam echo sounder.

Private companies started developing their own multibeam sonar systems in the 1970's, but it wasn't until technological improvements were made in the 1980's and 1990's that these systems could be used more widely for high-resolution mapping. These systems, however, were first widely available for shallow water mapping and it wasn't until the introduction of low frequency systems in the early 1990's, like the Kongsberg EM 12 (12 kHz), that full ocean depths could be reached by multibeam technology.

In contrast to the towed systems already described, multibeam systems are mounted to the hull of vessels and can only collect bathymetric data (note: See Section 4 on MBES Backscatter), still leaving the need for separate side scan sonar and sub-bottom profiler sensors (typically towed behind the vessel) for the survey of submarine cable systems in shallow water, burial areas.

Today, however, vessel-mounted shallow and deep water multibeam echo sounders, coupled with towed side scan sonar and sub-bottom profiler systems, are now industry standard in the surveying of submarine cable systems.

2. Airborne LiDAR (Light Detection And Ranging) Bathymetric Surveying

Airborne LiDAR bathymetry (ALB) relies on the known physical properties of light with each laser pulse directed to the water surface / bottom and back using a rectilinear or elliptical scanning mirror. The return pulse is received, digitized and recorded [2].

ALB data acquisition is effective in water depths up to approximately 40 m and produces datasets including point cloud / surface models, orthophoto mosaics, and reflectance data. However, the operational success of ALB depends on water clarity, turbidity and weather and is often most appropriate for calm and clear water conditions.

The overall benefit of this technology is its speed of data collection, mobility, rapid response, survey of difficult or impossible areas, safety in dangerous areas, and the simultaneous survey of water, structures and land.

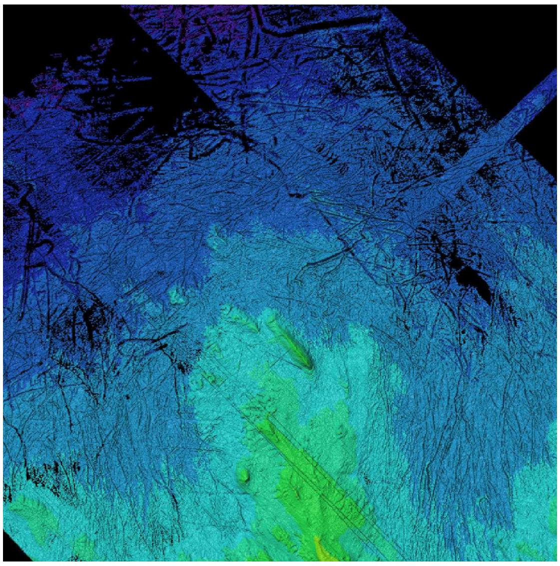

Figure 3: Ice scour in the Canadian Arctic, mapped by ALB, in approximately 20 m water depth

ALB has been explored for use on submarine cable projects, particularly projects that are very remote and difficult or costly to get a vessel to (e.g. remote islands). In addition, it has been explored for areas that have a high degree of operational hazard or difficulty transporting equipment from site to site (e.g. the high Arctic).

While ALB has its advantages enough to be considered in the survey of some very specific types of submarine cable projects, it is often outside the budget to mobilize and operate a plane in addition to a traditional vessel. Furthermore, the datasets collected from ALB do not provide any sub-bottom data and cannot be ground-truthed for burial or installation assessment without standard marine operations conducted from the ground / water. Therefore, for the cable industry, it can never be a stand-alone replacement for terrestrial and marine operations and will typically be too costly to even supplement vessel-based operations even when there is a strategic advantage. ALB technology, however, is mentioned in this paper for completeness of survey methodologies that have been, or could be, considered for the submarine cable industry.

3. Underwater Autonomous Vehicle (AUV) Technology

Similar to ALB mentioned in the previous section, Underwater Autonomous Vehicles (AUV) have been considered for use in the submarine cable industry.

AUVs are state-of-the-art technology commercialized over the last decade for use in the public sectors such as the oil and gas industry. AUVs have also been implemented in the search for downed aircraft and have also been used for environmental data collection in addition to the standard geophysical utilities they were developed for.

The benefit of AUVs is their standalone survey capability in collecting multibeam bathymetry, side scan sonar, and sub-bottom profiler, all of which are standard datasets required for the installation of submarine cables. In addition, AUVs can collect this data along pre-programmed survey lines and at much higher resolution than vessel-mounted or towed equipment.

The resolution of AUV data collection has to do with the altitude above the seabed at which the data is collected. Running an AUV close to the seabed equipped with a standard suite of survey sensors will produce better data than that collected from the same sensors on a vessel far away from the seabed. This resolution, however, comes at a cost.

Due to the proximity to the seabed, AUVs can only collect data in narrow swathes, thus requiring many more survey lines to complete a standard corridor required for a cable. As a result, operational efficiency is lost.

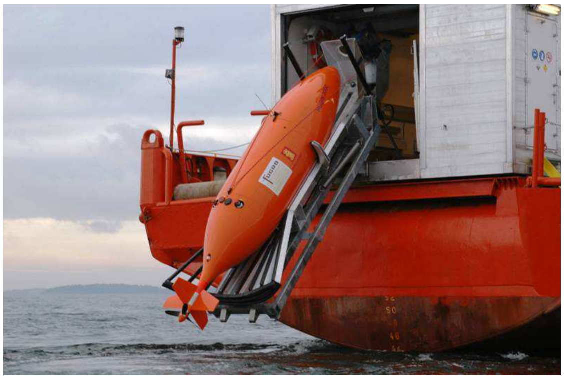

Figure 4: A Kongsberg Hugin AUV launching from a survey vessel.

In addition, AUVs have depth limitations and cannot operate in and survey to full ocean depth, thus limiting their utility for large cable systems. As well, they require a vessel to operate from and as a result, the cost to operate both the AUV and a supporting vessel is very cost prohibitive to the submarine cable industry making in impractical both from an operational and cost perspective for the survey of cable systems.

4. High Resolution MBES (Multibeam Echo Sounder) Backscatter versus Standard Towed Side Scan Sonar (SSS)

Side scan sonars are specifically designed to collect acoustic backscatter that can be used to interpret variations to the seabed composition. In contrast, multibeams are designed specifically to collect bathymetry data with backscatter only being a secondary product from the acoustic soundings. Both, however, can be used to detect the seabed, indicating variability of seabed composition including sediment types, seabed features (natural and man-made), rock outcrops, etc., all based on the variations of physical impedance of the acoustic signal.

Backscatter is not a new technology, but the use of multibeam backscatter instead of side scan sonar is not typical in the submarine cable industry even though it presents some distinct advantages.

Primarily, the advantage of multibeam backscatter is operational. When conditions are too risky to deploy a side scan sonar tow fish, backscatter collected from a vessel-mounted multibeam echo sounder can be implemented safely and done simultaneously to bathymetric data acquisition. In addition, multibeam data acquisition can be performed from 5 to 8 knots vessel speed while side scan sonar data acquisition is achieved at a maximum vessel speed of 4 knots.

In a recent multi-regional cable route survey, a side scan sonar was not able to be deployed due to fish traps on the seafloor and lots of mid-water column floating fishing gear. In a route distance of about 40 km, 3 to 5 multibeam/backscatter lines were surveyed with a swath width of 300 m using a Kongsberg EM 122 (1°x2°). Backscatter was obtained at the highest possible resolution and allowed for the discernment of small targets and seabed features.

The figure below is a comparison made between high resolution backscatter data collected from an EM 122 versus a high resolution side scan sonar (Edgetech 4200FS -105/410kHz in Dual Frequency HDM mode; capable of detecting a 0.5x0.5m target) over some overlapping areas with interesting seabed features.

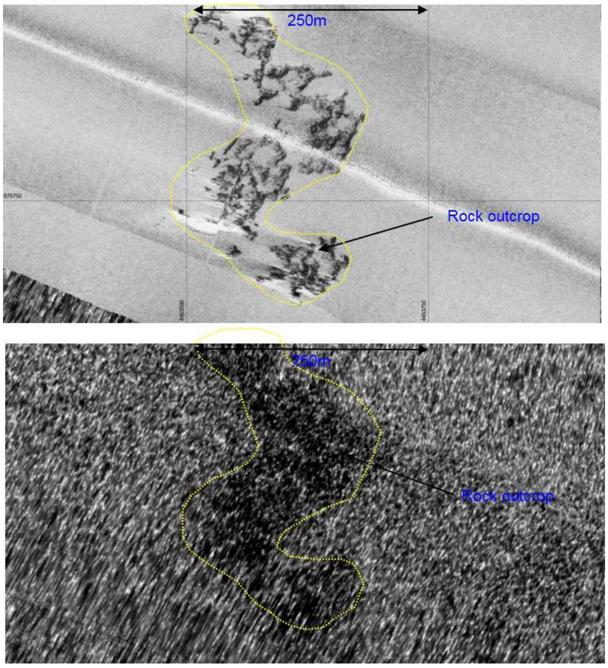

Figure 5: Geological feature comparison between side scan sonar (top) and backscatter (bottom) data at the same scale. © Fugro

Based on the attached image it is apparent that side scan sonar records provide higher resolution data of geologic features while multibeam backscatter provides lower resolution data. Typically 1 m objects or any seabed feature can very well be detected in side scan data; however, multibeam backscatter cannot discern anything less than 4~5 m in size. Only rock type features of at least 5 m size can be interpreted and small sonar contacts are still difficult.

Multibeam technology, however, is evolving quickly and improved backscatter resolution will reach its optimum soon. It is therefore possible to consider that future resolution will get even better with new systems and may equal or even exceed side scan sonar technology.

As of now, obviously multibeam backscatter cannot replace side scan sonar based on resolution, but it can definitely be used as a proactive and efficient means to safely collect data where towed equipment is unsafe to be deployed. In addition, in areas where the most prominent features are of primary importance to identify, and therefore features most likely to represent a risk to cable route engineering, then the equipment and methodology should be considered as a survey solution in challenging areas.

5. Deep-Tow SAS (Synthetic Aperture Sonar, SAS) Versus Standard Towed or Autonomous Underwater Vehicle (AUV) Side Scan Sonar (SSS)

Fugro did a comparison of two overlapping datasets acquired over the same survey location, using different equipment: AUV mounted Edgetech 2400 combined side scan sonar and sub-bottom profiler and a towed Go Phoenix ProSAS60 synthetic sonar aperture system. The AUV operated at an altitude of approximately 100 m above the seabed. The SAS system was deep-towed at an altitude between 100 and 150 m above the seabed [3].

Based on the figures below, the data resolution of the deep-tow (SAS) equipment used is clearly exceptional for the same altitude and same conditions of survey as the AUV (standard SSS).

The seabed features in the SAS data are much less distorted and with less acoustic shadows and smaller scale structures within outcrops can be better identified while the side scan sonar shows rather uniform high reflective features.

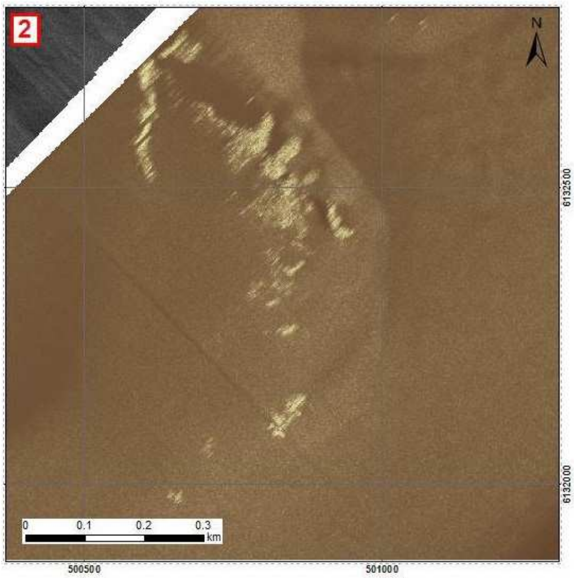

Figure 6: AUV-mounted side scan sonar data over geologic features © Fugro

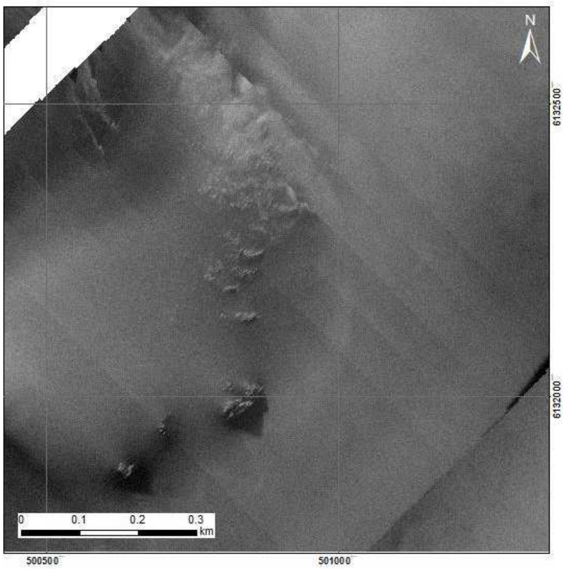

Figure 7: Deep-towed SAS data over same geologic features as Figure 4 © Fugro

Generally, the SAS system can achieve this by illuminating points on the seabed from different angles resulting in less acoustic shadows than in side scan sonar data, less distortion and better small scale feature identification. This new SAS technology is therefore very interesting to the marine survey industry with an obvious future application to submarine cable route and geophysical surveys.

Additionally, the SAS system can be towed at much higher altitudes with better data resolution as compared to conventional deep-tow side scan sonar systems, offering better operational safety of the equipment. On the downside, however, processing of SAS data is far more complex and processing artefacts are likely to occur. Furthermore, both side scan sonar and SAS systems have a similar spatial coverage, but the SAS data is acquired at about half the speed of conventional towed side scan sonar operations.

The average speed of a deep tow side scan sonar system is 2.7 to 2.9 knots, while the ProSAS is 1.8 knots. This is due to the SAS processing required to generate the resolution required at the far ranges. However, technology is improving and an upgraded SAS system is claiming to be able to acquire data at 3 knots with a 3 km scan range.

Speed being a critical point in cable route surveys, where projects are mostly lump sum, the SAS has a disadvantage in operational efficiency. However, the striking difference in data resolution over complex seabed features cannot be overlooked as a technological advance allowing for more accurate interpretation of seabed features.

6. Drones / Unmanned Aerial Vehicles (UAV) and Vessel-Mounted Laser Scanners for Inshore Surveys

The UAV (unmanned aerial vehicle) or drone is a technology that is now booming around the world - with cheaper systems every day and controllable by any common person (no need for specialist operators), they are the potential new tool relevant to seabed and topographic surveying at submarine cable landfalls. This technology is particularly relevant in intertidal zones that are inaccessible with small boats or by foot with topographic personnel & total stations or other equipment.

Figure 8: A UAV (drone) flying with mounted camera

The UAV or drones can fly as remotely controlled aircraft (e.g. flown by a pilot at a ground control station) or can fly autonomously based on pre-programmed flight plans or more complex dynamic automation systems.

Drones can capture data to generate point clouds, orthophotos and digital terrain models. They are a safe, cost effective and valuable with better data resolution with less or no survey lines inshore/onshore, and are well suited to complex projects carried out in remote or challenging locations.

At the inshore / terrestrial overlap, particularly in challenging locations, vessel-mounted laser scanning can be an alternative survey tool. While laser scanning is not a new technology, its implementation on a vessel and for the purposes of surveying a submarine cable landfall has not been widely used.

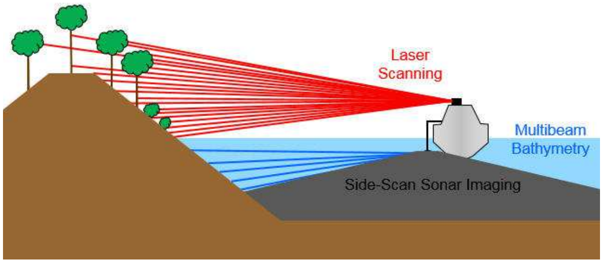

Figure 9: Illustration of vessel-mounted laser scanning to provide inshore and terrestrial data overlap

Vessel-mounted laser scanning can create point-cloud data at the surf zone and terrestrial interface and well onto land creating a seamless dataset at a cable landing.

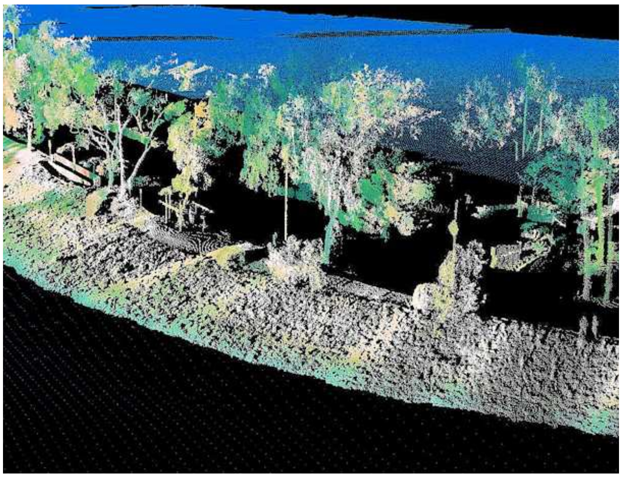

Figure 10: Integrated bathymetry and laser scanning data at the marine/terrestrial boundary

The benefits of collecting laser scanning data is to have a seamless and comprehensive integration of marine and terrestrial data. The application of the technology is particularly useful for cable landings that are difficult to access by boat or by land. The technology can be utilized on any small boat conducting standard inshore work in the very shallow water approaches to a landing.

7. REFERENCES

[1] D. Hussong, Personal Conversation

[2] D. Lockhart, E. Saade, J. Wilson, New Developments in Multi-beam Backscatter Data Collection and Processing, http://www.fugro-pelagos.com/papers

[3] Fugro Survey Pty Ltd, Comparison of SSS and SAS data, internal document

