3D acoustic method for the detection of buried objects

Introduction

Stema Systems, part of the GEOxyz group, has developed an acoustic cable detection system, called Silas 3D. The system aims to improve detection capabilities for buried objects and focuses on longitudinal objects such as offshore cables. Simultaneously, the system wants to offer an open solution, giving insight in the actual data which is used to determine burial depth. This paper will focus on the setup and results with regards to the detection of longitudinal objects (e.g. cables and pipelines) with a diameter of 25cm, and burial depths up to 4 meters.

Method and Theory

The Silas 3D system is an acoustic system, the acoustic signal propagation principles relate reflections to the presence of an object. The system consist of a frame containing a specific set of equipment, as well as accompanying software for both data acquisition and processing. Under good survey conditions, the system enables one to perform surveys while providing onboard real time visualization of the target.

The sound source is an array of transducers with operating frequency between 3 and 7 kHz. The reflected signals are recorded by a number of receivers (high sensitivity broadband hydrophones). The hydrophones are equidistantly spaced over a bar of 3.6m width, that is typically operated perpendicular to the sailing direction. The system setup can be compared to a multibeam system with swath protruding within the seabed and with extended data processing techniques. The system swathes at a ping rate of 5 – 10 pings per second to acquire a 3D acoustic reflection data volume that can be visualized over various directions, tailored to the needed investigations.

The system is deployed in combination with high accuracy positioning and altitude / gyro sensors. For interpretation and depth of cover (DoC) assessment, multibeam data are required for high-definition seabed detection along the complete swath. A high-accuracy motion sensor is interfaced with the system to correct the wave-field calculations for movements between shot and arrival with respect to the reference level. This allows synthetic beam forming by using multiple shots in wave-field calculations to increase S/N ratio and resolution (SAS technology).

There are currently 3 setups available: one pole mounted setup, for shallow water surveys, one ROV setup, for surveys in deeper water, and one trailing arm setup, for intermediate water depths (10 – 20m WD typically). During a survey project, a multitude of setups can be configured, tailored to the requirements. Even though every setup has slightly different configuration requirements in the processing software, data can easily be combined for the final delivery.

Processing and interpretation

Processing of the acoustic data volume is done using the Silas multichannel processing software, in which the seismic data are matched to position data and are corrected for motion. With the use of the spatial configuration of the frame, trigger delay and sound velocity data, signals from different hydrophones (channel data) can be stacked to create a set of beams, covering a swath of 8.0m in width.

The 3D data volume can be visualized over various directions, tailored to the needed investigations. The initial output after processing of the seismic data in Silas, is a set of images of each beam in the acquired data volume. The centre beam view corresponds to a vertical section of the seabed taken along the centre of the transmitter and receiver system (shown as a red rectangle in Figure 1, top right), and thus relates to a regular single channel sub-bottom profile along the sailed line (Figure 1, top left). The image displays the recorded seabed and subsurface sediments, hence giving information about the geology and structure of the subsurface.

The multichannel plan-view, which can be assimilated to an image of the swath of the system, gives a top view of the recorded data. The plan-view is taken as a horizontal profile along the data volume, of a given thickness, at a chosen depth relative to the seabed. The width of the plan-view is directly related to the swath width (8.0m) after stacking the data, and the length of the picture corresponds to the length of the sailed seismic line. It is important to highlight that the reference system of the plan-view is thus not the XY-plane. The colours visible in the plan-view are related to the strength of the reflected acoustic signal; the scale of rising backscatter intensity ranges from white to black. The returning signal is strongest in the middle of the swath, closest to the array, this leads to a nadir reflection showing as a dark, continuous, straight band in the middle of the plan-view. The middle row of Figure 1 shows the profile through the 3D data volume on the right (orange), and the resulting plan view in this section on the left.

The cable, or any other linear structure along the sailing direction, appears as a dark line in the plan-view, with a strong acoustic signal that follows the system offset from the object (Figure 1, middle left). This allows the distinction from the nadir reflection, which appears as a straight-line feature because it is uncorrelated to the sailing direction. In the plan-view, triangular shaped markers, or contacts, were picked along a track interpreted to be the cable. A green line (see Figure 1 middle left) is then created (referred to as 'active object'). Along this line, a cross section along the observed cable, is assembled. This line takes the recorded navigation into account (thereby converting the relative positions in the plan-view to true XY-positions of the cable) and aligns the traces from which reflections can be interpreted, in which the Z-position of the cable can then be interpreted.

The cable view or longitudinal profile presents a vertical profile of the recorded data along the green line in the plan-view (active object; Figure 1 middle left). If the reflector in the longitudinal view is satisfactory (can be improved by iteratively interpreting the longitudinal profile and plan-view), a line is drawn along the reflector that is interpreted as the cable reflection. If there is no reflector that is consistent enough to be interpreted as the cable reflection in the long-view, contacts with different interpretations can be added along the trajectory. Those contacts have different comment codes than cable contacts and indicate background information on reasons the cable could not be detected. This longitudinal view along the cable is presented in the last row of Figure 1, indicating the image and contacts on the left (highlighted in purple), and the profile through the data volume on the right. It should be noted that the profile in the last row is thus a combination of different beams throughout the 3D data volume.

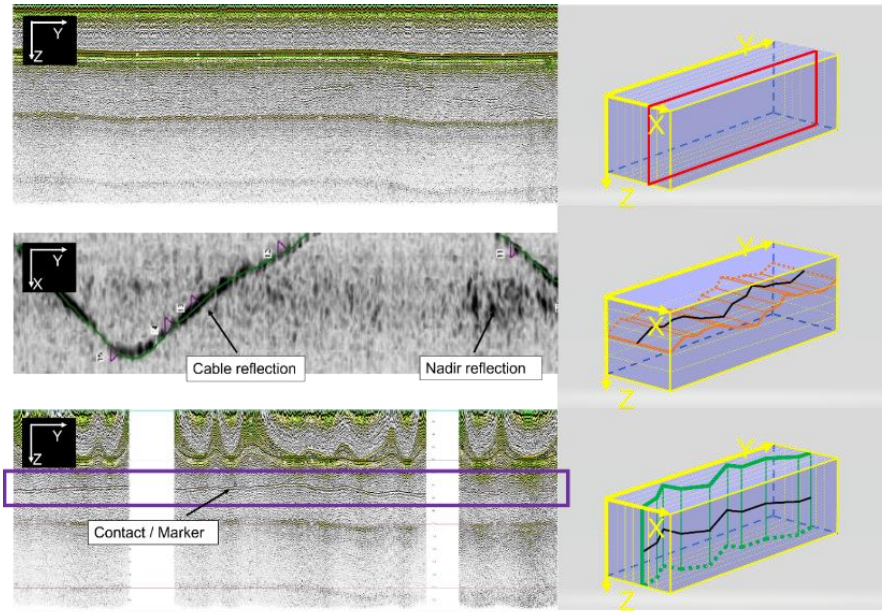

Figure 1 *The different Silas 3D data formats and visualization options for an example dataset. Each row consists of the seismic data (left) and a visualization (in colour) of the profile in the 3D data volume (right).*

Results & data examples

Silas 3D has been used on several projects in the North Sea and Baltic Sea. The best results were obtained in quiet environments and relatively soft and undisturbed sediments (sand, silt, mud) (Figure 2 left). For cables with a diameter of 25cm, up to 85% detection rate could be established, with burial depths of up to 4 meters. Smaller cables will typically be more difficult to detect, however the system has proven successful in detecting cables as from 12 to 15 cm of diameter up to 4 m burial depths using the 3 – 7 kHz transducers.

In one of the datasets acquired, a link could be made between data quality and cable installation method, and indirectly to geology. To explain this, an understanding of cable installation methods is needed. The cables that were investigated, were installed using a combination of 3 techniques: (1) plough (mechanical trenching), (2) vertical injector (big tool using water under pressure) and (3) plough (with use of high-pressure water). When cables are installed using high-pressure water in very soft unconsolidated sediments, it could happen that cables are buried deeper (3 to 4 meter burial depth, in areas where expected depth of burial is 1.5m) and with more variability in burial depth, giving an acoustic detectability of medium quality (Figure 2 right, Figure 3, Kp 35 - 39). When the vertical injector is used in glacial till, the cables are installed at a more constant depth, and acoustic detectability is of good quality. When geology allows the plough to be used for cable laying, the cables are laid without the use of water under pressure and are laid at their expected burial depth. In these cases, detection quality is good (Figure 2 left, Figure 3, Kp 39 – 45). The same observation could be made across different years, and in different areas. It can therefore be suggested that the use of water under pressure in very soft unconsolidated sediments reworks the sediment a lot, which results in more variations in burial depth, and creates more diffractions and noise in the acoustic signal.

Challenges

As with all other (acoustic) survey systems, the system also comes with challenges. In general, acoustic systems are strongly affected by the presence of (albeit non-systematic, shallow) gas in the subsurface, resulting in areas of acoustic blanking (Missiaen, Murphy, Loncke, & Henriet, 2002). Just as rock dumps on top of a cable can attenuate acoustic waves, other challenges with acoustic systems can also be related to the influence of sedimentology and sub-seabed type as different types of sediments can also have an effect on the penetration of the acoustic signal, potentially lowering the detection capabilities of the system (LeBlanc, Panda, & Schock, 1992). These findings are supported by survey results, as it was found that glacial deposits in combination with dredging methodology can have an impact on the detectability of subsurface longitudinal objects.

Next to these truly physical challenges, accuracy of as-built information will also have an influence on the detection results. This is not related to the working methodology of the system, but due to (1) the operational planning for acquisition and (2) processing workflows.

Further developments

Silas 3D is in constant development. Over the last year, the main focus was on speed and performance of the system. In the next 2 years, the acquisition to processing ratio, which has been halved in the last year already, will be improved even further, mainly by adding tools to automate and simplify the workflow. Next to that, more focus will go to the system itself. Over the coming years, tests will be performed with different hardware types and setups, to study the impact on data quality. The system will be integrated on different platforms, to e.g. increase the data acquisition speed. The simultaneous use of extra (non-acoustical) sensors will be studied, in order to enable good quality data in areas where acoustics will provide lower quality data, to further improve the detection rates.

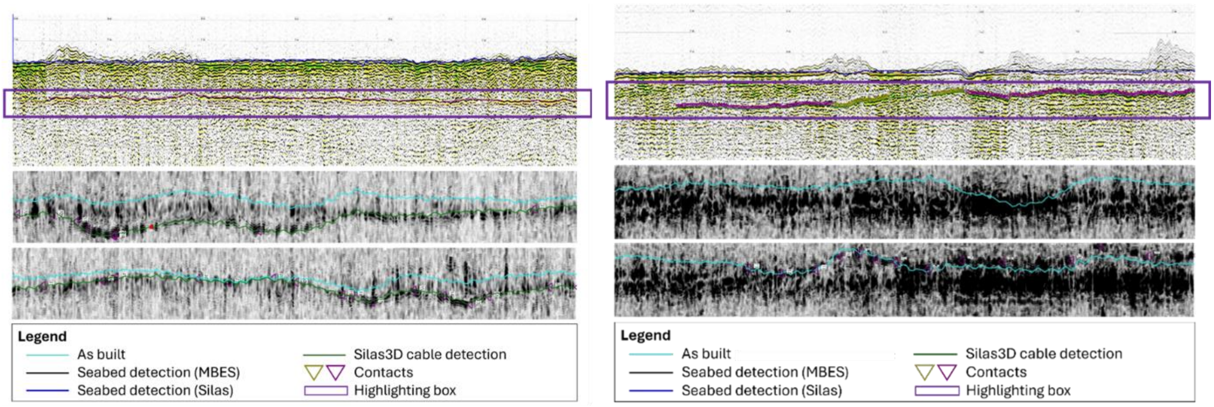

Figure 2 *Example cable detection in a sandy area (left), in acoustically more challenging area (right).*

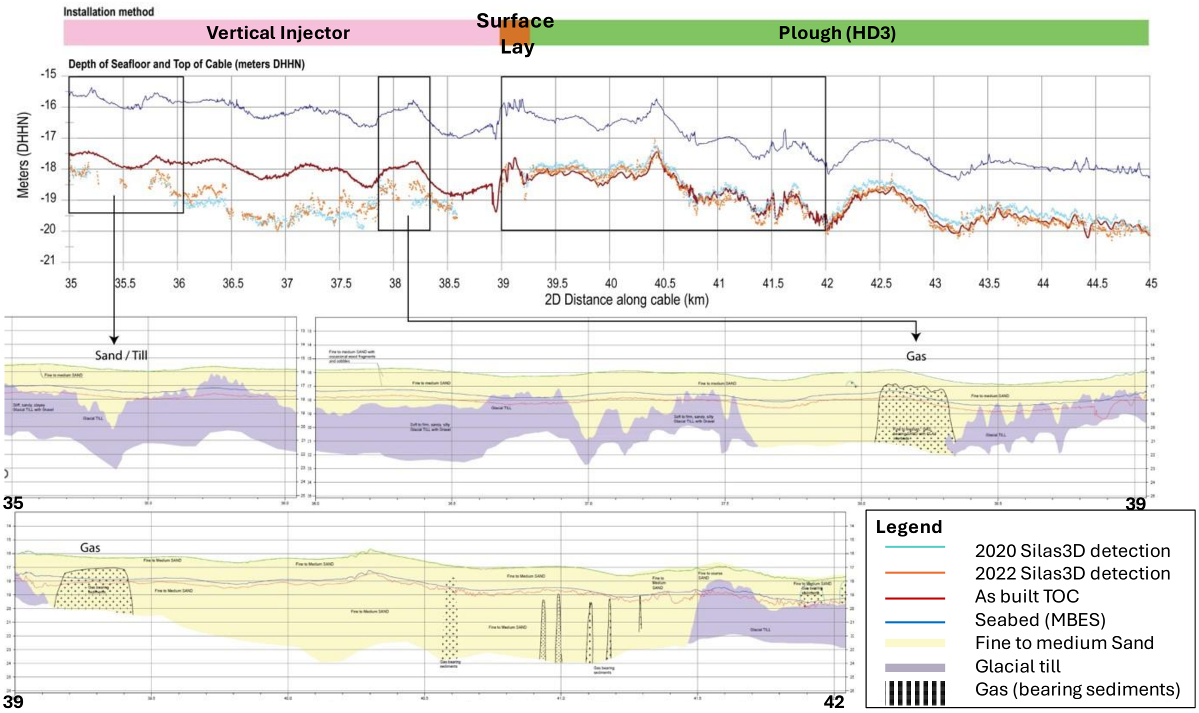

Figure 3 *Schematic overview of results obtained over several years for the same objects in the same location with link between quality of detections and installation method / sedimentology.*

Conclusions

Silas 3D has been used on different projects both for commercial and non-commercial surveys and is continuously being improved. Results are proven to be repetitive across different sensor setups on different vessels, acquired over a multitude of years, and they provide good lateral continuity. Because of the different projects executed so far, more understanding is gained in the operational capabilities of the system, which has resulted in a roadmap for further development.

References

LeBlanc, L.R., Panda, S. & Schock, S.G. (1992) Sonar attenuation modelling for classification of marine sediments. The Journal of the Acoustical Society of America, 116 – 126.

Missiaen, Murphy, Loncke, & Henriet. (2002). Very high-resolution seismic mapping of shallow gas in the Belgian coastal zone. Continental shelf research, 2291 – 2301.