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HD3D Acquisition Yields Outstanding 4D Results

Summary

PGS has demonstrated the effectiveness of its 4D acquisition strategy many times since its original publication more than two years ago. The recent Draugen 4D survey in the North Sea is a compelling example of the 4D acquisition strategy yielding outstanding source-receiver azimuth repeatability. Consequently, the acquisition imprint on the 4D signal will be minimized.

The Ramform Valiant acquired three customised 4D monitor surveys for Shell Exploration and Production offshore Norway and UK in 2004. All surveys were acquired using shot point repetition and overlap. The navigation data of these 4D surveys have been subject to a post survey analysis conducted by the R&D group within PGS. The objective of the study was to demonstrate the superior source-receiver azimuth preservation and repeatability provided by the underlying 4D acquisition strategy.

The seismic survey conducted over Shell's Draugen field in 2004 is a milestone in 4D acquisition with respect to repeatability. The Ramform Valiant deployed an overlap configuration with 10 streamers at 37.5m separation in order to repeat a previous survey shot by the Atlantic Explorer in 2001. When the 2001 survey was acquired, the vessel towed 6 streamers at 75m separation over a 4 streamer pre-plot. From 1998, another survey exists that was acquired as a conventional 3D using 4 streamers and 75m separation. The 2001 survey did not attempt to repeat the 1998 survey exactly but resulted instead in an ideal 4D base survey with overlapping coverage and close to zero infill. The denser streamer separation deployed in 2004 by the Ramform Valiant combined with the overlap shooting and the shot point repetition has resulted in a much more accurate match of the source-receiver azimuths of the 2001 survey than the previous 4D experiment (Figure 1).

Year of Survey	Nominal Configuration	Streamer Overlap	Vessel Streering
1998	4 streamers @ 75 m separation	None	CMP coverage
2001	4 streamers @ 75 m separation	4+2 6 streamers	CMP coverage
2004	4 streamers @ 75 m separation	10 streamers @ 37.5 m separation	Shot Point Repetition

Table 1: *Acquisition strategies used in acquiring the Draugen 4D surveys. The PGS 4D acquisition strategy used in 2004 yielded an outstanding improvement over the 1998 vs. 2001 4D results (refer to Figure 1).*

Shot Line Repetition

Shot point repetition is a first order method to repeat azimuths for all offsets. The principle is intuitive and straightforward:

- The CMP (Common Midpoint) binning grid used in processing of any Monitor survey is based upon the CMP grid used in the processing of the Base survey. In other words, every CMP location is fixed in space by the Base survey.
- By definition, the CMP position is equidistant between each shot and receiver pair contributing to that CMP. The CMP geometry is purely a function of surface source and receiver geometry.
- If the shot position is repeated for a given CMP location (any source-receiver offset), then by definition the receiver position must also coincide, and the source-receiver azimuth must be identical between Base and Monitor surveys. If the azimuth is repeated then the source-receiver raypath must be identical, and any acquisition-related imprint on the 4D signal will be minimized.
- HD3D acquisition with close streamer separation will optimize the likelihood of the appropriate receiver locations being available to repeat azimuth for every offset and every CMP location. The Draugen 4D case example from the North Sea is a compelling

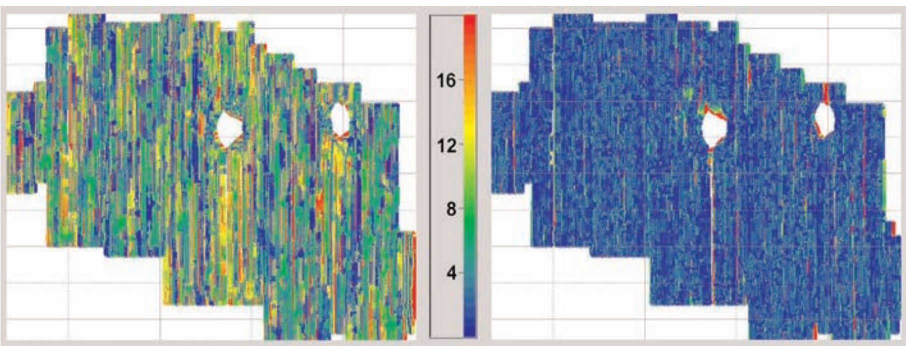

Figure 1: *4D source-receiver azimuth difference plots between two sets of successive surveys. The colour maps display azimuth differences from 0 (blue) to 20 (red) degrees. The comparison on the left is the 1998 vs. 2001 surveys, and the comparison on the right is the 2001 vs. 2004 surveys.*

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demonstration of the PGS 4D strategy yielding outstanding azimuth repeatability (Figure 2).

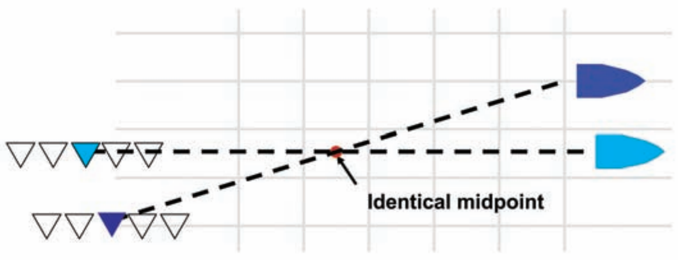

Figure 2: Demonstration of how source-receiver azimuth will be different for a given CMP location when the shot position is not repeated. This principle applies for all source-receiver offsets. If the azimuth is different the 4D signal will probably reveal an artefact due to the non-repeatable acquisition at that CMP location.

Streamer Overlap

Streamer overlap is a robust method to maximize the repeatability of azimuths at sail line boundaries, whilst simultaneously reducing primary infill requirements:

- A given streamer spread (*n* streamers with *d* streamer separation in meters) will have a nominal sail line separation equivalent to (CMP bin width x Number of CMP lines). For both single-source and dual-source shooting the nominal sail line separation is equivalent to 0.5*nd*. Streamer overlap involves additional streamers being towed with the same nominal sail line separation. Streamer overlap will provide a surplus of CMP traces in a broad zone along each sail line boundary. The width of the overlap zone is proportional to the degree of streamer overlap used. Typical overlap configurations are one or two streamers, e.g. 10 or 12 streamers on an 8 streamer pre-plot.
- As demonstrated in Figure 3, the additional streamers only contribute CMP traces when feathering moves one side of the streamer spread into the CMP bin locations near the sail line boundary. Consequently, the outer streamers allow each CMP to be populated with more traces than would otherwise be available with "conventional" shooting. Hence, there is a reduced requirement (often none) to reduce the nominal sail line separation in order to maintain acceptable CMP coverage. In other words, overlap shooting reduces the primary infill requirements in the case of variable streamer feathering between adjacent sail lines.
- The surplus of traces in the overlap zone ensures that a consistency in azimuth repeatability is provided when using the PGS 4D acquisition strategy - irrespective of whether the azimuths being repeated are in the centre of the sail line or at the boundary of the sail line.
- Overlap streamers can be used prior to CMP binning to optimize cross-line processing operations such as 3D interpolation, 3D regularization, and 3D SRME.
- Overlap shooting enables a suite of binning strategies to be available for all cross-line CMP locations. This optimizes 4D repeatability during binning.
- Surplus traces from the additional streamers used in the overlap zone will be rejected after binning so that fold normalization for imaging is uniform everywhere throughout the survey area.
- The cost of streamer overlap is small compared to "conventional" shooting when Ramform vessel technology is available, as the vessel is operationally capable of towing 12 - 16 streamers with minimal operational overhead.

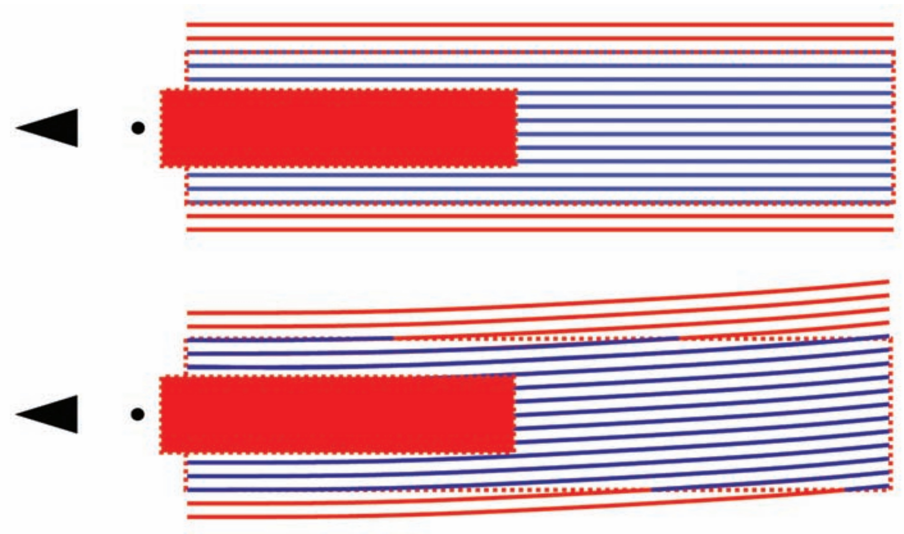

Figure 3: Demonstration of CMP binning with streamer overlap. The "live" area of CMP bins populated during acquisition is highlighted in solid red. For zero feathering the "excess" overlap streamers are plotted in red also. Streamer feathering allows the overlap streamers to contribute to CMP binning, as seen in the lower part of the figure.

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