First wide scale field trial of autonomous underwater vehicles seismic programme

Introduction

It is generally accepted by the industry that seismic surveys acquired using seabed seismic receivers deliver the optimum measurement of subsurface reflectivity. Two seafloor acquisition systems exist currently: one using seismic sensors attached to cables and the other one uses receiver nodes that are placed on the seabed with the assistance of a remote operating vehicle (ROV). Over the last ten years the cost of ocean bottom seismic projects has been reduced considerably as a result of investment by the seismic acquisition contractors in efficient receiver deployment solutions. These engineering efforts include the move to automation and robotization of seismic data acquisition for exploration and development activities in the oil and gas industry. One such engineering project was the development of autonomous robotic nodes which autonomously navigate to and from their pre-plot location. The objective of the robotic sensor technology is to replace cables and ROV operated conventional systems with a robotized solution for faster, cost effective, and safer seabed seismic acquisition. Therefore, we are developing a robotic-based technology, which utilizes autonomous underwater vehicles (AUV) as seismic sensors without the need of using remote operated vehicles for deployment and retrieval.

In this presentation, we outline the details of the first large scale field trial using autonomous ocean bottom nodes and we illustrate with a number of field data examples the successful field deployment and retrieval of the 200 AUVs and the processing of 3D seismic recorded data.

SpiceRack - The Autonomous Robotic Node

SpiceRack is a joint development program between Seabed Geosolutions and Saudi Aramco which started at 2014. The goal was to develop an ocean bottom receiver technology that would provide a step change in deployment and recovery efficiency and open up new seismic acquisition configuration models. What makes SpiceRack unique to most systems available in the market is the freedom of the autonomous underwater vehicles (AUVs) to navigate autonomously, and the flexibility of the technology to be adapted for many seismic imaging purposes. For example, for deep exploration targets usually large offsets (distances) have to be acquired to image the targets adequately. For shallow hazards, imaging a dense short offset survey must be considered. SpiceRack has the ability to switch between the two without any redesign. It taps into specialized seismic imaging services and reservoir surveillance (4D) where imaging is required in congested areas where seabed production facilities are present.

Over this six-year period many prototypes have been developed and tested (Figure 1) as the shape and physical characteristic of the node have been altered and refined.

Figure 1 The evolution of the AUV design through the six-year project duration

The autonomous node has a very different expected usage than AUV’s used for non-seismic applications. It is required to have some negative buoyancy to ensure acceptable seafloor coupling which has the negative consequence of requiring more power to surface the AUV. Furthermore, the autonomous node will spend the bulk of its mission on the seafloor whereas other AUV applications
require the units to navigate continuously. These unique AUV applications required specific focus and careful engineering design.

The development of the acquisition solution is not simply the integration of a seismic recorder into an autonomous underwater vehicle. It requires additionally the development of command and control in regards to positioning and underwater navigation of large swarms of nodes in parallel and the development of efficient launch and recovery systems. All these solutions have been developed in parallel and were tested on the Mediterranean Sea pilot project.

**Acquisition Layout**

This survey was a follow up of the first pilot which has been successfully conducted in 2017 using 20 AUVs (Tsingas et al., 2019). The project was acquired in the Mediterranean Sea in water depths of 40m with a fixed receiver patch deployed in a 2400m x 2100m regular grid of 200 units forming 8 lines of 25 receivers (Figure 2(a)). The AUV node grid sampling was 300m (crossline) x 100m (inline) for a total receiver area of 5.04 km². Six seafloor positions spread over the grid were occupied and collocated with Manta nodes to provide data comparisons especially when assessing seismic receiver coupling. The AUV nodes were launched directly from the deployment vessel as would be the expected deployment model and recovered to a basket lowered from the deployment vessel. The positioning, command and control of the AUV units were achieved through acoustic communication with the surface vehicle. Once all the units had deployed to the seafloor, a 18.04km² carpet of seismic source points was acquired with 50m x 50m spatial sampling. A total of 82 shot lines with 88 shot points per line were acquired using a 320 cuin airgun array which was the maximum tolerable volume allowed for the area. Figure 2(b), depicts the distribution of offset and azimuth achieved with this type of acquisition geometry. On command, after completion of the source acquisition grid, the AUVs wake up and navigate autonomously to the basket location.

In general, the acquisition was successful and the experiences gained during this experiment will assist immensely the ongoing engineering efforts towards the development and deployment of significantly larger crews.

**Results**

Evaluation of the seismic data took two separate efforts, namely, the comparison of the SpiceRack AUVs against the Manta nodes for all 4 components and a fast track time processing of the SpiceRack nodes. Figure 3(a), shows both hydrophone components of the AUV (left) and Manta (right), respectively (i.e., for one specific location). Figure 3 (b), shows the Vz components for both nodes.
The hydrophone measurements of the two units (Figure 3(a)) are effectively identical when you consider the small difference in position. However, the two units have a different shape and a different weight in water which will have an impact on seafloor coupling for the vertical and horizontal geophone sensors.

Figure 4 (a) shows the Vx components for both AUV (left) and Manta node (right) where Figure 4(b) illustrates the Vy components for both AUV (left) and Manta (right). Since the AUV is lighter in water than the Manta node, it was identified that it recorded higher levels of reverberating low frequency water velocity events. While this is not significantly higher on the vertical geophone as shown in Figure 3(b) it was considerably higher on the horizontal components (Figures 4(a) and (b)).

In order to continue the evaluation of the AUV seismic response in reflectivity imaging a simple 3D processing workflow was performed. It involved the following steps: tilt corrections in x and y, applying a de-bubble filtering, FK and low rank applications for linear and random noise elimination, velocity analysis a post stack 3D migration, a gap deconvolution and a post migration FXY denoising. Figure 5 shows three inlines from the Vz component extracted from the south, middle and north location of the 3D migrated volume. The high fidelity of seismic character which shows the variation of geological structure (below 1 sec two-way time) can be easily identified on these images. Following a 4 component denoising application to eliminate the shear wave contamination from the vertical geophones and a linear noise elimination from the Vz component to attenuate the water bottom generated mud-roll, a PZ summation was applied to obtain the upgoing wavefield.
Figure 5 Three inlines from the Vz AUVs geophone component extracted from the 3D migrated volume.

Figure 6 depicts a 3D poststack time migrated inlines extracted from the migrated upgoing wavefield volume. A spike decon, a low-rank and fxy type filters were applied in the post migrated domain. Again, the displays illustrate a transition from layer cake horizontal formations to a high structural and dipping geological layers.

Figure 6 Three inlines of the upgoing AUV wavefield extracted from the 3D migrated volume.

Conclusions
Ocean bottom seismic acquisition has been traditionally considered only for a small portion of the total seismic market, even though there are aspects of the measurements which are highly desirable. This project has shown that the innovative robotic node technology has the potential to realize significant uplift in project efficiency while maintaining data quality and could ultimately achieve the desired goal of matching wide tow streamer survey costs. With this project study we have successfully integrated the three sub-components of the development project; 1) engineering of an AUV containing an ocean bottom seismic recorder 2) Command and Control of multiple units in parallel as they navigate to and from the pre-plot location 3) Autonomous Node Launch and Recovery. It was shown that with the current processing analysis of the seismic data the obtained images demonstrated high fidelity results by managing the resulting noise. It is strongly envisioned that the introduction of robotics in seismic acquisition activities will significantly reduce costs and minimize human intervention and, consequently, HSE risk.

References