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Wellbore Positioning Technical Section

The Industry Steering Committee on
Wellbore Survey Accuracy (ISCWSA)

Dynamic Gyrocompass Surveying: Safe and Efficient Wellbore Kick-off in Noisy Top-Hole Environments

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SPEAKER BIOS

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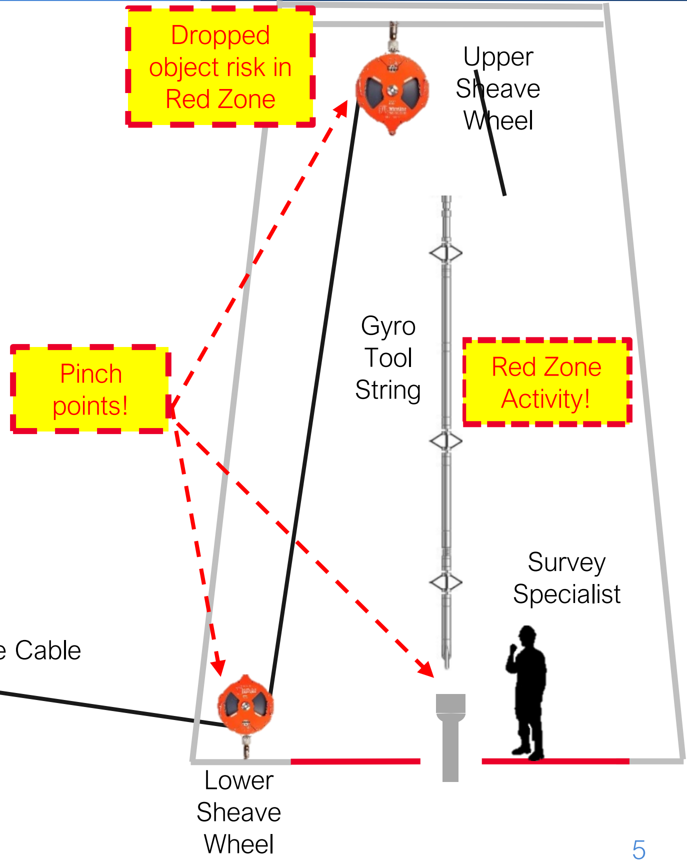
Presentation based on SPE-230767, Dynamic Gyrocompass Surveying: Safe and Efficient Wellbore Kick-off in Offshore Environments

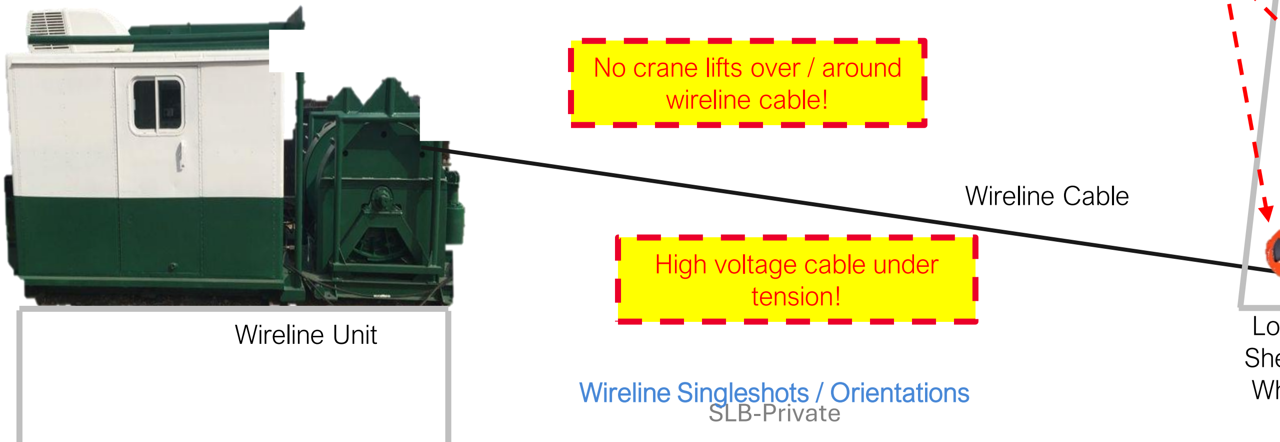
- Previous survey collection methods in “noisy" environments.
- Dynamic Gyro Compass theory
- Concept Validation
- Discussion Points
- Conclusion

The “good” old days…

- Single shots and gyro steering
- Scribe lines and UBHO subs
- Endless wireline runs and “one more check shot for the DD”
- Sleepless nights… and days..

- Wireline orientations.
  - Each run can take upwards of 1 hour.
  - Additional personnel onboard.
  - Pipe stationary with no circulation for extended periods during runs.
  - Scribe line required for steering.
  - HSE issues.





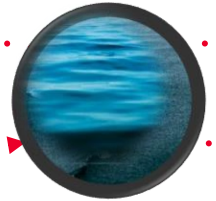
Normal mode

GWD tool run in normal collection mode and completely susceptible to external environment
Scribe line required and gyro wireline single shots required for verification
Extremely time consuming
Released: 2002

IMT mode

Ground breaking effort to collect a usable gyro measurement on floating rigs with GWD. Very long sample time and filtering done.
Scribe line required

Released: 2009



Extended Mode

IMT 2.0
Enhanced capability by transition to solid state gyro technology.
Multiple duration options available
Effective but still not guaranteed

Released: 2020

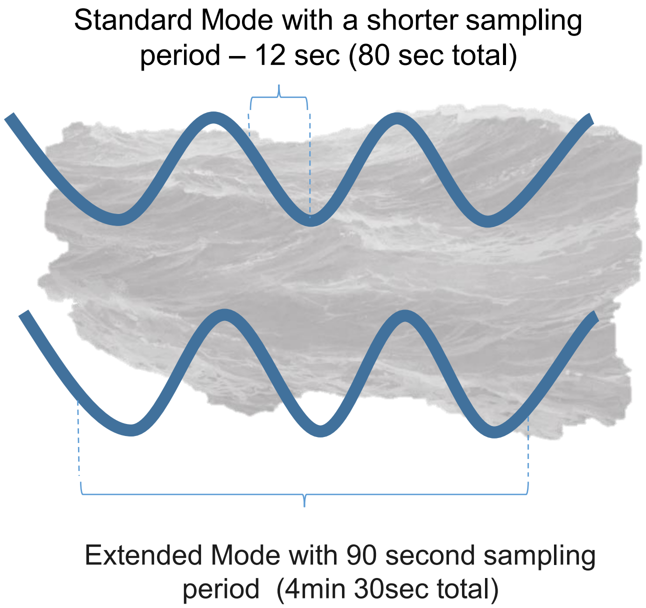
DGC

Engineered solution which leverages multiple sensor measurements to quantify
Survey on connection and confidence under the most extreme conditions

Released: 2025

Standard Mode

Extended Mode



- Compensation always required.
- Survey Repeatability may be monitored for survey acceptance – time consuming (typically 10 minutes per survey) and can lead to hole wash-out.
- Secondary Procedures applied to mitigate noise (e.g. Weight on Bit).
- If unsuccessful, options are to rotate a single down to bed in BHA and retry or run wireline sighting gyro.

- The gyroscopic tool needs to be stationary to measure the components of earth's rotational needed to calculate the survey
- External motion induces rotational components that contaminate the gyroscopic readings, making it difficult to isolate the Earth's rotational signal
- The Dynamic gyrocompass method addresses the problem by estimating the tool motion-induced rotational components and removing them from the gyroscopic measurements
- The motion components are estimated by analyzing the rate of change of the accelerometer measurements
- Project Objectives:
    - Ability to survey over connection with QC passing 1st time.
    - Inclination range: 0 –10°
    - Performance equivalent to extended mode IPM.
    - Sample time – maximum 10 minutes

- The triaxial gyroscope measurements are expressed as

$$\omega_x = \omega_{Bx}^B + \omega_{Ex}^B, \qquad \omega_y = \omega_{By}^B + \omega_{Ey}^B, \qquad \omega_z = \omega_{Bz}^B + \omega_{Ez}^B$$

where ω_{Bx}^B, ω_{By}^B, and ω_{Bz}^B are the motion induced components, and ω_{Ex}^B, ω_{Ey}^B, and ω_{Ez}^B are the components of the Earth's rotational rate

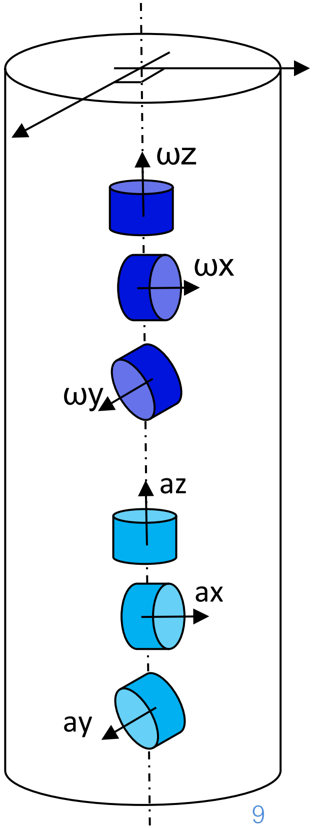
- The expressions for the induced motion, derived from the Euler equations, and simplified for low inclination, up to 10 degrees, are

$$\omega_{Bx}^B = \frac{\dot{a}_y}{\cos I} \approx \dot{a}_y$$

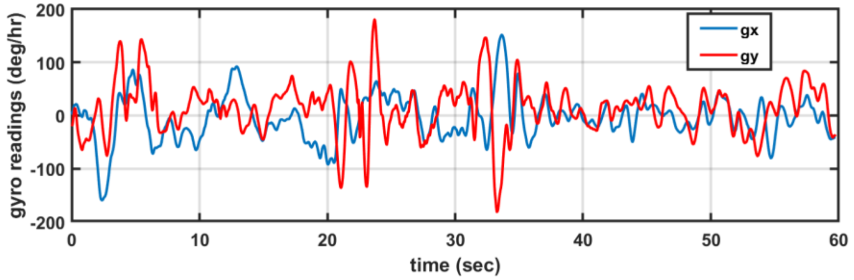
$$\omega_{By}^B = \frac{\dot{a}_x}{\cos I} \approx \dot{a}_x$$

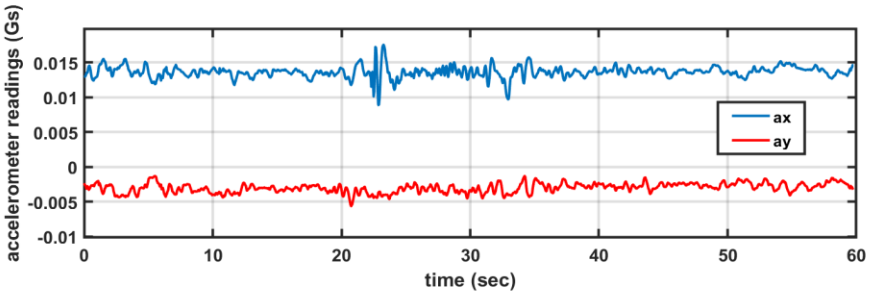
where $\dot{a}_x$ and $\dot{a}_y$ the rate of change of the accelerometer measurements with respect to time

The compensated rates are then used to compute the azimuth and inertial (or gyro) toolface following the standard computation formulas.



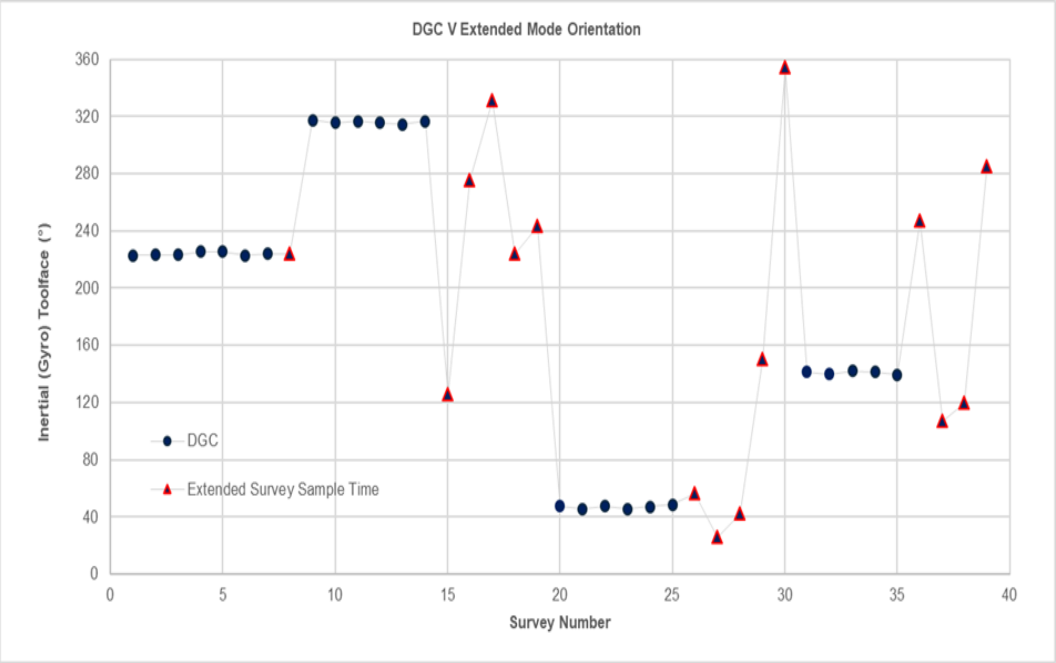
- Several DGC tests were conducted on deck on semi-submersible rigs
- The effect of BHA / tool movement can be seen in the gyro and accelerometer readings in the plots
- There is a high correlation between the gyro and the accelerometer readings, resulting from movement
- Horizontal Earth rotational rate is about 7˚/hr but BHA / tool movement generates greater than 100˚/hr.



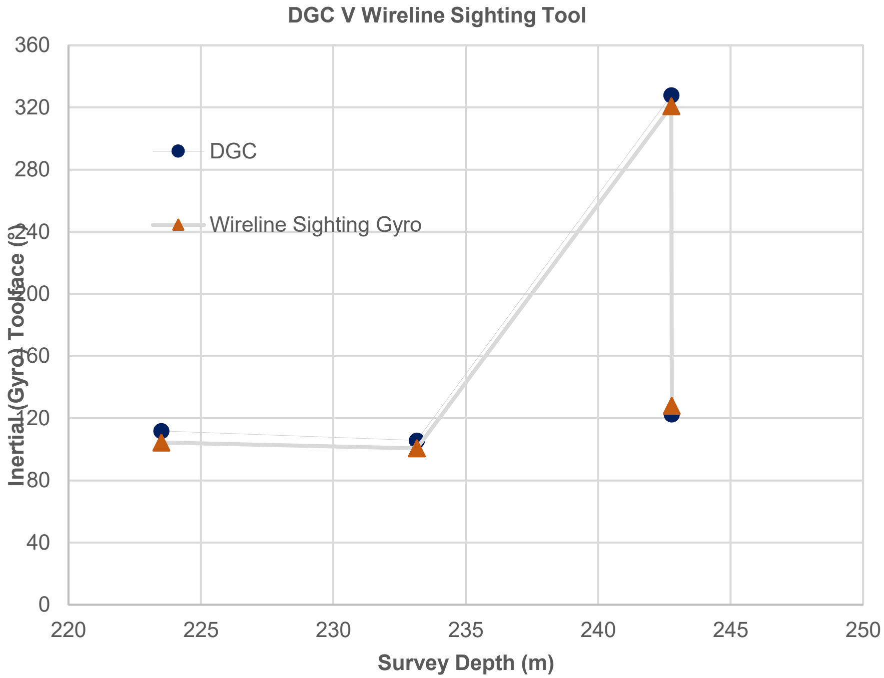


Test Results (tool run on deck)

- Data was collected alternating between DGC mode and GWD Extended Time Mode.
- Tool underwent a 4-quadrant rotation at less than 1 degree inclination.
- DGC results show relatively stable gyro (or inertial) toolface.
- All the DGC stations passed QC while only 6.25% of the GWD Extended Time Mode stations passed QC.



- The DGC Tool was integrated into the gyro sighting tool and data for DGC was collected in memory mode.
- Tool was run on Clair Ridge –West of Shetland.
- DGC results were computed post-drilling and compared with the sighting tool results.
- DGC showed good correlation with orientation results from the sighting gyro tool.



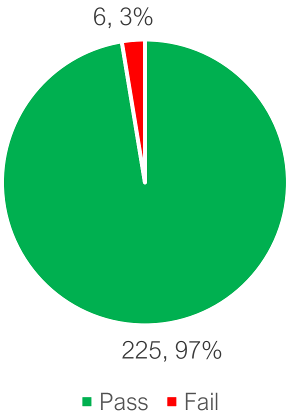
- DGC was utilized for surveying the tophole when 2 wells were drilled from the Clair Ridge platform.
- Well 1 - 11 DGC surveys were produced and presented (from 230.28m to 323.95m).
- The sighting gyro was also run at two depths, and the inertial toolface (ITF) results were compared with the DGC results at close depths, to confirm that the DGC worked as expected.
- Only two sighting gyro runs were performed due to the length of time required to run the sighting tool and favourable comparison from the first 2 runs.

Tool Code	Depth (m)	Inc (°)	ITF (°)	Δ ITF(°)	Δ ITF Tolerance (°)	ITF QC
DGC	227	0.44	346	-8.24	25.70	PASS
Sighting Gyro	184.3	0.3	337.76			
DGC	239.79	0.37	69	-2.88	25.70	PASS
Sighting Gyro	240.9	0.34	66.12			

- As the well inclination and depth increased, it was possible to compare the DGC azimuth data with the gyro multishot survey utilizing the traditional gyrocompass method. Comparison was favourable.
- Typical pilot hole operation - 1.2 days survey reduced to less than 0.3 days by enabling DGC.

Survey	Depth (m)	Inclination (°)	Azimuth (°)	Δ Azimuth (°)	Tolerance (°)	Azimuth QC
Trad. Gyrocompass 1	286	1.8	332.49	2.55	9.24	PASS
DGC 1	285.86	1.67	335.04			
Trad. Gyrocompass 2	296.24	2.23	333.78	-5.51	8.04	PASS
DGC 2	296.15	2.09	328.27			
Trad. Gyrocompass 3	304.98	2.72	330.35	-5.07	7.04	PASS
DGC 3	304.93	2.77	325.28			
Trad. Gyrocompass 4	314.51	2.92	331.93	-3.13	6.57	PASS
DGC 4	314.45	3.36	328.8			
Trad. Gyrocompass 5	324.05	3.24	333.19	-1.93	6.41	PASS
DGC 5	323.95	3.65	331.26			

- To date 21 deployments completed in 5 countries. Sea state of 6m wave heights successfully navigated from a Drill ship in deep water.
- Pie chart below shows data from first 17 deployments processed using current firmware based on 231 survey attempts.



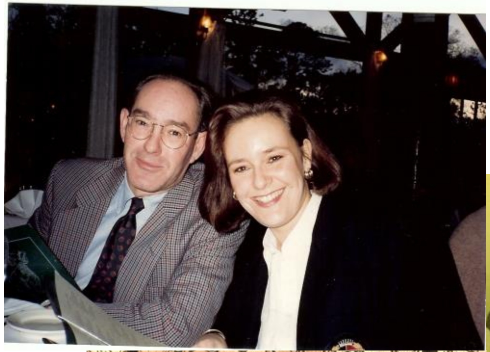
- In DGC, tool movement is compensated for in real time by effectively making use of the accelerometer and gyroscopic sensor data
- DGC delivers accurate inclination, azimuth and toolface measurements, with appropriate quality control, without requiring wireline sighting runs or repeated surveys. It meets the standard top-hole GWD tool code.
- All objectives achieved:

Ability to survey over connection with QC passing 1st time.	✔
Inclination range: 0 –10°	✔
Performance equivalent of extended mode IPM.	✔
Sample time – maximum ~~10 minutes~~ 6 minutes	✔

Acknowledgements

- Thanks to ISCWSA and Slb for the opportunity to present.
- Thanks to co-authors on the paper from SLB and BP and to BP for their support in accommodating testing and initial field deployments.

In Memoriam- Bob McMahan 1950-2026



- Founded Gyrodata in 1980
- Strategy was to “be the very best”
- Never stopped sensor developments/improvements
- Primary focus was always to retain and nurture all employees