

# Autonomous Nodes For Time Lapse Reservoir Seismic: An Alternative To Permanent Seabed Arrays

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The March edition of *Offshore Engineer* featured a story on the re-emergence of interest in the marine seismic business in ocean bottom services using node technology. The article focused on 'relative minnow', Norwegian company SeaBed Geophysical, a subsidiary of SeaBird Exploration.

In the late 1980s Statoil developed the SUMIC (SUBsea seisMIC) technique, recording shear and compressional waves by sensors fixed to the seabed. Providing a brief history of nodes, it is stated in first break volume 25, December 2007, with regard to a pilot study carried out over Statoil's Tommeliten field in 1993:

*"The image of the Tommeliten reservoir structure through and below gas chimneys was made visible for the first time. 4C-3D acquisition with sparse receiver and full azimuth dense shooting was first developed by Subseaco/CGG in 1996. The first ever commercial 4C-3D of the Guillemot field for Shell was successfully acquired with 600 m between nodes using a dense shooting grid of 25 m x 25 m and wide offset. The nodes were linked by cable and recorded from the dynamic positioning vessel but the operations were not very efficient. Subseaco/CGG projects used the concept of sparsely planted sensors to obtain multi-component and converted wave data (Woge et al., 2003)."*

The *Offshore Engineer* article tracks the recent utilisation of node technology, with companies including Total, BP and Chevron—in Angola, the Gulf of Mexico and Nigeria, respectively—employing it on three deepwater acquisition projects over the past year.

The following paper, by SeaBird, provides an overview of how the technology works.



The CASE Abyss Node

## Abstract

Time lapse (or 4D) seismic monitoring of producing oil fields is an accepted method for optimisation of field development and product recovery, providing significant improvements in recovery rates and savings in drilling costs. This paper provides an overview of the concept and design of an autonomous seismic node recording system, and a comparative analysis of using nodes versus permanent sensor cable installations for 4D seismic analysis and monitoring of an oil field. The node approach has only recently been used by industry, but the development and testing of these systems has been in progress for nearly 20 years. This paper illustrates node seismic instrumentation and operation, description of directional sensitivity or vector fidelity, and the application of node seismic to the Cantarell Field in Mexico, a field with an extensive network of pipelines and surface platforms, all of which are serious obstacles in the path of an accurate and well-sampled seismic survey. A quantitative description of navigation accuracy versus water depth is provided, along with a comparative commercial analysis of the permanent cable installation at BP's Valhall Field with an equivalent array of autonomous nodes.

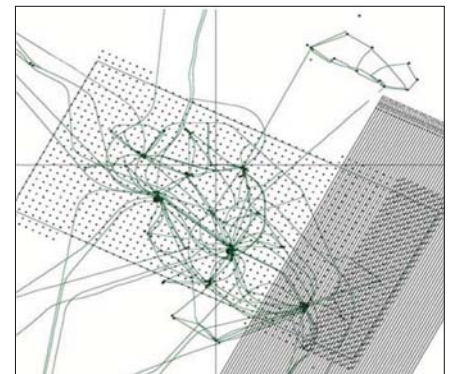


Fig. 2. Node positions, pipelines, and installations at the Cantarell Field.

## Introduction

Autonomous 4-component (x-y-z and hydrophone) seismic reservoirs, or nodes, have been developed as an important new tool for reservoir management. The advantages of nodes include:

- Vector fidelity;
- Ability to acquire data in and around pipelines and structures;
- Precise coupling to the seabed; and,
- Excellent orientation of the receiver axes.

The node illustrated in this paper was developed by the SeaBird Seismic Division of SeaBird Exploration, a technical development group which grew out of the Statoil research group in Trondheim, Norway. The CASE Abyss (Fig. 1) has been developed to operate as an autonomous sensor package in all marine environments up to 3,000 m water depth. The system can record 2 millisecond data samples on a continuous basis for up to 80 days.

### Benefits of Seabed Recording

An essential element of a successful 4D seismic project design is the normalisation of the parameters for data acquisition to be used for the initial programme and each repeat survey. It has been demonstrated (Berg & Anderson, 2008) that currently used subsea positioning techniques can reliably achieve sub-metre positions for reoccupations of seabed node receiver positions. In conducting towed streamer operations, there is generally a 1x10 km lens of data missed around any surface obstructions, including production or drilling platforms and FPSOs. This is a niche in which nodes are a dramatic improvement over towed streamer technology. As illustrated in Fig. 2, which shows the seabed node locations along with platforms and pipelines on a node survey over the Cantarell Field in Mexico, the seabed node approach can provide excellent coverage even in the most congested areas.

Depending on the geological structure of the field, depth-to-target, and commercial considerations, the nominal spacing for the seabed nodes are from a 200x200 to a 400x400 m grid. Use of a hexagonal grid can optimise the process by approximately 13%. Once the sensors are placed on the seabed by the ROV, the shooting vessel (or ROV/node/source vessel in a single ship operation) proceeds to shoot the energy source pattern over the nodes. With the source vessel only towing a short offset airgun array, the vessel can pass very close to installations on the field, as illustrated in Fig. 3.



Fig. 3. Source vessel operations near installations.

### Data Recording and Retrieval

The node system is designed to record 2 millisecond, 4-component seismic data samples continuously for up to 80 days. The data recorded includes converted wave (or shear wave) data, which can be a significant benefit in determining rock properties and imaging through gas-charged sediments, as illustrated by Chernikoff, et al (2007). As the systems are not cabled, a precise clock, with drift less than 1 millisecond per month is used

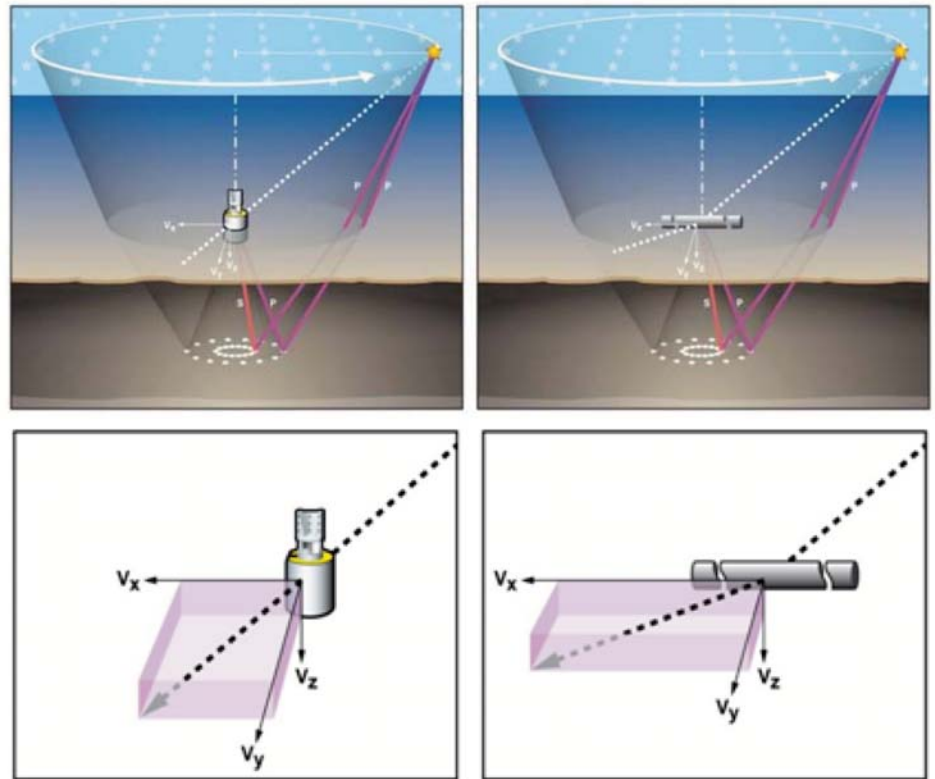


Fig. 5. Node (left) vs. cable. Vector analysis of received seismic energy at the sensor.

to synchronise the recording and shooting operations. Once the shooting operations are completed, the nodes are again recovered; the data downloaded and merged with the corresponding navigation data from the shooting vessel to provide an industry standard SEG-Y field record format for data processing.



Fig. 4. Node in deployed position.

### Environmental Aspects

When deployed, the node control system is resting on the seabed, and the sensor package is pressed into the seabed as shown in Fig. 4 using a specially engineered arm on the ROV. This low-impact form of ocean bottom seismic (OBS) makes nodes an acceptable option in many areas where conventional OBS cables or permanent seabed bottom cable systems would have a greater environmental impact.

### Installation Considerations

By contrast, permanently installed, buried cable field monitor systems:

- Must be commissioned prior to field development.
- Require a high up-front capex.
- May require costly service to replace or service sensors during the lifetime of the array.

In addition, the process of burying the cables will alter the physical properties of the sediments, which can have a negative impact on the coupling of the sensors with the seabed, an important factor in data quality.

### Vector Fidelity

By design, the node sensor package is omnidirectional, receiving unbiased energy from all directions when properly deployed. As illustrated below, the physical shape and construction of cables can produce an 'antenna effect' which aliases the energy received along the axis of the cable with respect to energy received from other directions (figs. 5 and 6). To illustrate this with real data, a test was conducted to compare first break energy received from both a node sensor and a section of seabed seismic cable. These results show that the first break energy received by the node is nearly uniform from all azimuths, and, by comparison, the cable data shows a directionality or aliasing, which can be difficult

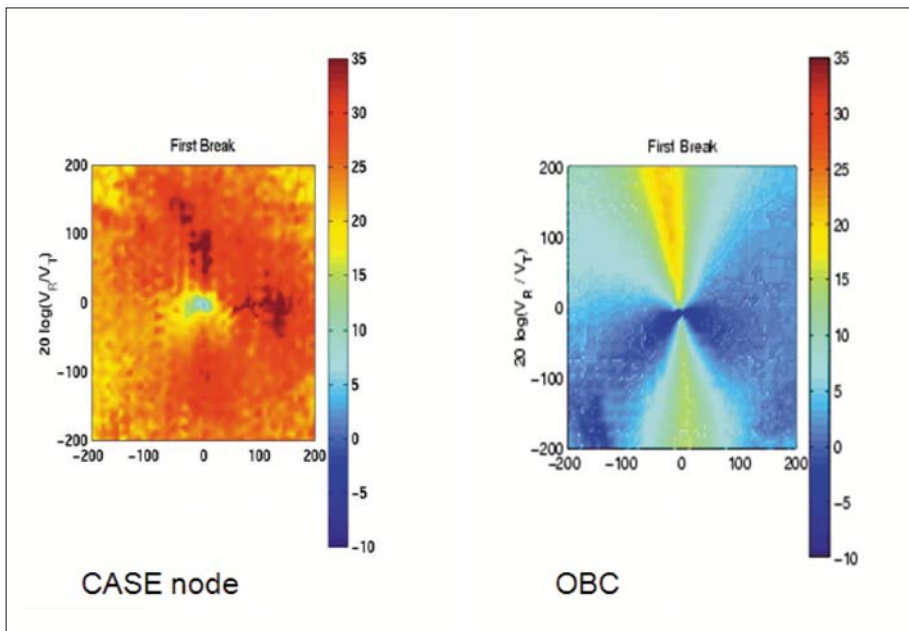


Fig. 6. First break energy for node (left) vs. cable for 10 x 10 m shots over a 400 x 400 m area centered over the sensors.

to mitigate in processing, and may impact the final data quality.

**Sensor Orientation**

When the node sensor is deployed by pushing it into the seabed, the ROV operator is closely monitoring a real-time output of the inclinometer which is integrated into the sensor package. This allows for a precise alignment of the vertical (z) axis. The horizontal axes are fixed with respect to the ROV gyrocompass and are also precisely known. The impact of misalignment of the z axis is illustrated in Fig. 7 and is caused by converted or shear wave energy from the x and y axes contaminating the z axis data. Although this can be compensated for in data processing, it is an imperfect correction, so minimising it provides for an improved dataset.

**Valhall Field Commercial Analysis**

There are only limited current industry case studies of a permanently deployed geophone array on an oil field. The BP-operated Valhall Field on the UK Continental Shelf is one. Using this example, Berg et al, (2008) made a theoretical comparison of the cost of the installation of the sensors at Valhall plus the cost of the source vessel operations over the initial nine years of the field's production. As shown below in Fig. 8, it was found that the node programme would be a lower capex during the initial nine years of production. It should also be noted that approximately 15% of the sensors originally installed have failed since their installation. Although current permanent systems are more robust, such risk remains a consideration. An additional issue for the permanent installation

is the requirement for a source vessel, which the operator must either equip and maintain, or take on the risk of variable market rates for and availability of such vessels.

**Conclusions**

Industry is now embracing the node approach for obstructed producing fields. At the time of this writing, successful node seismic surveys have been undertaken in the North Sea, Mexico, US Gulf of Mexico, and West Africa, indicating a growing acceptance of the technology. Nodes also provide a low impact alternative for environmentally sensitive areas. In commercial terms, a node approach can be commercially competitive with a permanent sensor array, and provide a more flexible solution for 4D seismic and long-term reservoir management.

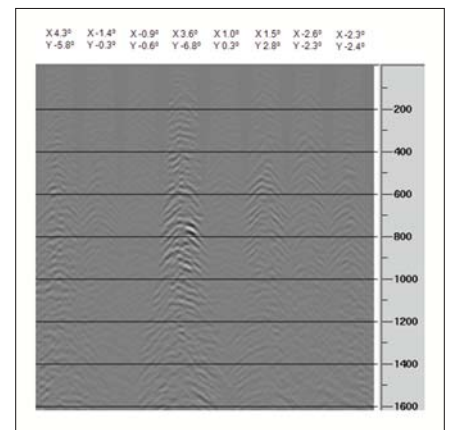


Fig. 7. Impact of tilt on vertical sensor.

**Acknowledgements**

The authors would like to thank Pemex for the opportunity to show data from the Cantarell survey.

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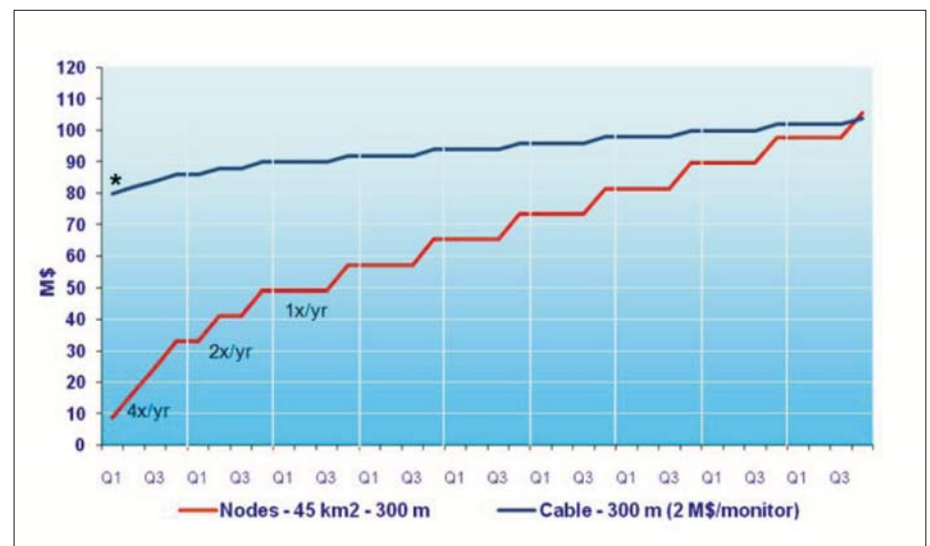


Fig. 8. Comparison of node survey costs (red) vs. cables (blue) at Valhall field.