A Novel Realtime Well Collision Avoidance Monitoring by Definitive Dynamic Surveys and Passive Magnetic Ranging

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Mahmoud ElGizawy, K&M technology Group

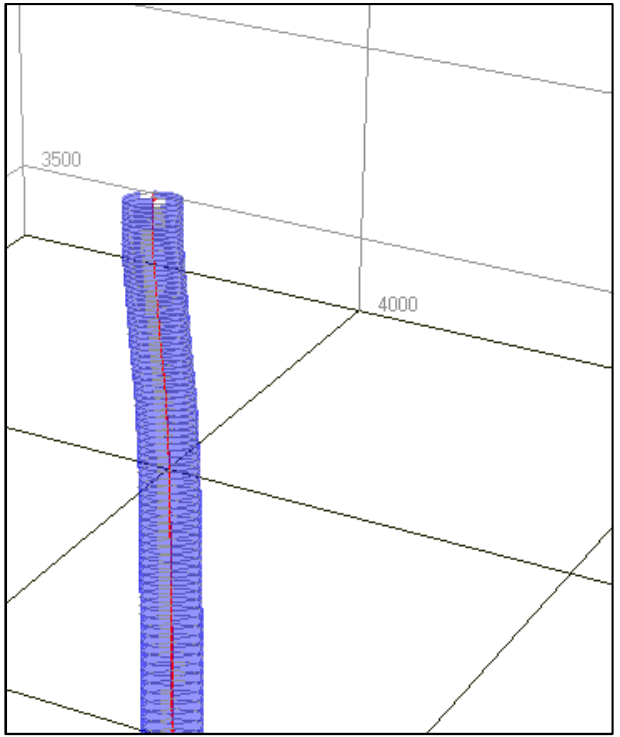
Mark Fraser, Scientific Drilling International

Ross Lowdon, Schlumberger

and Jamie Dory, Scientific Drilling International

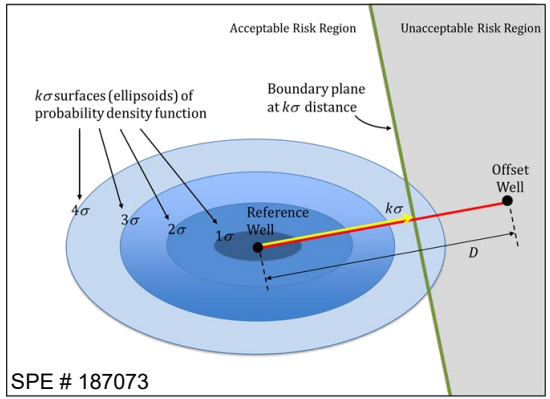
Standard Collision Avoidance Methodology

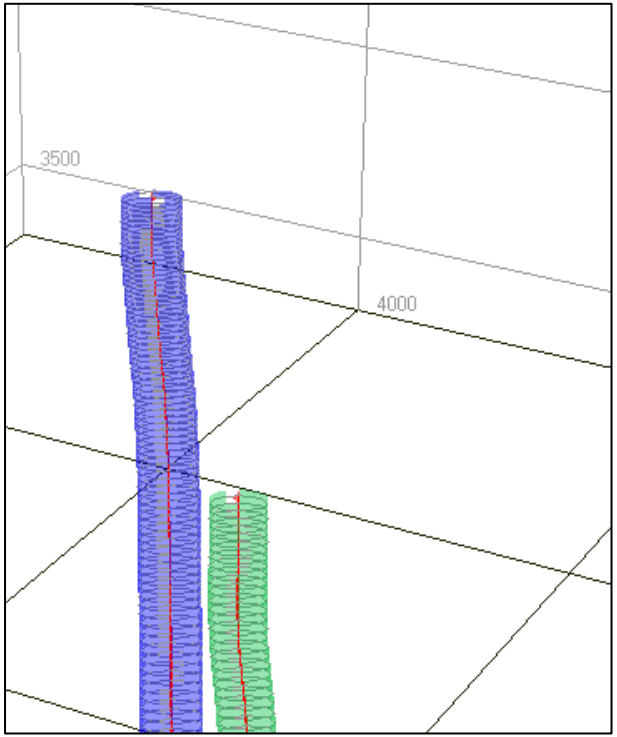
- Standard anti-collision methodology is to estimate position uncertainties based on sensor, operational and environmental errors particular to the survey instrument and running operation used.
- Position uncertainties are described by an ellipsoid at each survey station which propagates throughout the wellbore to create a ‘tunnel’, somewhere inside of which the actual position of the wellbore is situated.



Standard Collision Avoidance Methodology

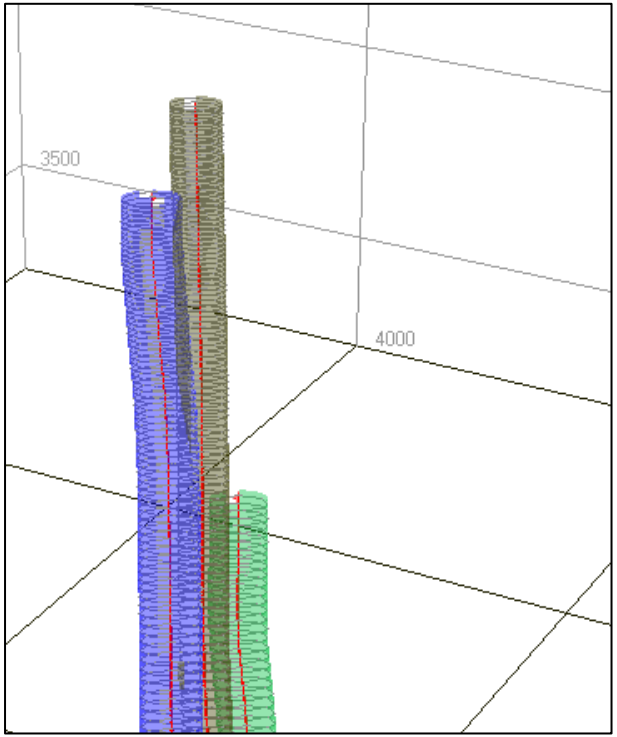
- The collision risk is defined as a ratio of the distance between the surveyed position and the combined ellipse of uncertainty, essentially describing mathematically whether these 'tunnels of uncertainty' from different wellbores meet at any point. As long as there is separation between the two, there is no collision risk.
- Generally works well from a safety perspective (providing all associated procedures are observed).





Standard Collision Avoidance Methodology

- In reality the majority of these ‘tunnels’ are empty space, we just don’t know the real position of the wellbore within it.
- There are a number of scenarios where it may be necessary or desirable to drill within a collision risk zone.
- These may be for either economic, environmental or safety reasons.



Close Proximity Drilling

Wellbore Separation

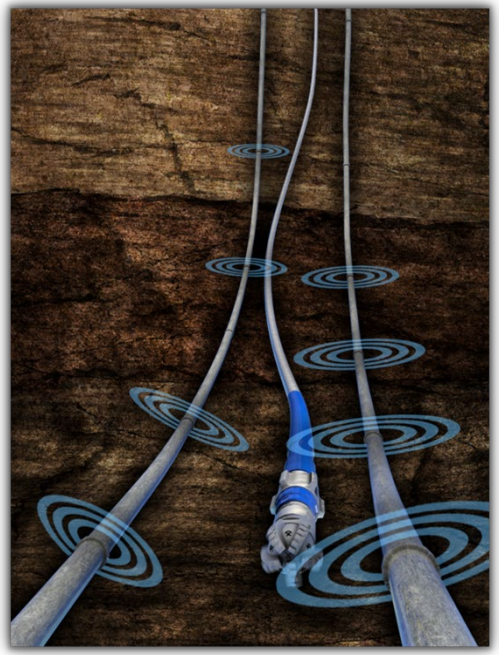
- Infill wells
- Replacement wells
- Frac recovery
- Slot recovery
- Carbon capture projects
- Top-hole congestion

Wellbore Intercept

- Relief wells
- Complex Abandonments
- Fish bypass & re-entry
- Production recovery

Passive Magnetic Ranging (PMR)

- Uses MWD raw data only, no extra tools.
- No requirement to trip.
- Can continue drilling ahead immediately
- No access to target required.
- Real time results performed remotely.



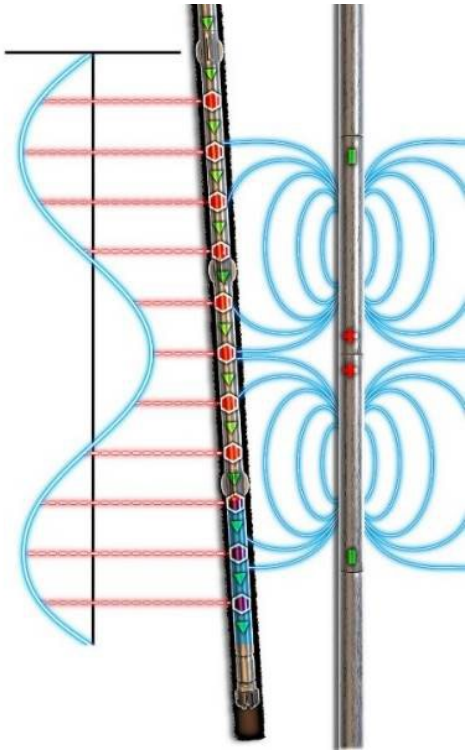
Passive Magnetic Ranging (PMR)

Monitoring

- Requires short spaced static surveys (nominally every single).
- Requires detection above normal survey noise.
- Doesn't tell anything about the location of the interference.

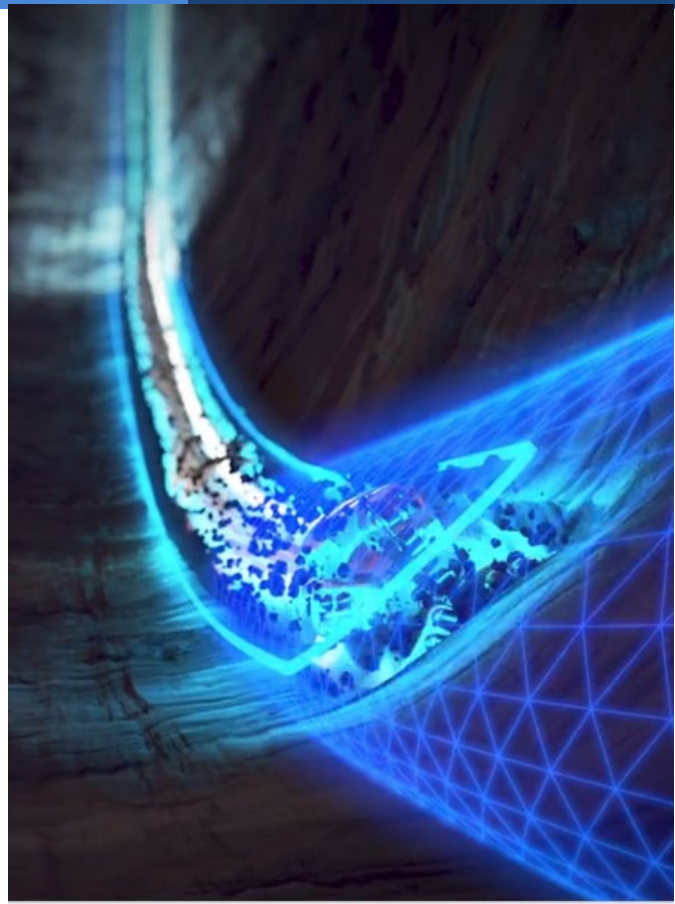
Ranging

- Measures the magnetic poles in casing string.
- Requires raw MWD 6-sensor data.
- Series of short spaced surveys (10-15).
- Provides a distance and direction to the source of interference.



Definitive Dynamic Surveys (DDS)

- Next generation surveying technology which enables real time definitive surveys to be taken while drilling.
- Save considerable rig time, produce higher density survey data, resulting in a more accurate wellbore position.
- Uses a six-axis sensor array, similar to that which is used in a standard MWD tool for static surveys.

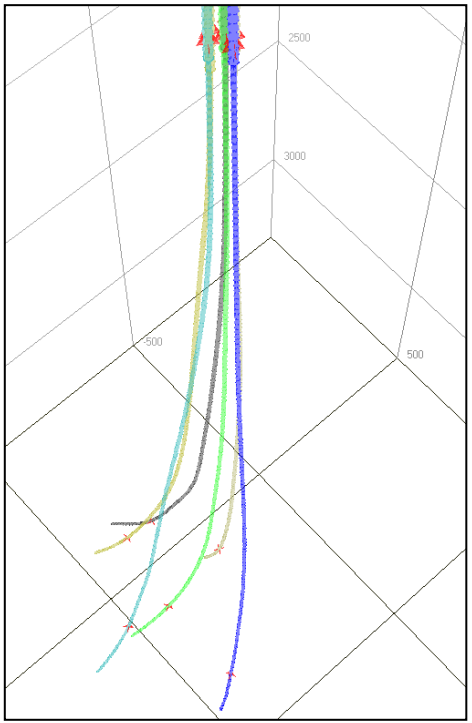


Definitive Dynamic Surveys (DDS)

- Higher sensor sampling rate, processing speed, increased memory and improved environmental corrections enable high accuracy dynamic surveys.
- The hardware and firmware changes help compensate for vibration, shocks, stick slip to enable the DDS surveys to considered as accurate and definitive.
- Survey quality is equal to or improved when compared to static surveys.

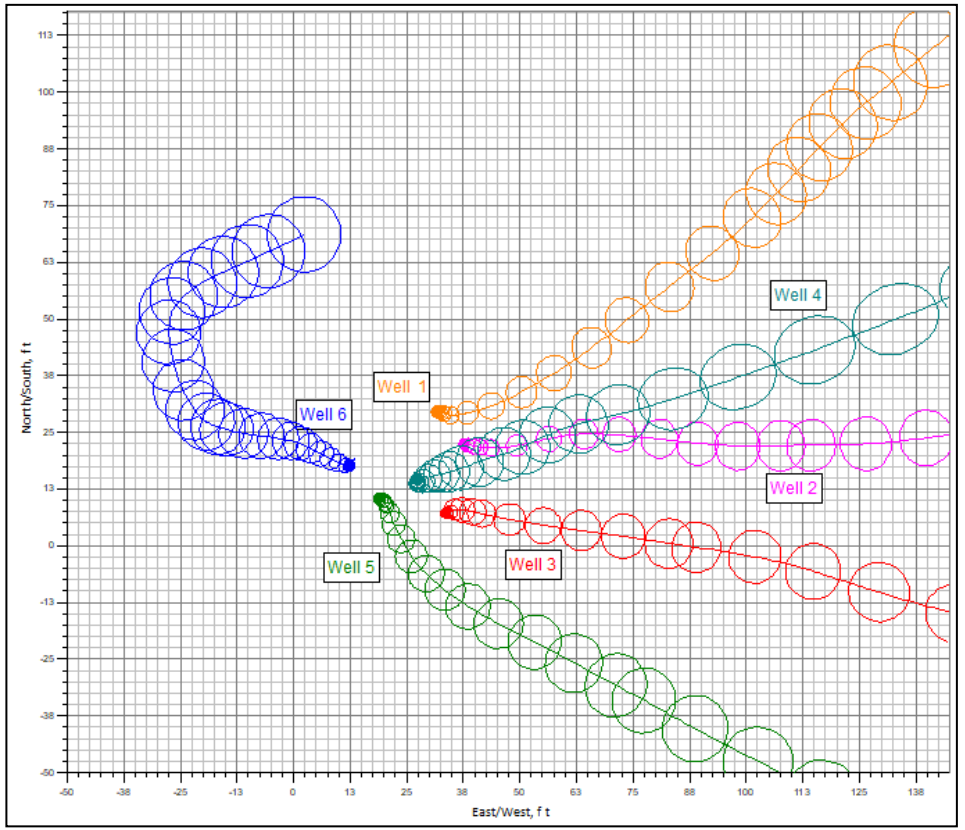
DDS/PMR Study

- Offshore platform
- Batch drilling of 6 wells.
- 24in section (approx. 600ft – 2500ft MD)
- 18 5/8 in, 96.5ppf casing
- All ranging was done using the data transmitted to surface in real time.
- No interference with drilling operation.
- Multiwell environment.

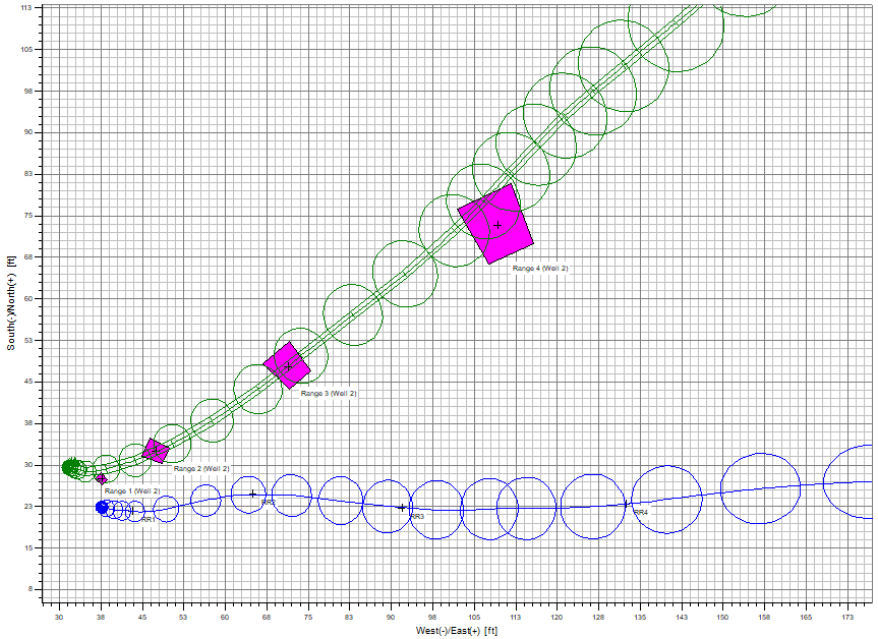


DDS/PMR Study

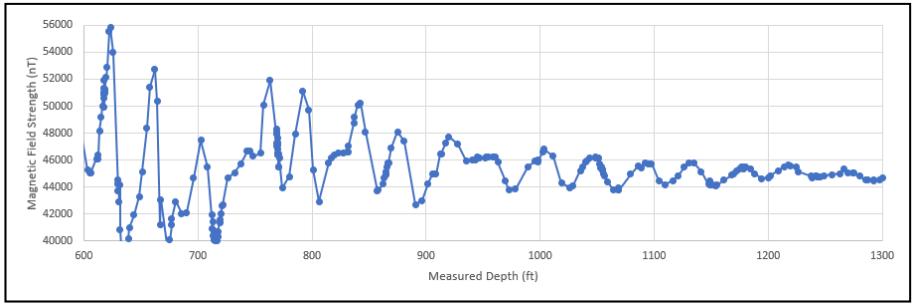
Drilling	Offsets
Well 2	Well 1
Well 3	Well 1 and 2
Well 4	Well 1, 2 and 3
Well 5	Well 1, 2, 3 and 4
Well 6	Well 1, 2, 3, 4 and 5



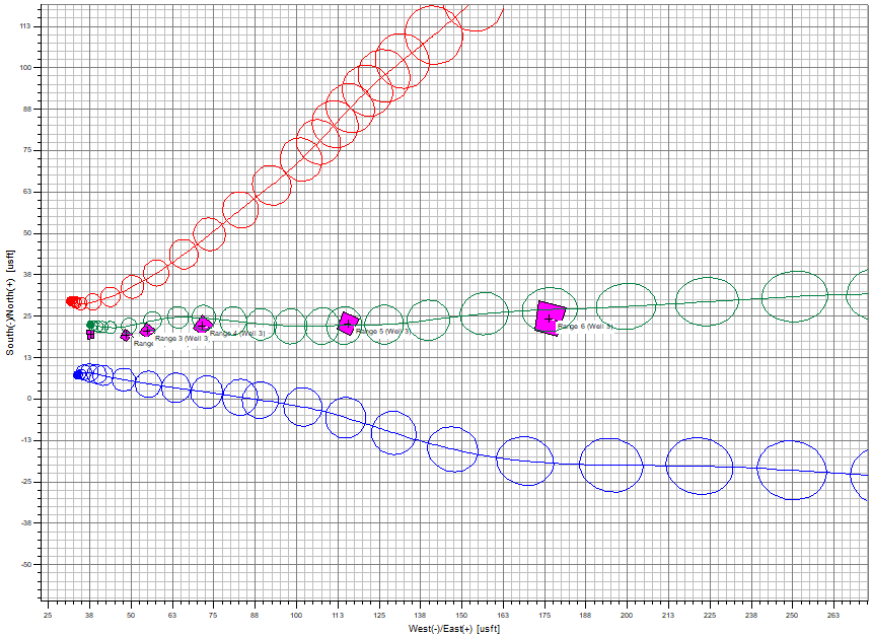
Well 2



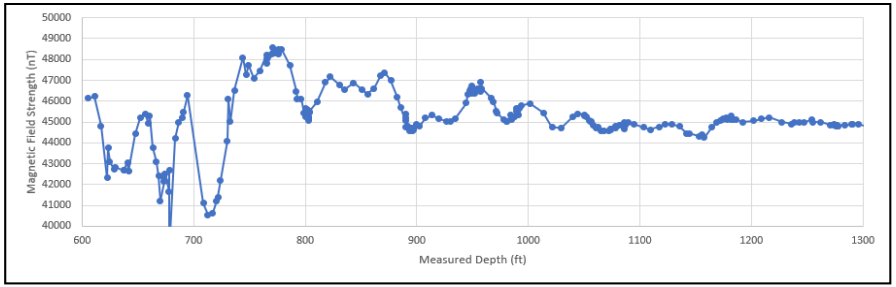
	Ranged Well	Ranging Depth, ft	Ranged Distance, ft	Ranged Direction, Degree	Surveyed Center-to-Center Distance	Surveyed Direction
1	Well 1	797	8.3	315.8	12.7	306.6
2	Well 1	1,100	19.2	293.0	19.5	290.5
3	Well 1	1,401	32.9	320.0	32.8	320.9
4	Well 1	1,764	56.3	335.0	60.0	333.0



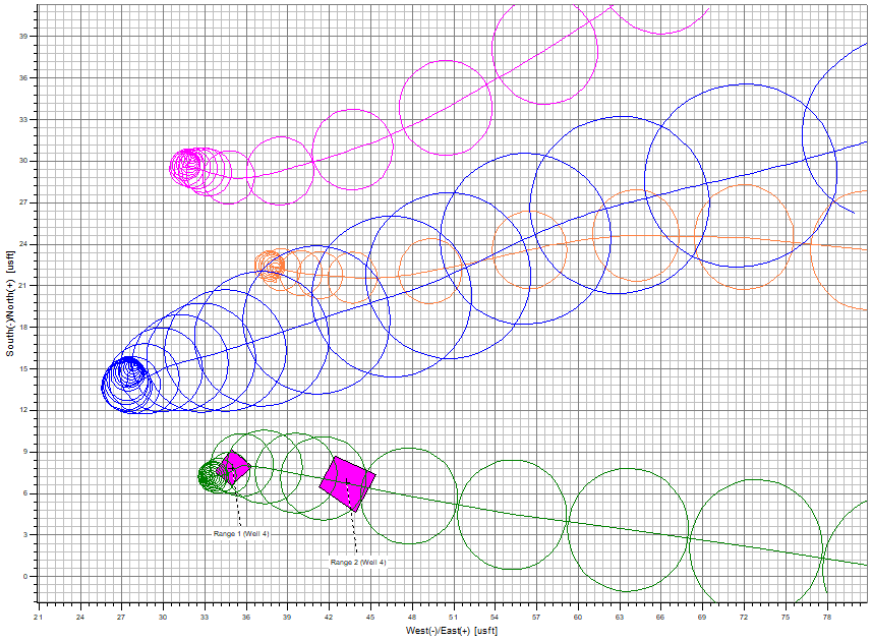
Well 3



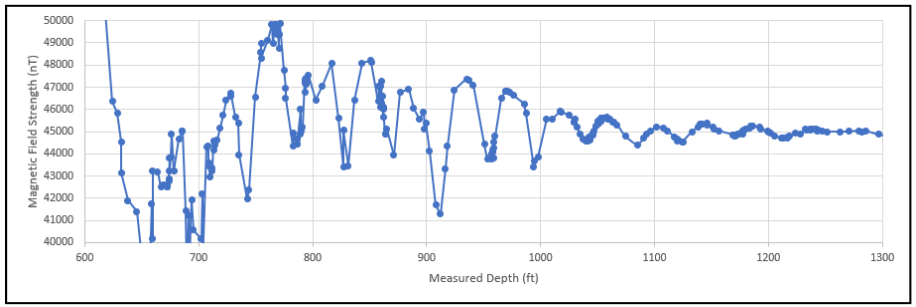
	Ranged Well	Ranging Depth, ft	Ranged Distance, ft	Ranged Direction, deg	Surveyed Center-to-Center Distance	Surveyed Direction
1	Well 2	659	12.6	358.4	15.4	16.3
2	Well 2	899.6	14.2	34.0	19.0	42.2
3	Well 2	983.2	17.8	40.7	22.9	45.0
4	Well 2	1,180.5	23.3	40.8	27.6	44.6
5	Well 2	1,629.8	28.0	24.8	29.0	34.0
6	Well 2	1,997.56	44.7	14.0	47.0	17.8



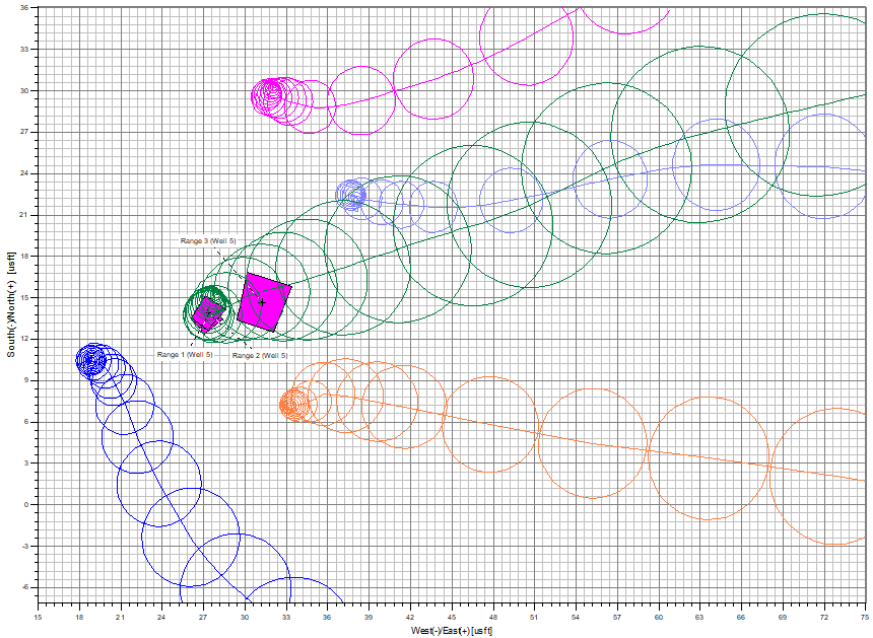
Well 4



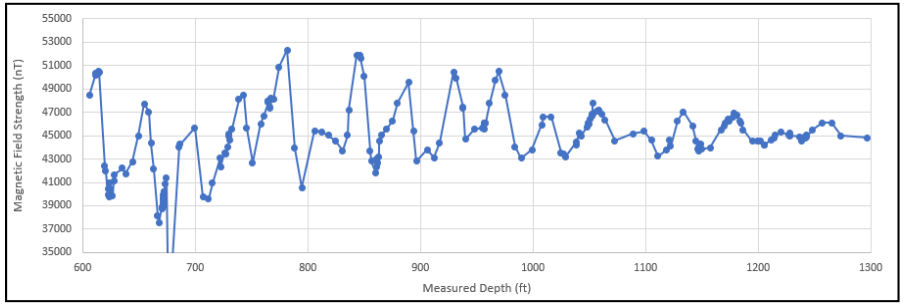
	Ranged Well	Ranging Depth, ft	Ranged Distance, ft	Ranged Direction, deg	Surveyed Center-to-Center Distance	Surveyed Direction
1	Well 3	750.4	9.9	128.7	10	128.5
2	Well 3	1,051.7	16.0	119.7	15.8	119.8



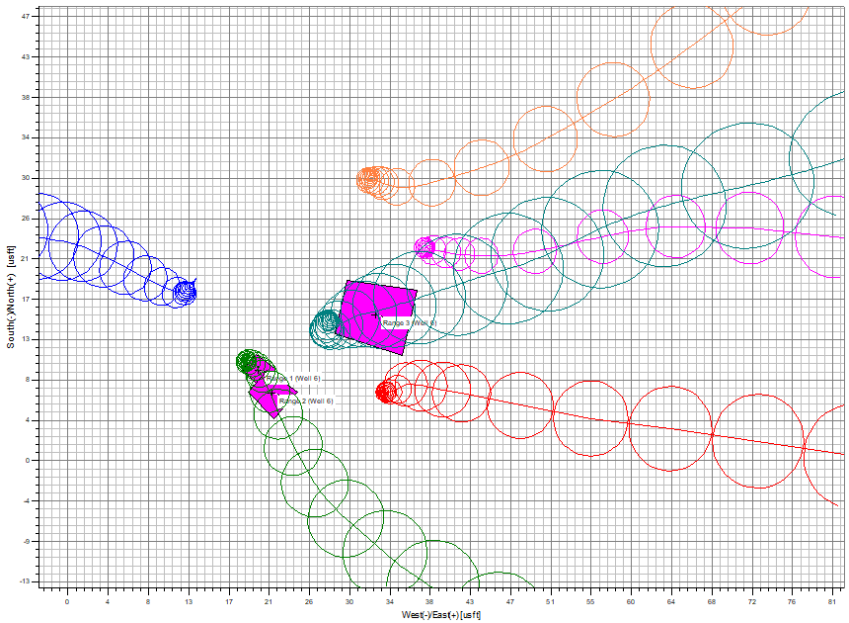
Well 5



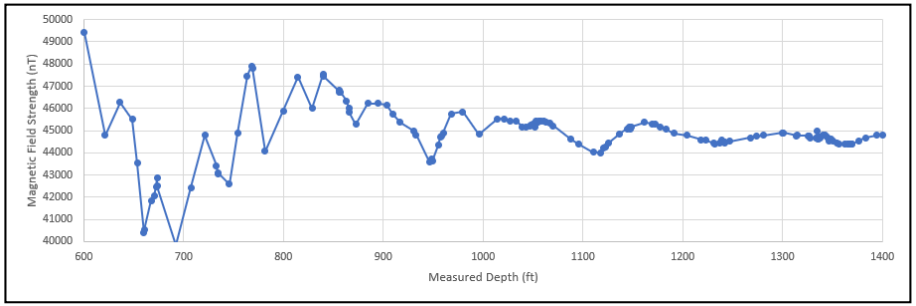
	Ranged Well	Ranging Depth, ft	Ranged distance, ft	Ranged Direction, deg	Surveyed Center-to-Center Distance	Surveyed Direction
1	Well 4	862.9	8.4	47.5	8.7	48
2	Well 4	934	9.4	36.5	9.8	40.6
3	Well 4	1,179.9	17.73	17.2	18.5	16.3



Well 6



	Ranged Well	Ranging Depth, ft	Ranged Distance, ft	Ranged Direction, deg	Surveyed Center-to-Center Distance	Surveyed Direction
1	Well 5	779.0	13.1	131.3	13.6	131.8
2	Well 5	958.4	19.5	131.1	20.7	133.1
3	Well 4	1375	37	102.9	38.9	100.9



Conclusions

- The quality of the real time dynamic six sensor data was very good from a ranging perspective.
- Ranging results were very consistent with the surveyed position of the wellbores and within their combined uncertainties.
- No extra rig time was used and no unnecessary stationary time was required to produce the results.
- Ranging is performed in the background while drilling and can be analysed for every magnetic pole in the offset casing string.
- Pre job planning is vital to ensure adequate data density.
- *Note: Gyro surveys will still be required in areas of magnetic interference for a definitive survey*

Applications

- Potential applications are not limited to collision avoidance:
- Relief well drilling, particularly in the follow phase, to save time on trips and wireline runs.
- SAGD: In conjunction with magnetized casing would likely reduce the requirements for tractor runs.
- Complex abandonments, particularly useful in areas like West Texas where certain formations are very unstable.