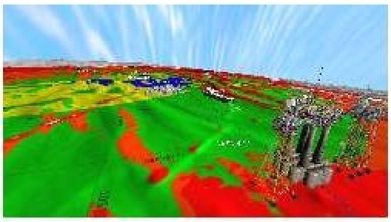
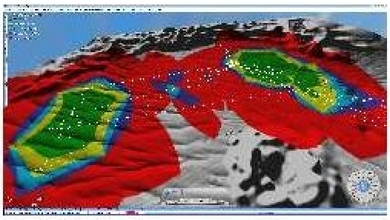
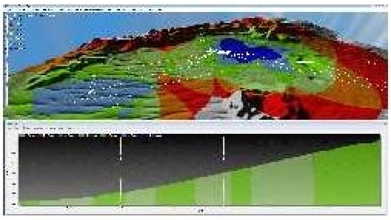
BEYOND TRADITIONAL LONG BASELINE TRANSDUCERS

Subsea Array Planning







The development of deepwater and ultra-deepwater subsea fields is one of the greatest challenges facing the offshore oil and gas industry today. The depths involved present a host of engineering challenges during both the development phase and the life of field maintenance programmes. A critical component of the development and maintenance of subsea oil and gas fields common to virtually all operations is accurate subsea positioning.

This article focuses on the latest technology used in deepwater positioning and on the development of new planning software and techniques to support the advances made in positioning systems.

Subsea Positioning
Subsea positioning is provided by acoustic signals transmitted through the water, either from vessel-mounted transducers (Short and Ultra Short Baseline - USBL) or from transducers deployed and calibrated on the seabed (Long Baseline - LBL). There is a fundamental difference between USBL and LBL: USBL measures range and bearing from a single transducer while LBL positioning is based upon trilateration - the measurement of multiple ranges from known locations. Other systems, such as INS (Inertial Navigation Systems), may be used in conjunction with acoustics to smooth and enhance relative positioning stability. The choice of system often depends on the water depth and required accuracy, with LBL systems providing high accuracy positioning independent of water depth. For this reason, large coverage LBL arrays are often prevalent in deepwater developments and their installation, calibration and maintenance can involve substantial time and costs. It is therefore beneficial to minimise the number of transducers, and system choice and array planning have a major effect on this.

NASNet
NASNet (Nautronix Acoustic Subsea Network) is the next generation LBL system, developed by Nautronix. It is a long range, high accuracy, multi-user system based around the latest digital spread spectrum signalling technology. The system more closely resembles a subsea acoustic GPS system than a conventional LBL system, and overcomes or reduces many of the restrictions associated with traditional LBL. One of the most significant factors limiting maximum range measurement is the local sound velocity profile. In deep water, this typically causes signals to refract towards the sea surface, leaving areas close to the seabed with no coverage. In order to mitigate this effect, the NASNet system transmits signals from a buoy-mounted transducer 100m above the seabed. This allows for ranges three to five times greater than those from a transducer mounted close to the seabed to be measured. The position of the buoy is measured and corrected for any current-induced movement. The planning, design and analysis of the NASNet Station network is critical to maximise the benefits of NASNet. To optimise the use and performance of the system, a significant advance has been made in the techniques and systems used in array planning.

LBL Planning
A well-designed subsea positioning array will provide high accuracy as well as reliable and comprehensive positioning coverage throughout the required areas. A poorly-planned array can adversely impact projects, whether simply by using more stations (and therefore more time and cost) than required, by providing reduced accuracy or, in the worst case, by failing to provide the required positioning coverage. The time and effort put into LBL array planning and the methods used vary enormously between regions, companies and individuals. Norsk Hydro took array planning to a new level for the Ormen Lange project between 2003 and 2008, using a variety of tools and contractors to optimise its LBL arrays for coverage and geometry. Nautronix and GeoLine have now raised the bar even higher, with the GeoLine3D software providing a dedicated array planning facility with even more advanced planning features. For an acoustic seabed array to successfully fulfil its purpose there are generally two main requirements: positioning ‘coverage' of the required area and positioning ‘accuracy'.

Coverage
The most obvious, perhaps, is coverage - the array needs to provide sufficient signal coverage (range reception from a minimum of three stations) to allow reliable positioning throughout all the required areas. Because of the limited (generally less than 1500m) ranges used in

traditional LBL, the refraction of the acoustic signal through the water has relatively little effect on the visibility within that range from the transponder. As the NASNet system is capable of ranges of 4500m at the seabed, the effect of ‘ray bending' becomes more significant, with a deviation in deep water of around 15m from the straight line. It is therefore important to first model the signal path from the NASNet stations, incorporating the effects of acoustic refraction, before using the model in conjunction with a seabed Digital Terrain Model (DTM) to derive a visibility plot - identifying which cells of the DTM will receive acoustic signals from which stations (see Figure 1).

Accuracy

The second major requirement for most arrays is accuracy - the installation and calibration of seabed arrays is a time-consuming and costly business compared with the use of vessel-mounted acoustic positioning systems. Seabed arrays are therefore normally used where a higher order of accuracy is a necessity. Although there are many contributors to accurate subsea positioning (quality of sound velocity, depth measurement, etc.), good array geometry can significantly mitigate the effect of range errors on the subsequently derived position. The same applies to satellite constellation geometry in GPS, where critical operations can be planned around times of optimal geometry. Dilution of precision (DOP) is used in GPS positioning as a dimensionless indicator of geometry, based purely on the geometry of the vectors between each satellite and the receiver. LBL arrays are of course static, which on the positive side means consistent geometry at any given point but on the other hand, it is not possible to wait until the geometry improves, as with GPS.

Quality Indicator

Various DOP values are quoted but, for LBL acoustics, horizontal DOP (HDOP) is generally the most valid. This reflects only the horizontal geometry which is the most relevant as a typical LBL array is at similar depth to a subsea receiver and therefore poorly suited to deriving accurate receiver depths. Instead, receiver depth is determined using a separate pressure measuring device and the measured density of the water column. The use of DOP values for array planning does have limitations due to their failure to reflect standard ‘good survey practice', such as positioning only within the boundaries of the array. A new quality indicator for Geometric Support (GSUP) has been defined that effectively quantifies the strength of array geometry, reflecting the number of available ranges and their angles of intersection, as a single percentage of ‘perfect' geometry. This allows acceptance criteria to be easily defined and understood both during planning and operations (see Figure 2).

GeoLine3D

The latest in array planning software is GeoLine3D (G3D) - a real-time dynamic visualisation and engineering analysis package for exploring, planning and analysing survey, engineering and construction activities. The GeoLine3D array planning module has been developed to provide the most accurate design and assessment of arrays by using an imported sound velocity profile to calculate the ray-bending effect on each possible acoustic ray path from a station. During ray tracing, the seabed topography and 3D object interaction is checked to determine which grid cells of the DTM will be visible from a particular station location. Arrays can be fine-tuned quickly and easily by relocating stations using the drag and drop functionality in the 3D environment, with the software recalculating the visibility from the new location. Grid cells on the DTM are colour coded according to the number of stations visible from each cell (see Figure 3). A minimum of three stations must be visible to calculate a position within the array, but arrays are normally planned with an expected coverage of four or five stations. This redundancy increases the reliability of the positioning and allows statistical quality control to be carried out, giving increased confidence levels in the positioning quality.

Following the calculation of visibility for each cell, GSUP and DOP values may be calculated to give an indication of the geometrical balance of the array at all locations. Again these values can be rendered as colour-coded values on the DTM, for export either as geo-referenced graphics or as a new XYZ file. Multiple routes can be imported or defined in GeoLine3D software as coverage may be required for pipeline or cable laying, where positioning quality within a relatively narrow route corridor is more relevant than that over wide-scale areas. The calculated station visibility and GSUP/DOP values along a defined route corridor can then be calculated and assessed.

Ease of Use

Most array planning is carried out onshore, well in advance of the offshore phase of the project. Sound velocity profiles and seabed terrain data used during planning and analysis are, if available, normally provided by the client. However, quality and accuracy can vary, so the GeoLine3D module is designed to be powerful, efficient and easy to use offshore. The array layout can therefore be easily updated and visibility plots verified when new data become available. Operationally, this allows the fine-tuning of array design if conditions are found to have significantly changed between planning and offshore installation. By using GeoLine3D to visualise the digital terrain model in conjunction with the powerful array planning module, Nautronix have been able to significantly improve the reliability and efficiency of array design, minimising potential offshore downtime through lack of coverage and therefore providing significant risk mitigation and cost savings.