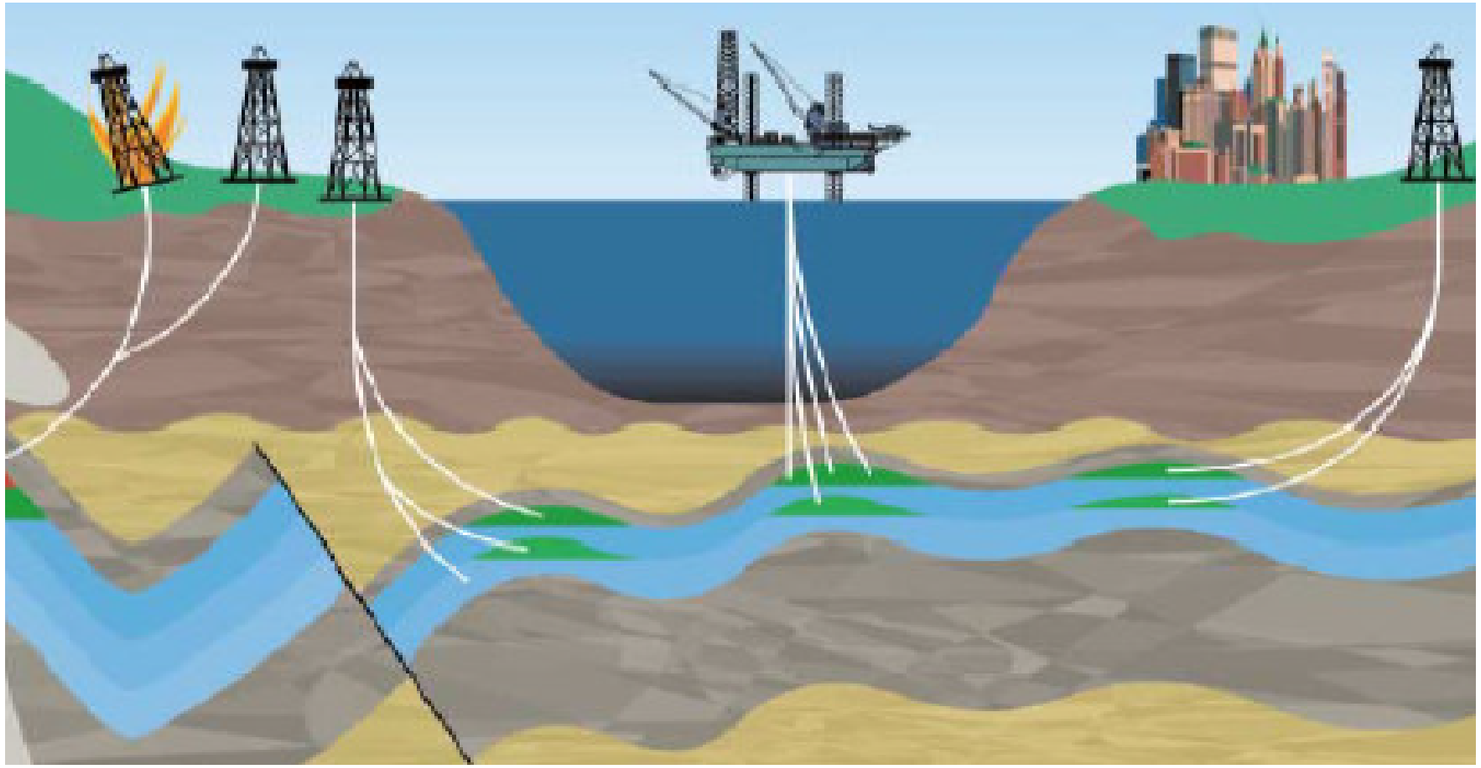
# Definitive Survey Methodology

## Update to an Old Concept for Higher Reliability

# Why Is Well Positioning Important?

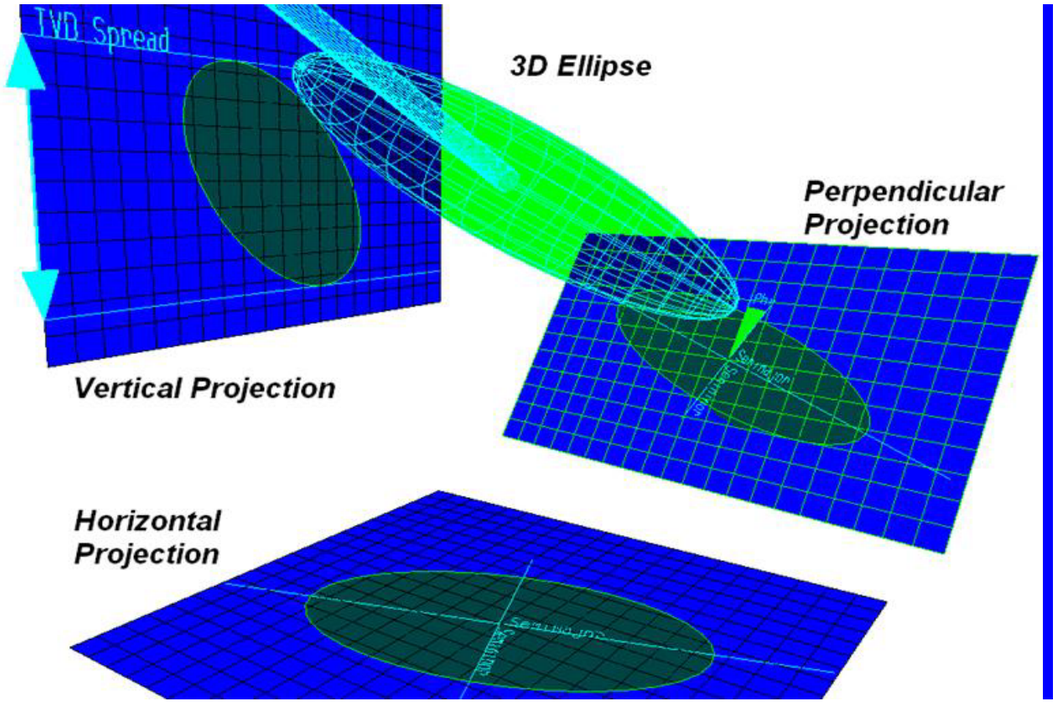


1. Wellbore is placed in the geological target
2. Risk mitigation, helping operators avoid HSE events
3. To make the production activity more sustainable

# What Is Wellbore Position?

| MD (m) | Inc (deg.) | Azimuth (deg.) |
|---|---|---|
| 3,182.24 | 14.99 | 11.02 |
| 3,219.45 | 16.18 | 11.16 |
| 3,256.62 | 17.4 | 12.31 |
| 3,293.82 | 19.06 | 5.7 |
| 3,330.99 | 19.8 | 10.82 |
| 3,368.17 | 21.42 | 12.9 |
| 3,405.37 | 23.04 | 16.08 |
| 3,442.53 | 24.73 | 11.83 |
| 3,479.73 | 25.75 | 13.04 |
| 3,508.24 | 25.74 | 12.47 |

Directional Data




Uncertainty of Position

# Wellbore Survey Reliability

## Assumptions and Limitations of the Model

| | |
|---|---|
| I | Rigorous and regular tool calibration. |
| II | A sufficiently short survey interval to correctly describe the wellbore. |
| III | Field QC checks, such as total magnetic field, gyro drifts, total gravity field and magnetic dip angle on each survey measurement. |
| IV | The use of non-magnetic spacing for MWD surveys according to industry norms. |

> *ISCWSA*
>
> *The model only applies to surveys under normal industry best-practice procedures.*

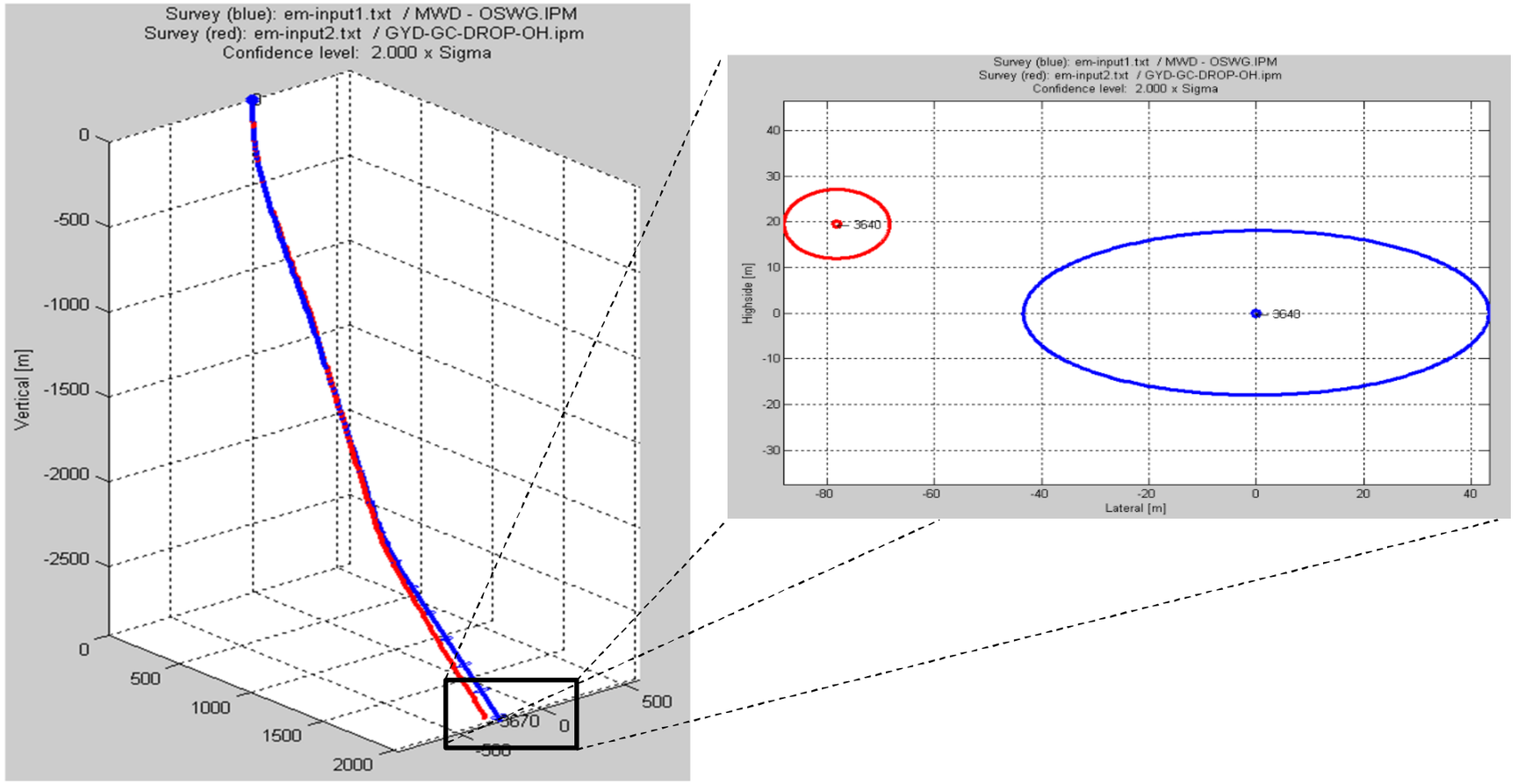
# Update To An Old Concept For Higher Reliability

- A directional survey that passes individual QC and FAC may still have undetected errors outside its error model

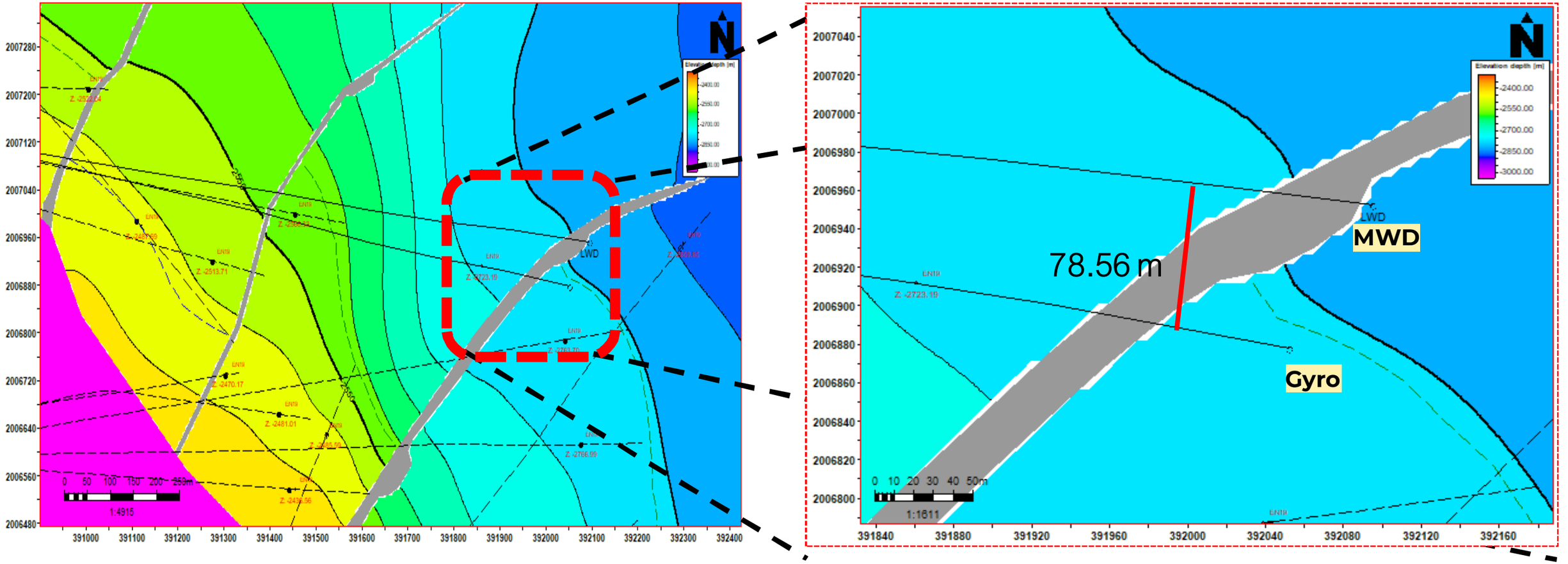
- The directional survey that is rejected by the individual tool quality control does not meet the premises of its error model, and therefore, the EOU assigned to the tool is no longer valid

- Passing the single tool QC is a necessary condition but not sufficient

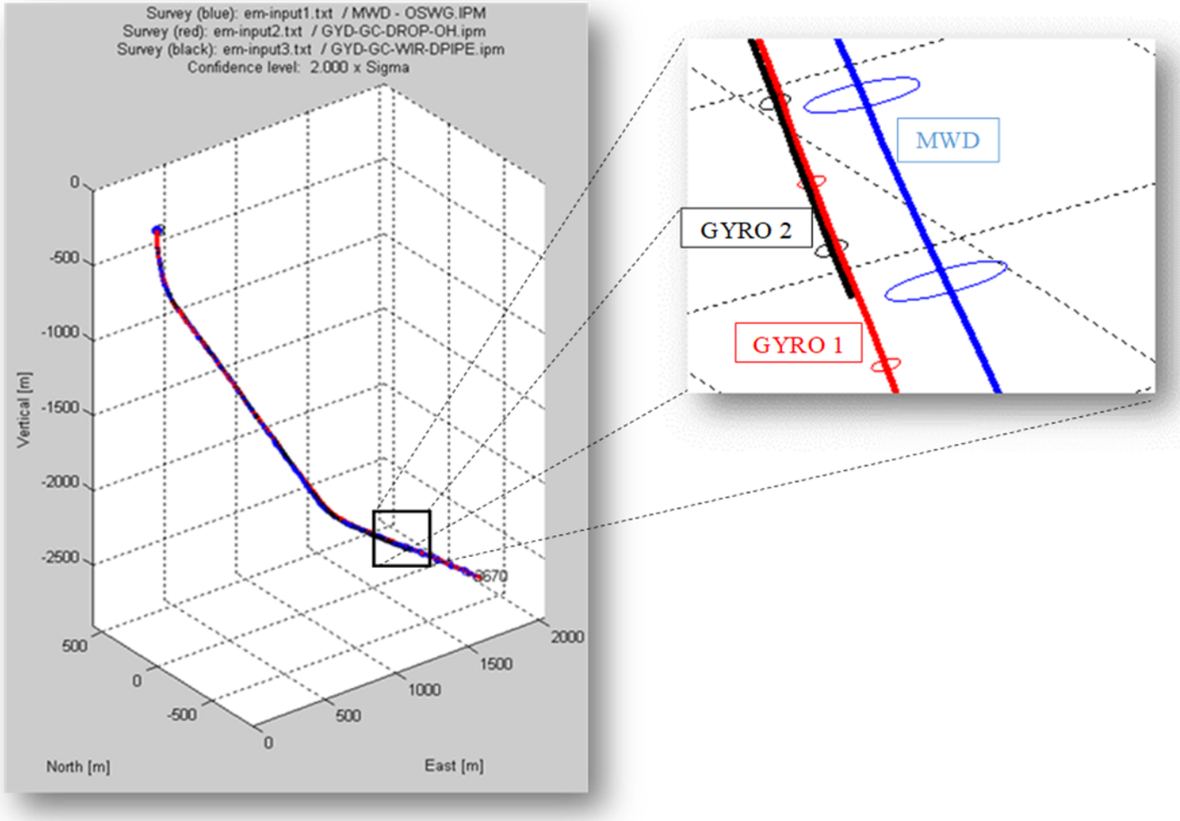
# Quality Control Pass But Not Sufficient

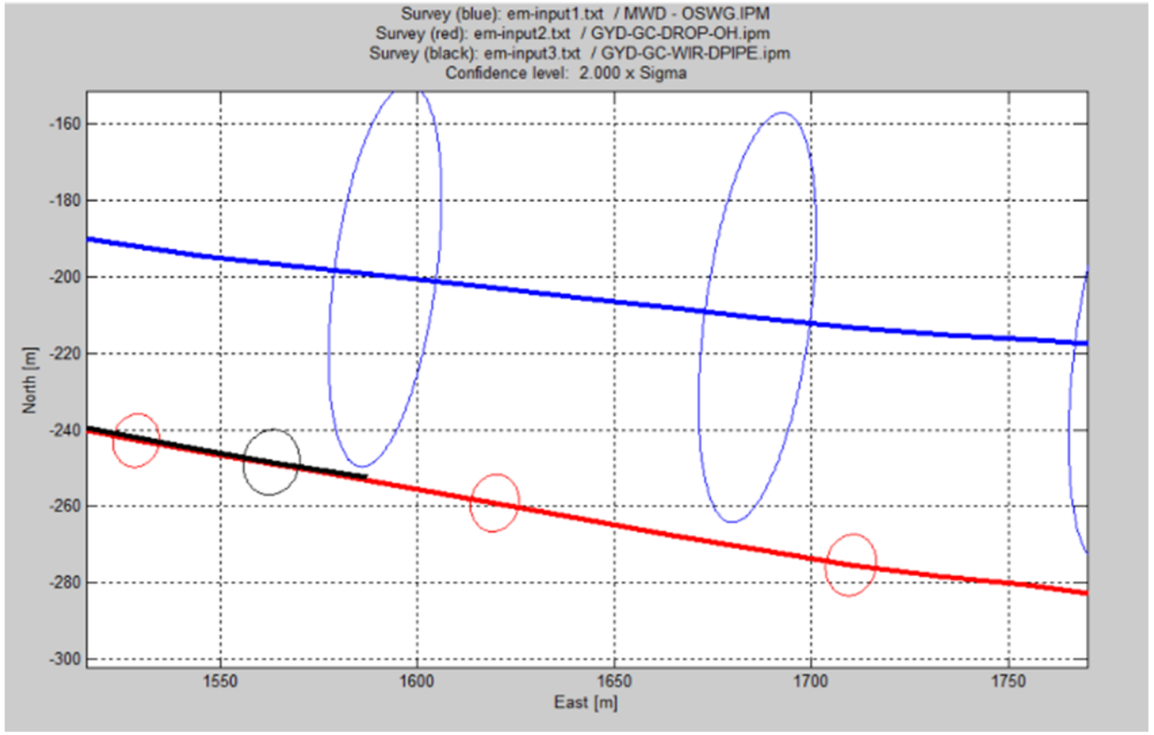


# Quality Control Pass But Not Sufficient



# Quality Control Pass But Not Sufficient



# DEFINITIVE SURVEY METHODOLOGY – OPERATING PROCEDURE

**Job Preparation**

- Gyro & MWD tool in the BHA

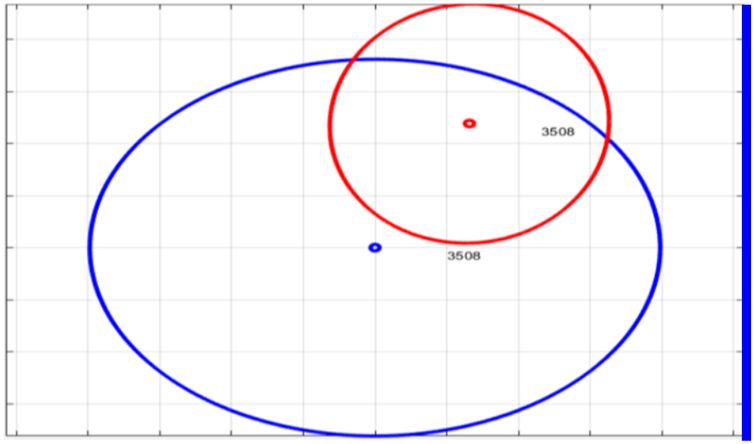
**During Operation**

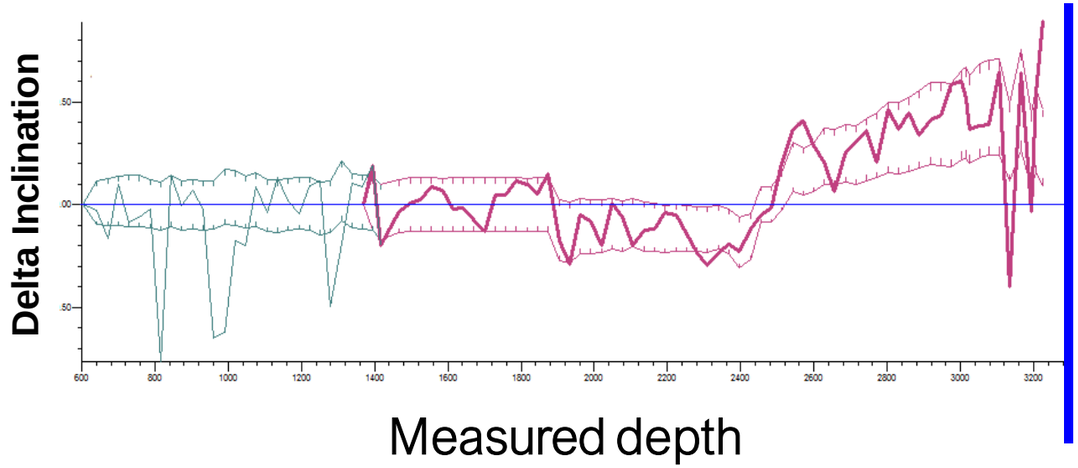
- Real Time
- Post Drilling

**After the job**

# Definitive Survey Methodology

- Comparison between surveys of distinct and independent sensors
- Relative Instrument Performance (RIP), Chi-Square test and Uncertainty Ellipse Comparison




| Highside, Lateral, Along-hole, Co-ordinate Difference Test | Pass | Pass | Pass |
|---|---|---|---|
| Chi-square test value: | 3.5 | 13.2 | 0.0 |
| Tolerance: | 34.4 | 34.4 | 34.4 |
| No. Overlapping survey stations used: | 15 | 15 | 15 |

# The Methodology Applied In Remote And Autonomous Drilling Operations

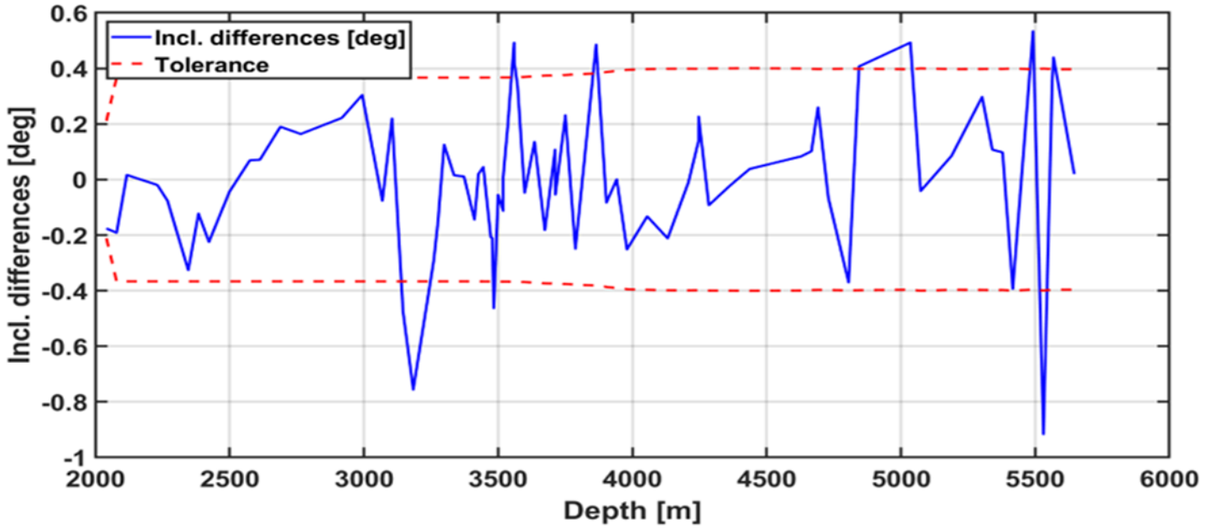
- It is a common practice nowadays for wells to be carried out with remote monitoring, and this tends to evolve into an autonomous activity as new methods and technologies become available.

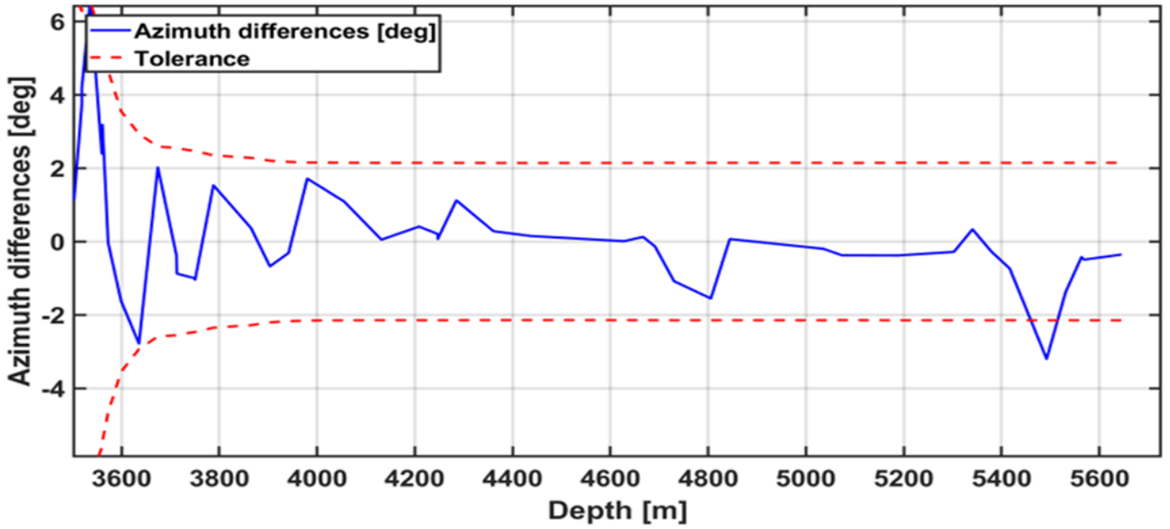
- New gyroscopic technologies, such as solid-state GWD, make it possible to overcome operational challenges in a cost-effective way.

- The comparison of surveys in real-time, with different and independent sensors, allows the verification of positional data and favors the execution of autonomous drilling operations with high reliability.

# Reference: Well A

- 12 ¼" x 13 ½" section
- MWD and GWD tools provided surveys approved in their internal quality controls during drilling
- Maximum depth of the GWD sensor at 5708m
- GWD inrun tool was programmed to outrun memory mode

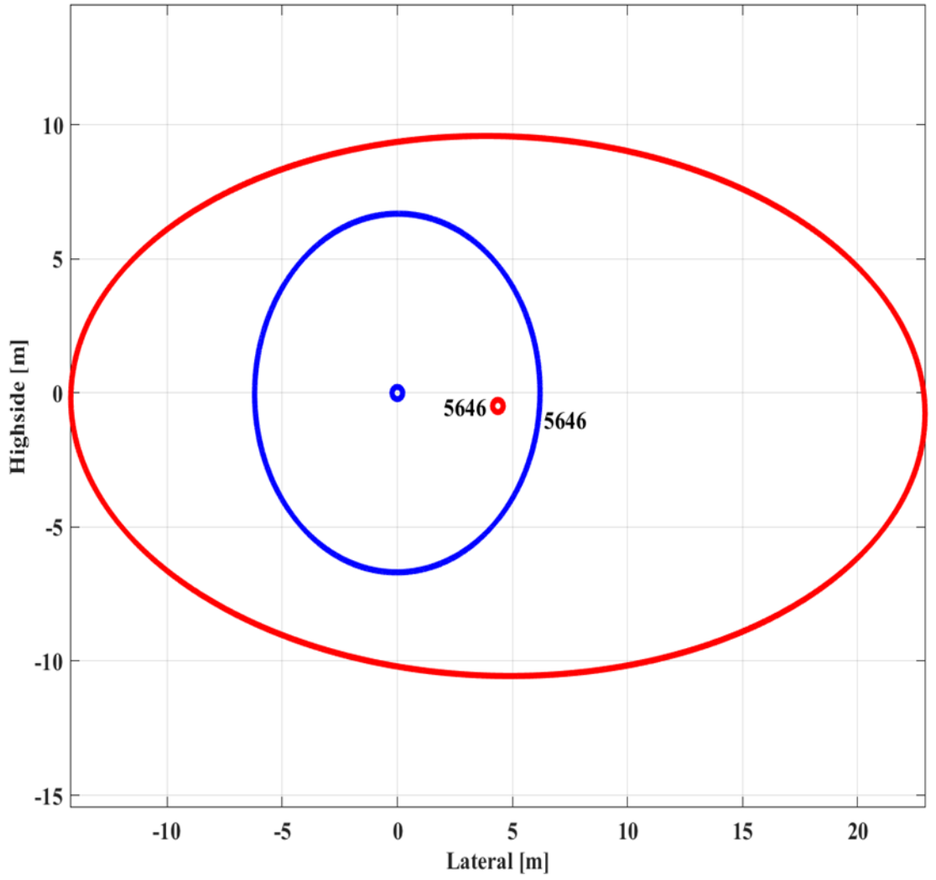


# Reference: Well A

| RIP test | Mean Results | | STD Results | |
|---|---|---|---|---|
| Inclination | 0.031 | Good agreement | 2.132 | Disagreement |
| Azimuth | -0.069 | Good agreement | 1.388 | Average agreement |

| Highside, Lateral, Along-hole, Co-ordinate Difference Test | Pass | Pass | Pass |
|---|---|---|---|
| Chi-square test value: | 10.6 | 21.5 | 0.0 |
| Tolerance: | 34.4 | 34.4 | 34.4 |
| No. Overlapping survey stations used: | 15 | 15 | 15 |

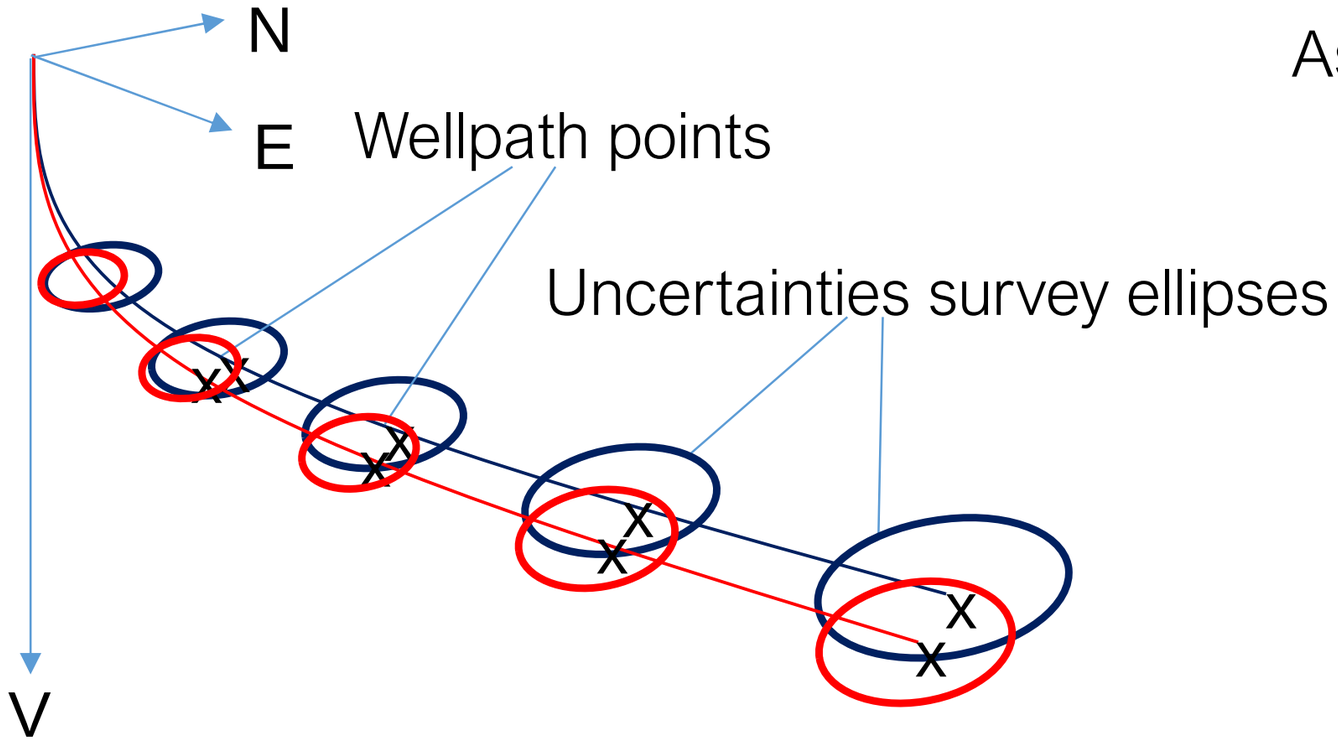


# Reference: Well A

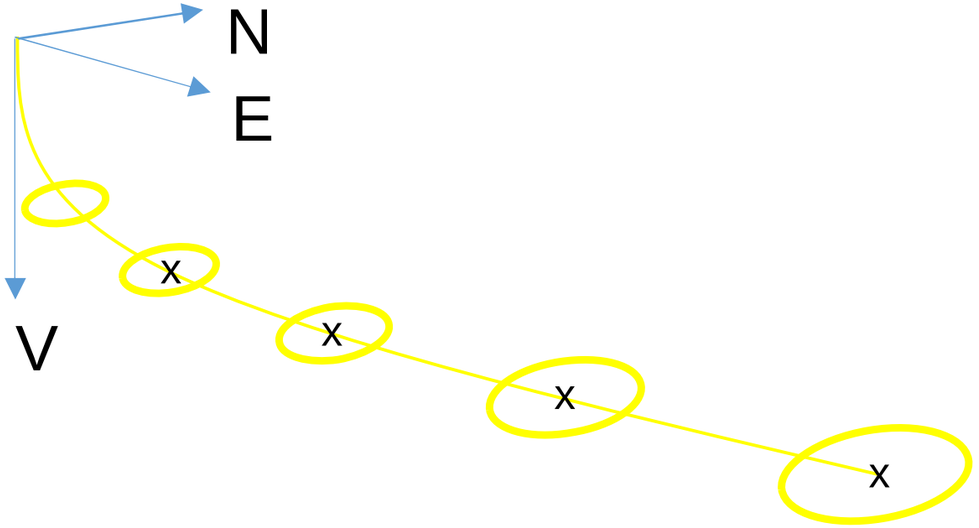
| Tool | Semi-major Error | Semi-minor Error | Ellipse Area | Tool IPM |
|---|---|---|---|---|
| MWD | 19.64 m | 13.54 m | 835.43 m² | MWD_AX_SAG |
| GWD inrun | 11.47 m | 10.43 m | 375.83 m² | solid-state_GWD |
| GWD OMM | 8.65 m | 7.82 m | 212.61 m² | solid-state drop gyro |

| Tests | The result of tests performed |
|---|---|
| Relative Instrument Performance (RIP) test | Average agreement |
| Chi-Square test | Pass |
| Comparison of EOU in TD | Very good |
| Definitive Survey Methodology | Pass |

# Next Step For More Accuracy




Average the surveys!
Assuming the surveys passed the Definitive Survey Methodology



# Conclusion

- Definitive Survey Methodology is based on the overlap of surveys from two tools with different operating principles and references, and it is always an advantage over data from a single tool.
- The Definitive Survey Methodology optimizes well-to-well error model analysis, allowing non-experts to verify the reliability of positioning data.
- Comparison between surveys before entering the reservoirs allows the fulfillment of the directional objectives as close as possible to the projected trajectory.
- A steppingstone for Averaging Survey.

# Conclusion

- The Definitive Survey Methodology enables real-time auditing, increasing reliability in autonomous operations.
- Today's drilling practices must not be a challenge for tomorrow's operations.
- Ensuring the positioning of wells enables optimizing contingency plans and minimizing possible negative consequences of drilling wells. This reduces the environmental impact of the oil & gas industry.

# Questions