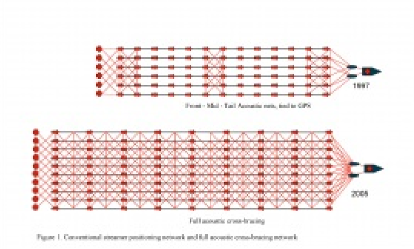
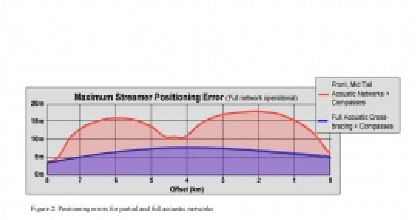
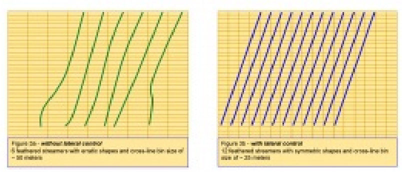
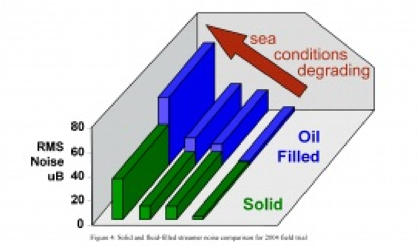
USE OF ENHANCED ACQUISITION TECHNOLOGIES

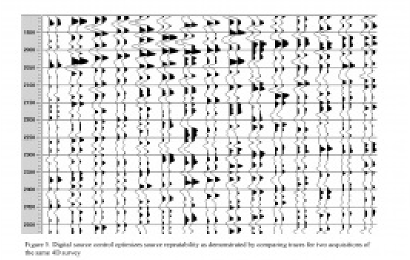
Optimising 4D Repeatability

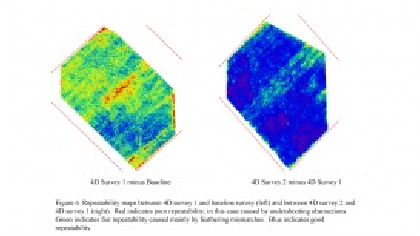












During the past thirty years subsurface seismic images have allowed Exploration and Production companies internationally to commercially develop thousands of hydrocarbon reservoirs. In response to increasing world demand some companies are employing more costly and complex seismic data-acquisition techniques to help them discover the next major field.

A less costly alternative is to enhance the recovery rate of existing reservoirs by performing multiple surveys of the same reservoir over time. This technique, known as '4D seismic', gives companies the ability to dynamically track and monitor fluid movement and pressure change within reservoir compartments. Armed with this information asset man-agers can identify bypassed reserves, adjust injection programmes to maintain stable production, position new wells in response to fluid movement, or make similar decisions to extend the life of the existing reservoir. New seismic technologies can provide E&P companies with the quality of data required for imaging such reservoir changes over time.

4D Transformation
There has been a transformation in 4D over the past several years, from an immature reservoir-monitoring method promising better asset utilisation to a mature business model embraced by many E&P companies and supported by multiple seismic contractors. Since 3D-towed streamer survey serves as the baseline for future 4D-projects, enhancing the current capability to acquire highly repeatable 3D-streamer data adds significant value all around. Regardless of system type, improving 3D (and by definition 4D) towed streamer capabilities depends on the following system enhancements:

- better streamer shape estimation to reduce positioning errors
- ositioning streamers closer together for increased image resolution
- higher streamer signal-to-noise ratio to reduce noise susceptibility
- improved source performance and repeatability through digital timing control
- integrated navigation and data-management systems for real-time course correction and processing-ready data.

Together the various parts of the acquisition system must operate as an integrated unit in order to optimise 4D-imaging capabilities in the towed-streamer environment.

Improving Positioning

First things first. Better estimates of hydrophone receiver-group locations are needed. Magnetic compass headings and GPS receivers on buoys near the front and rear of the streamers have been the mainstay of the industry and will continue to form the backbone of positional accuracy. However, rough weather degrades compass measurements and subjects the entire streamer spread to errat-ic shapes.

Continuous survey-course correction at towing speeds greater than 2 metres per second creates further uncertainty in receiver location. The impact can lead to highly correlated 3D-positioning errors. In the 4D-world the impact is more serious when trying to match subsequent time-lapsed surveys to original baseline data.

The most effective strategy for improving streamer- positioning accuracy is the implementation of full acoustic cross-bracing. With the new generation of acoustic systems available to the industry today, acoustic networks traditionally deployed at the front, middle and tail of the cables can be extended across the full length and breadth of the streamer network. This results in substantial improvements in pos-itioning accuracy.

Upgrading 50% of compass measurements to acoustic nodes effectively means that for every heading-sensor observation removed from the network six to eight direct acoustic range observations are added. Since acoustic measurements are less severely impacted by adverse weather conditions, these additional ranges offer a check on or replacement for compass measurements. Furthermore, additional redundancy and continuity in the acoustic network allows estimation of spatial and temporal variations in propagation velocity. Perhaps the most significant benefit to using full acoustic cross-bracing for streamer positioning is the abil-ity to closely and accurately monitor streamer positions in real time and so enable active streamer control. This leads on perfectly to the next enhancement: spread stabilisation.

Enhanced Stabilisation

High-resolution seismic acquisition requires a vessel to tow multiple streamers: six, eight, twelve or more. In a perfect world all towed streamers would move through the water parallel to each other and in line with the vessel. However, conditions such as current change, wind, and vessel heading change cause the streamers to feather and form asymmetrical shapes. Because of these outside influences streamer control and positioning face many constraints:

- asymmetrical streamer shapes
- cross-line bin asymmetry
- non-repeatability of receiver locations
- streamer feathering control
- difficulty in acquiring data around obstructions.

Separately or in combination these constraints hamper accurate 4D-imaging of the subsurface. Lateral streamer control is a promising technology that will mitigate many of today's acquisition constraints while preparing a platform for the solution of tomorrow's challenges. Lateral streamer control stabilises streamer spread, resulting in more symmetric and repeatable coverage patterns. Operating on the same principle as vertical (or depth) streamer control devices, lateral control devices give vessel-navigation and data-management systems the ability to compensate for uncontrolled streamer movement. With this level of control more streamers can be towed safely, much closer together, with less chance of streamer tangling. This improves available cross-line resolution, achieving greater high-resolution seismic data.

When integrated with full acoustic cross-bracing, lateral streamer control allows quicker real-time repositioning of streamer sections, an entire streamer, or the entire spread, to better match receiver location of prior surveys. It also allows for shorter line change time by reducing the run-in distance required for straightening streamers at the start of line.

Reduced Noise

Towed streamers are susceptible to a number of noise sources, including 'self noise'. The vessel, tailbuoy and cable levellers (birds) will all generate some level of jerking on the cable. In fluid-filled streamers there is little damping of this noise as it propagates along the cable-stress members and bulges of fluid move up and down the streamer. Reducing or eliminating these noise sources is not always possible. Another method is to lessen the susceptibility of the streamers to them.

For several years now, solid stream-ers have offered a solution. Solid streamers are subject to all the same noise generation mechanisms, but the propagation of noise is significantly dampened, resulting in lower overall noise levels. Increasing the signal-to-noise profile is always good for the quality of a seismic image, particularly as we seek to explore ever-deeper objectives and to improve the repeatability of 4D-imaging. There are equally important operational benefits with solid streamers. As sea conditions degrade, a ten to forty-decibel improvement in noise susceptibility can significantly expand the operational weather window, thus increasing productivity and decreasing the cost per square kilometre of 3D-data.

The addition of the lower noise susceptibility of solid streamers to full acoustic cross-bracing and the streamer-spread stabilisation discussed above enhances a streamer crew’s capabilities in estimating receiver location and adjusting the location of streamer sections or the entire spread. It also lessens the impact of various noise sources, even in deteriorating weather conditions.

Improved Performance

Up to this point we have limited our 4D-repeatability improvements to the streamer portion of the total acquisition system. While streamer positioning is perhaps the most difficult aspect of 4D-repeatability, accurately repeating the positioning and performance of the seismic energy source is also critically important to a successful 4D-survey. Marine source arrays typically comprise many individual airguns of different sizes that are triggered to discharge compressed air simultaneously. With the recent development of digital-source control, airgun synchronisation has improved by an order of magnitude from 1 to 0.1 millisecond of error. Additionally, the digital source controller system can monitor and control the depth and pressure for each airgun and record a near-field hydrophone at each gun for use in processing for signature measurement.

Real-time Data

Now that all the in-water components of the acquisition system have been enhanced to acquire highly repeatable, high-fidelity 4D-images, the time is ripe to join them with integrated quality-control systems and project-management tools. The latest software systems combine real-time navigation with ocean-current monitoring and prediction, to optimise field data acquisition. So that 4D-acquisitions are no longer subject to the numerous subjective decisions of an operator regarding what data to include or what filtering algorithms to apply. Rather, these new quality-control systems aggregate current data from streamers, sources, GPS buoys, sea-state and atmospheric monitors, and vessel-navigation monitors, to adjust in real time source and streamer positions to best match the original baseline acquisition.

Together, all these acquisition enhancements in streamer, source and integrated-navigation systems will optimise the repeatability of 4D-surveys while minimising operational costs.