Advanced Wellbore Surveying And Ranging Technologies Breaking Boundaries

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SPE-230750-MS

Speaker Bio

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- Wellbore Challenges
- Surveying Tools
- Survey Fusion
- Combined Surveying: Actual Execution
- Surface Test for Ranging
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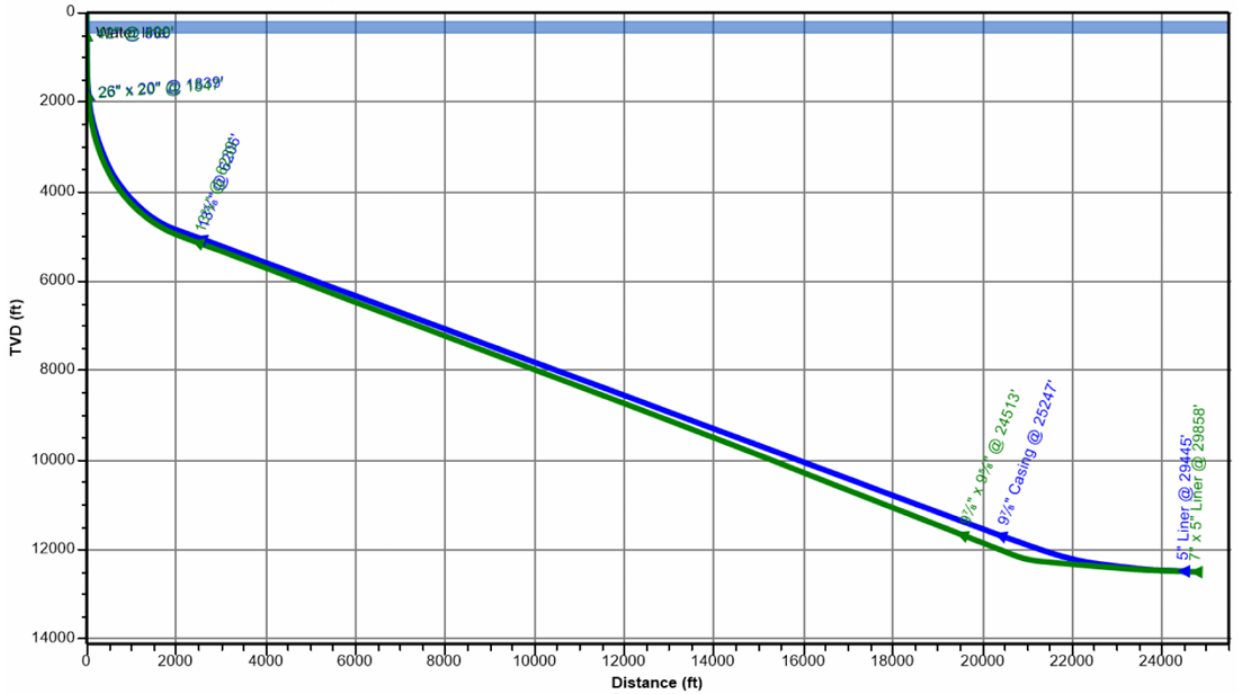
Wellbore Challenges



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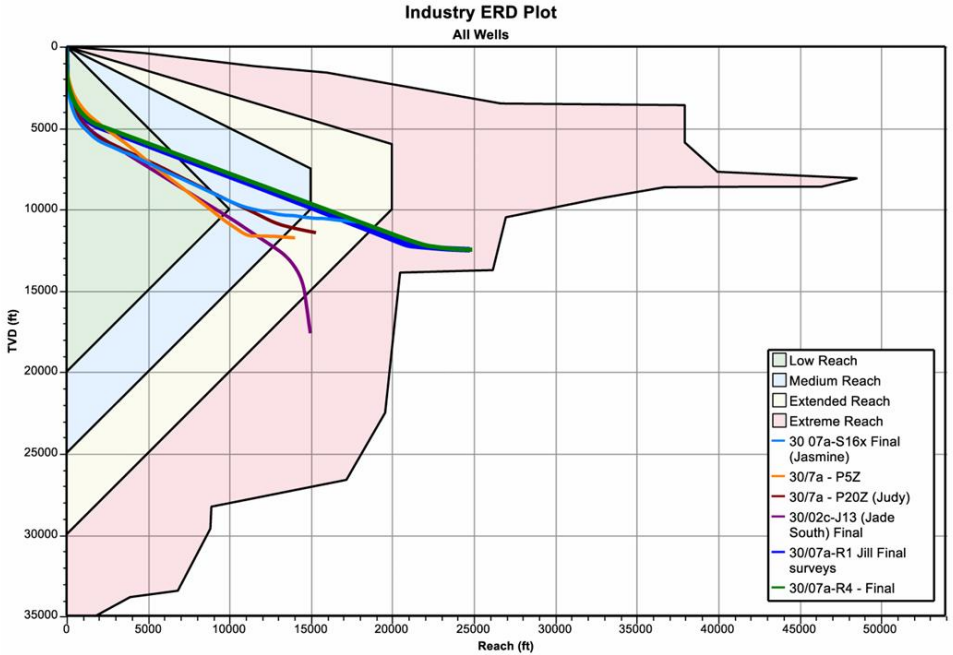
Wellbore Challenges



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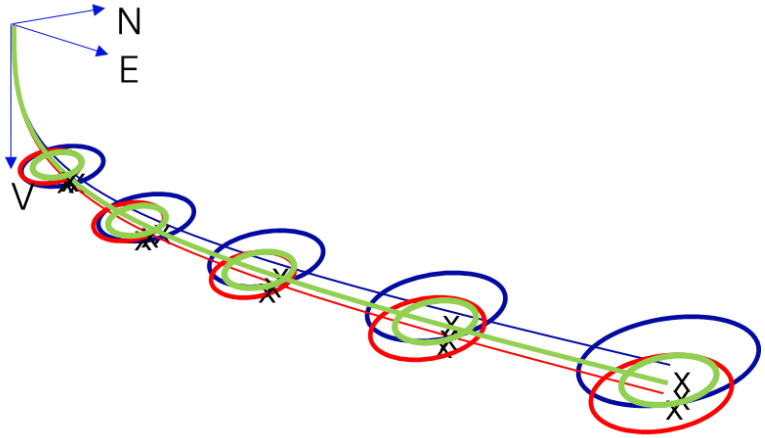
Wellbore Challenges

Hit Tight Targets	Complex ERD Well	Maintain 50 ft from Offset Well
• Tight TVD target +/-50 ft TVD at depth 25000 ft MD	• Drilling challenging well with total depth 30k ft MD	• Maximize reservoir recovery mandates well position in close proximity of the offset wells

Methodology – Survey Redundancy



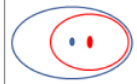
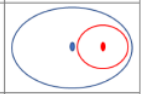
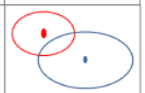
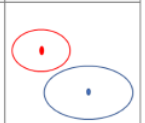
- Gross error detection where Field Acceptance Criteria (FAC) of each individual survey tool are unable to detect
- Reduce positional uncertainty smaller than the most accurate of the two surveys
- Maximize production by precisely placing the well sweet spot within the reservoir
- Safe drilling and collision avoidance in congested field

Methodology QA/QC

- The two surveys must pass appropriate QC tests and procedures relevant for each survey tool

- The two surveys must pass mutual QC tests to verify that they are in agreement with each other
  - RIP Relative Instrument Performance test
  - Chi-Square test
  - EOU overlap test

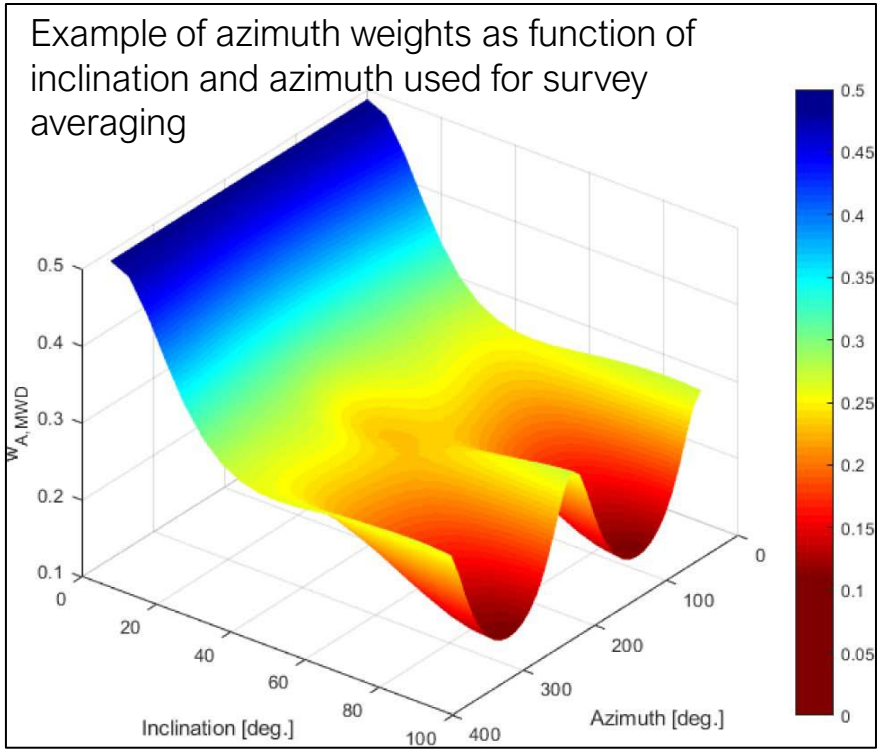
Mean Tolerances	STD Tolerances	Results
abs(mean_diff) <= 0.50	std_diff <= 1.00	Good agreement
abs(mean_diff) <= 0.75	std_diff <= 1.50	Average agreement
abs(mean_diff) <= 1.25	std_diff <= 2.00	Poor agreement
abs(mean_diff) > 1.25	std_diff > 2.00	Disagreement

Level Agreement	Description of Agreement level	Action	Pictorial Description of Agreement Level
Very Good	MWD ellipse fully encompasses gyro ellipse, and gyro ellipse encompasses centre of MWD ellipse.	No further investigation needed.	
Good	MWD ellipse fully encompasses gyro ellipse, but gyro ellipse does not encompass centre of MWD ellipse.	No further investigation needed.	
Average	MWD ellipse does not fully encompass gyro ellipse but overlaps with it. The center of the gyro ellipse lies inside the MWD ellipse.	No further investigation needed.	
Poor	MWD ellipse does not fully encompass gyro ellipse but overlaps with it. The centre of the gyro ellipse lies outside the MWD ellipse.	Investigate – if unresolved consider re-survey.	
Unacceptable	Ellipses do not overlap.	Probably re-survey immediately and investigate.	

Methodology

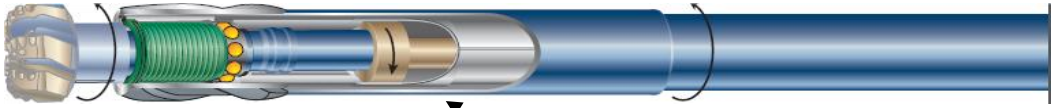
- After all relevant QC tests have been successfully passed, the overlapping survey data are interpolated to common measured depth points.
- The two surveys are then combined by weighted average using weights derived from the uncertainties of both data sets
- Generate a new (combined) survey with a listing MD, inclination and azimuth values as in any other survey
- Create an error model for the combination of tools that is independent of the actual survey data
- The error model is realized as a standard format Instrument Performance Model IPM file that can be utilized by common error analysis software

Example of azimuth weights as function of inclination and azimuth used for survey averaging



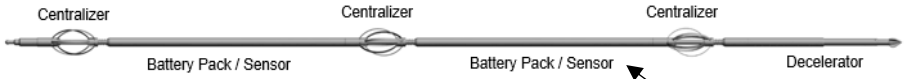
Bang et al. SPE-195621-MS (2019)

Surveying Tools

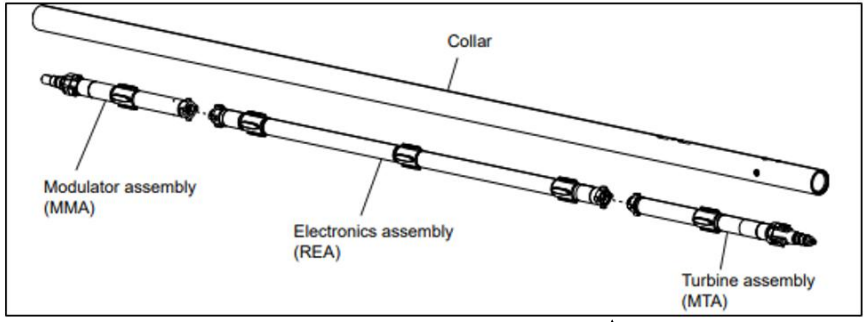


Near Bit Inclination in Point The Bit RSS tool

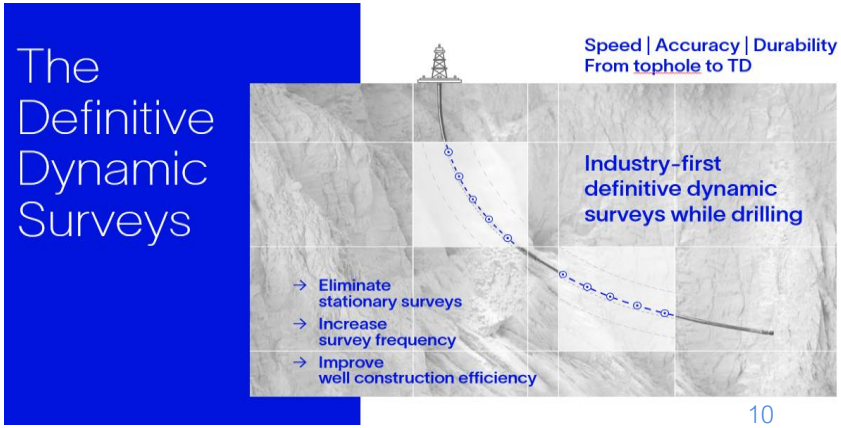
Solid-State MEMS Gyro While Drilling



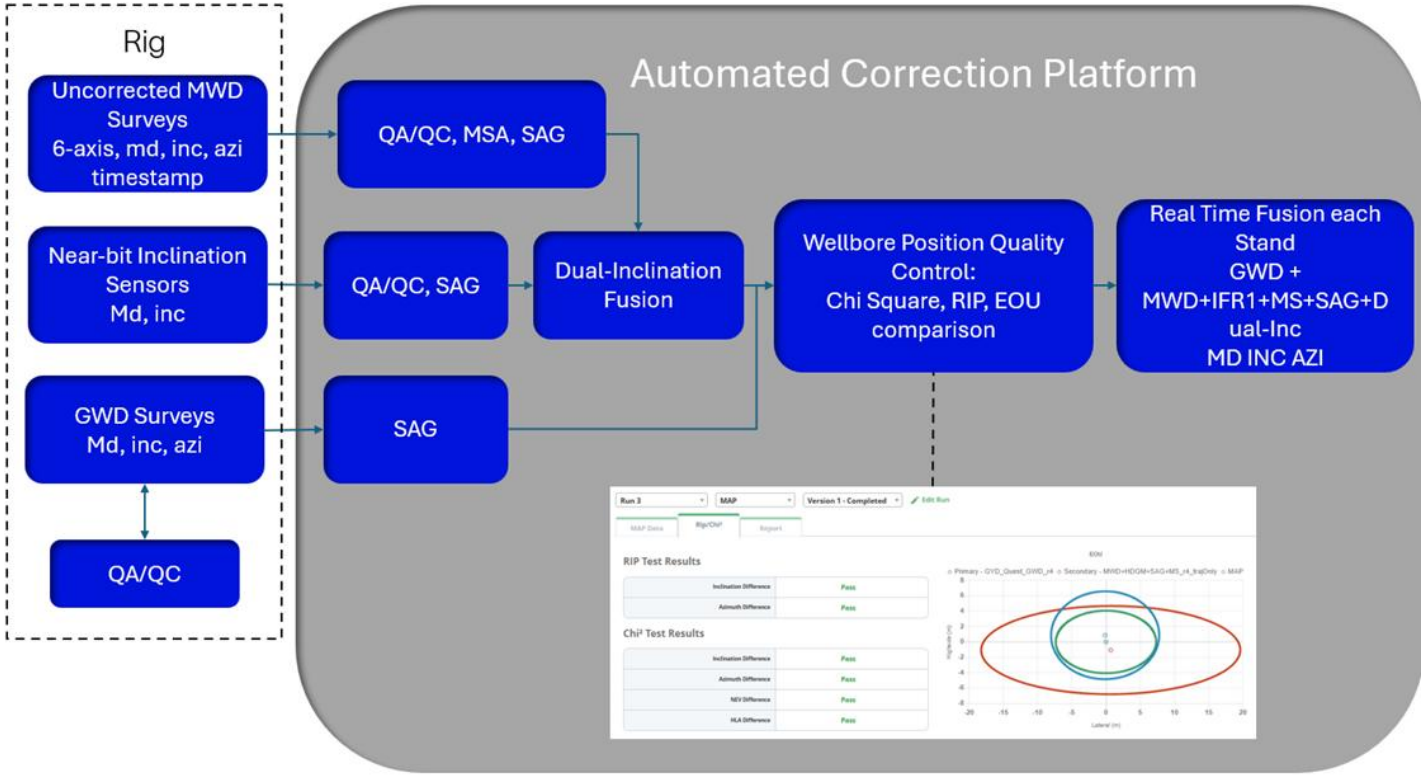
Solid State Dual Probes Drop Gyro



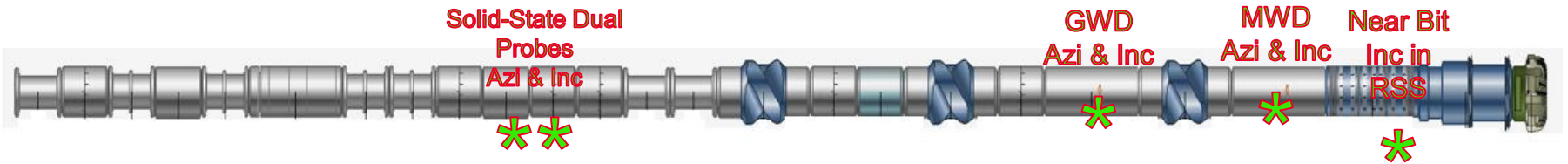
Measurement While Drilling with DDS Survey



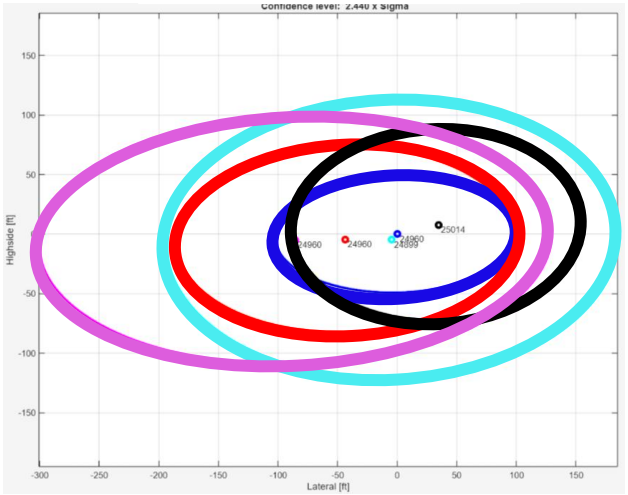
Survey Fusion



Combined Surveying: Actual Execution 12 ¼”



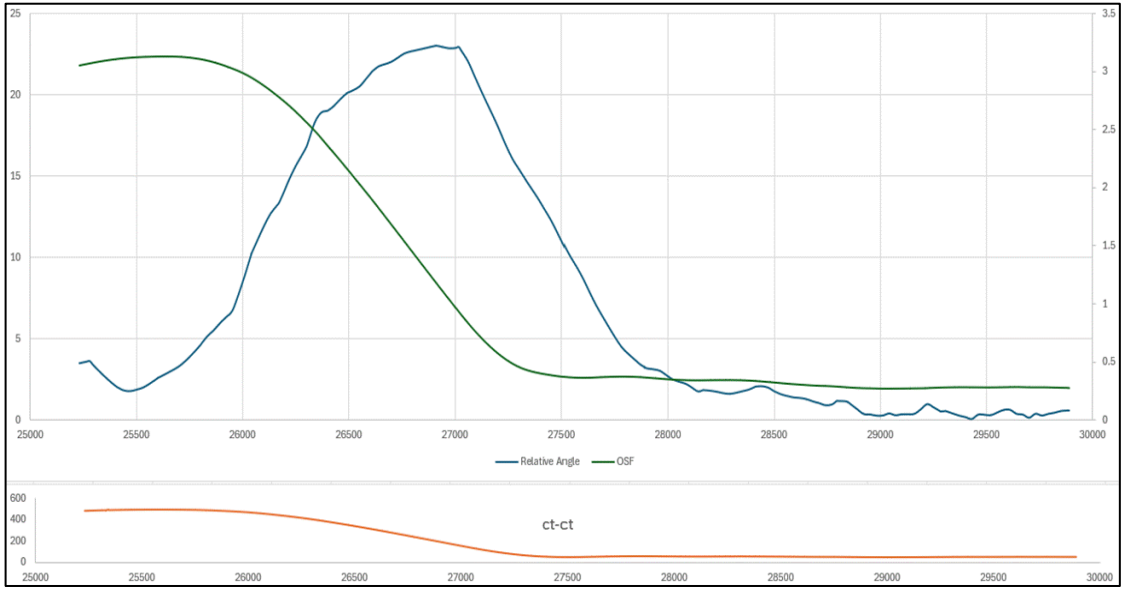
- Most definitive surveys use only 1 survey measurement.
- Survey uncertainty can be reduced by combining data from multiple sensors (Dual Inc DDS MWD + Solid-State GWD).
- Drillers target still not hit despite these improvement, then Solid-State Dual Probes gyro dropped at TD.
- Survey Fusion combining Dual Incl MWD + Solid-State Dual Probes gives 4 points of measurement for inclination and 3 for azimuth.



8 ½” Anti-Collision

Despite significant EOU reduction, well twinning required tight spacing between two wells, reaching 48 ft and eventually causing anti-collision rules to fail with a Separation Factor (SF) of 1 26,990 ft MD while drilling an 8 ½ inch hole.

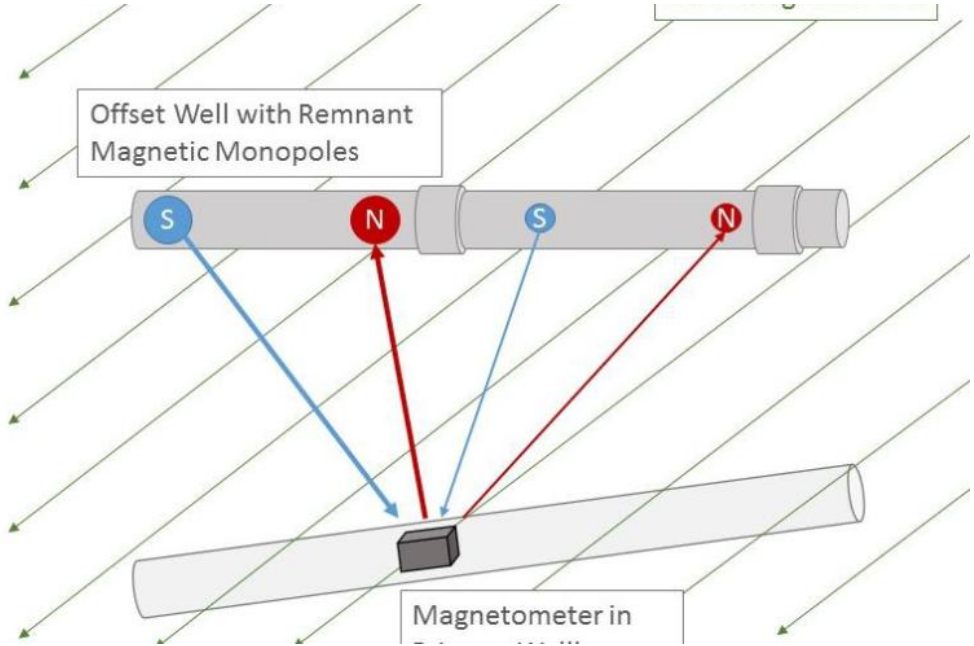
The MWD tool planned for use while drilling the 8 ½ in hole had a definitive dynamic surveys feature, providing continuous six axis survey for passive magnetic ranging analysis while drilling.



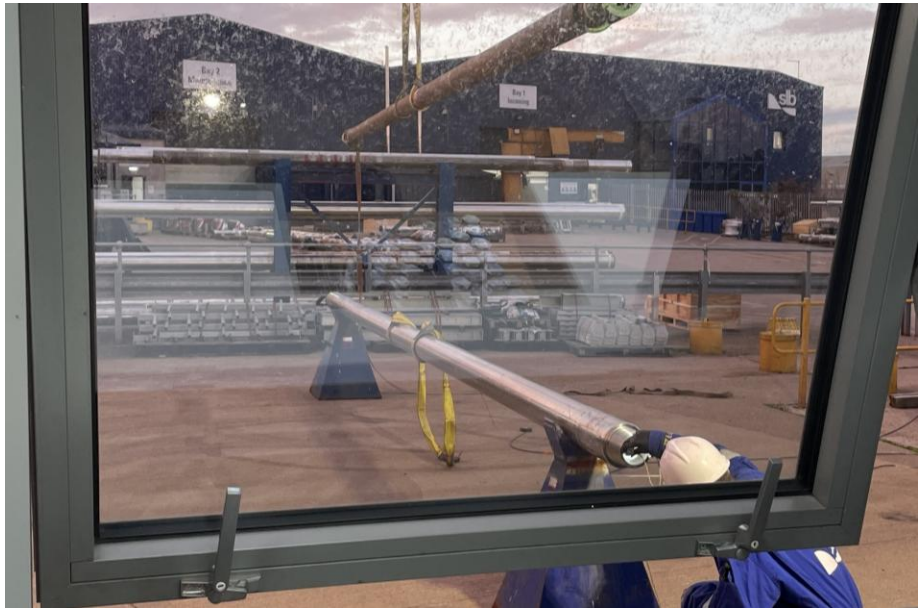
Passive Magnetic Ranging for CA

Analyze the magnetic “interference” measured by the MWD

The magnetic “interference” is used to estimate the range and direction to the offset well from the active well



Surface Test for Ranging

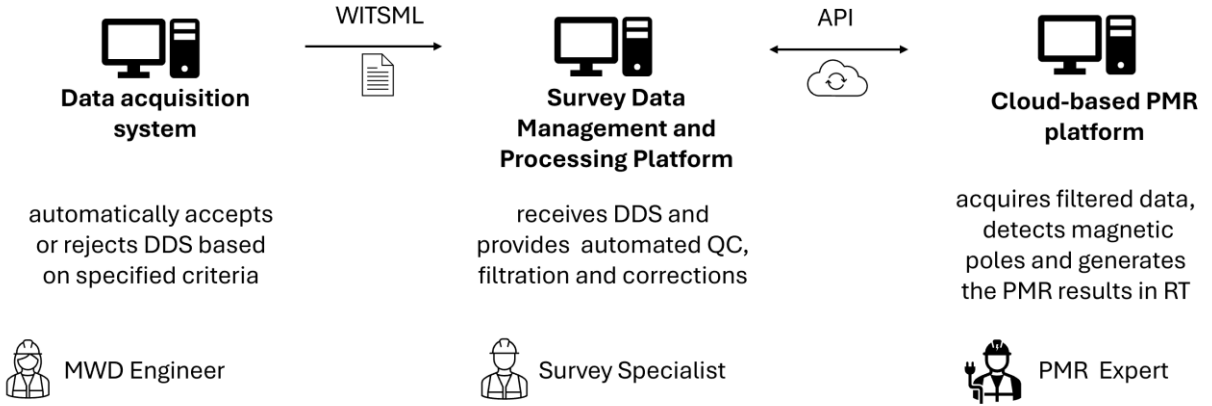


- 110Cr135 Super martensitic stainless steel with 13% chromium (affect standard ferromagnetic properties)
- Test the magnetism of the 6” casing joint with 2 7/8” perforating gun inside.
- External magnetic interference can be observed on High Resolution MWD measurements from the liner
- Confirmed by the measurement sensitivity with varying the distance between the MWD tool and the liner. Test is limited to crane max range of 22 ft

Distance (ft)	Distance (m)	Avg. Total H (nT)	Anomaly = (Total H – 48,100) (nT)
5	1.524	49,648	1,548
10	3.048	48,672	572
15	4.572	48,480	380
20	6.096	48,448	348
22	6.706	48,416	316

Passive Magnetic Ranging for CA

- Uses MWD raw data only, no extra tools
- No requirement to trip
- No access to target required
- DDS is pumped up while drilling and rotating
- Survey data management platform
- Real-time PMR Processing



Conclusions

Accurate wellbore positioning is critical for ERD wells to safely hit tight geological targets while avoiding offset well collision.

A **29,450 ft** ERD well was successfully placed within a tight geological target using **real-time integration of three independent RSS/MWD/GWD surveys**, validated by **a post-run drop gyro**.

A **real-time automated survey correction and fusion** engine minimised positional uncertainty through advanced multi-source correction algorithms while drilling with no rig time

Proactive Passive Magnetic Ranging (PMR) enabled safe trajectory steering in close proximity to an adjacent offset well

The integrated positioning workflow delivered **precise target placement, collision avoidance, and optimal well spacing** under extreme ERD conditions