"A Dynamic Support System For Wellbore Positioning Quality Control While Drilling"

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IOGP Geomatics / Statoil
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What we do…

A mathematics research company that creates *paradigm-shifting solutions* to hard problems in many fields that have immense operational complexity.

Tackles problems where off-the-shelf technology, systems or software solutions do not exist or are insufficient.

TTM's solutions impact clients' current business models and technologies.

What do our clients have in common

- Complex data sets
- Data and analysis go beyond use of spreadsheet or traditional stats / maths – just too many factors to analyse
- Analysis requires new ways of looking at data -- multiple inter-relationships
- Need new tools that are integrated into existing processes – must fit within the system and context of how organisations do business
- Supports decision-making to drive better outcomes

Dynamic Support System for Wellbore Positioning Quality Control Overview

- **Path Construction**

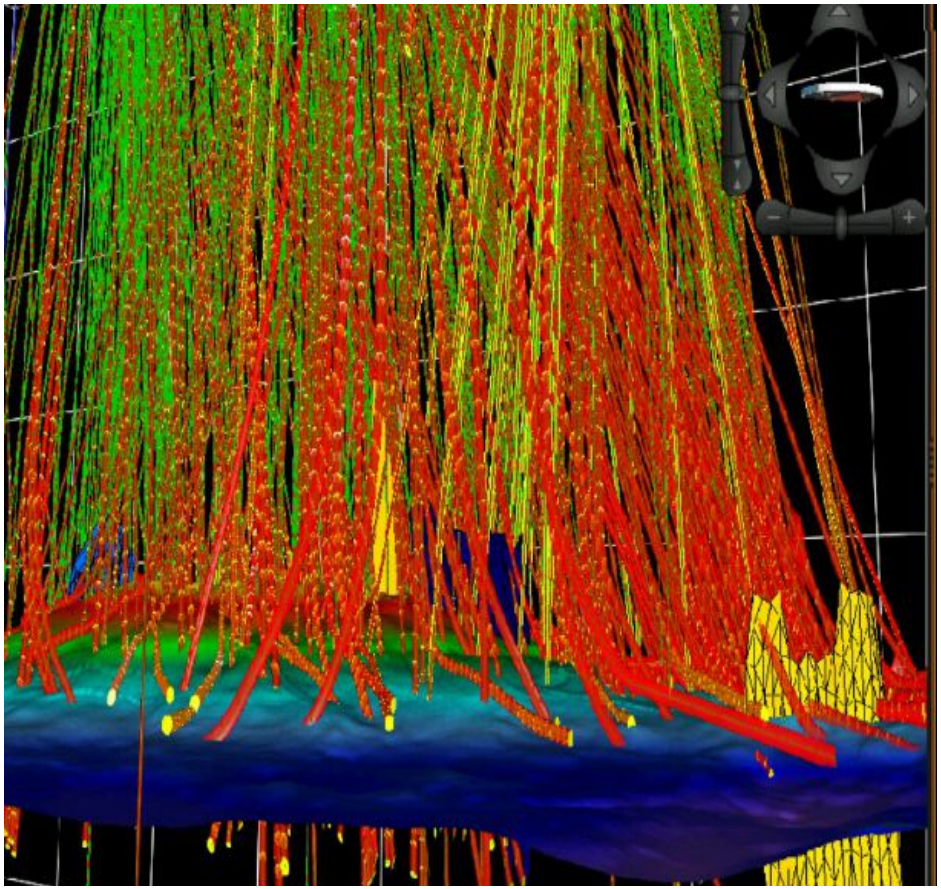
- Mathematically unsound
- Poor use of sensor information

- **Quality Control**

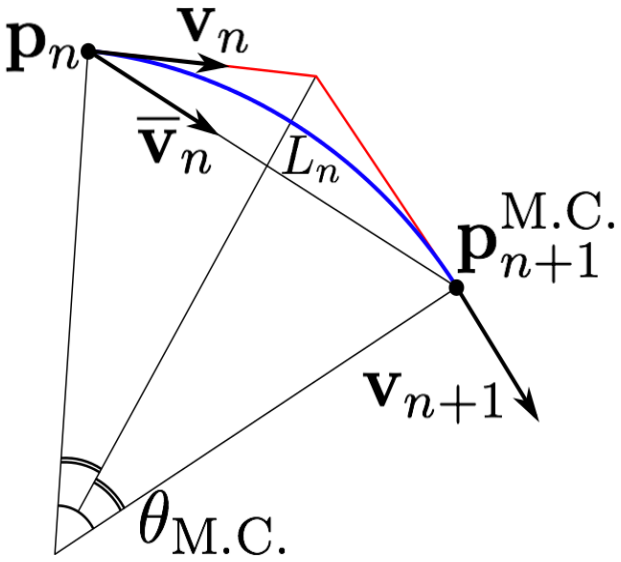
- Grossly incorrect measurements can pass QC
- Subjective interpretation
- An alternative source of information

- **Uncertainty Modelling**

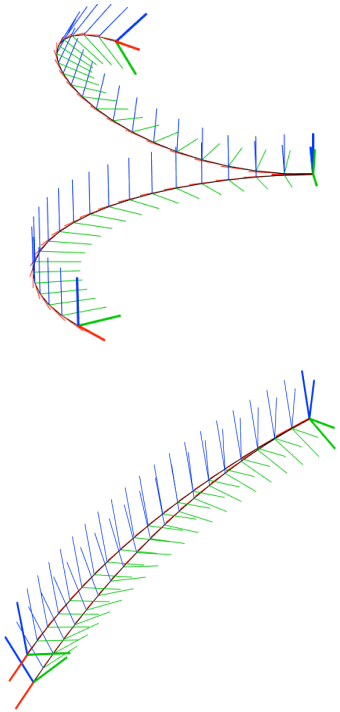
- Inadequate mathematics
- Refinement cannot solve problems
- Impacts all aspects of field development



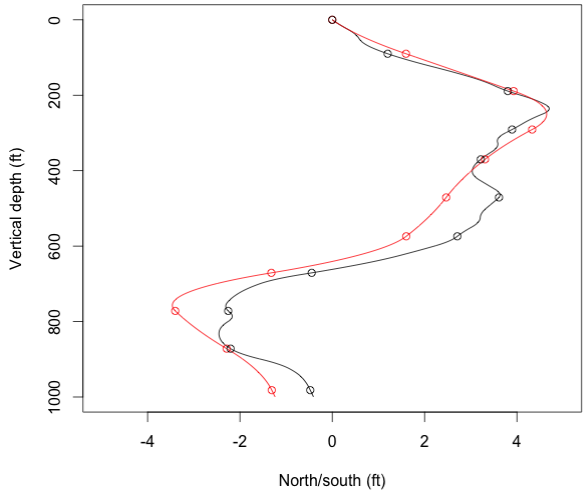
Dynamic Support System for Wellbore Positioning Quality Control Path Construction



Left Minimum curvature (MC) method.



Middle Example well sections by MC vs novel TTM methods.



Right Well paths generated by MC and novel TTM algorithm. Despite being equally consistent with data they disagree on the well position.

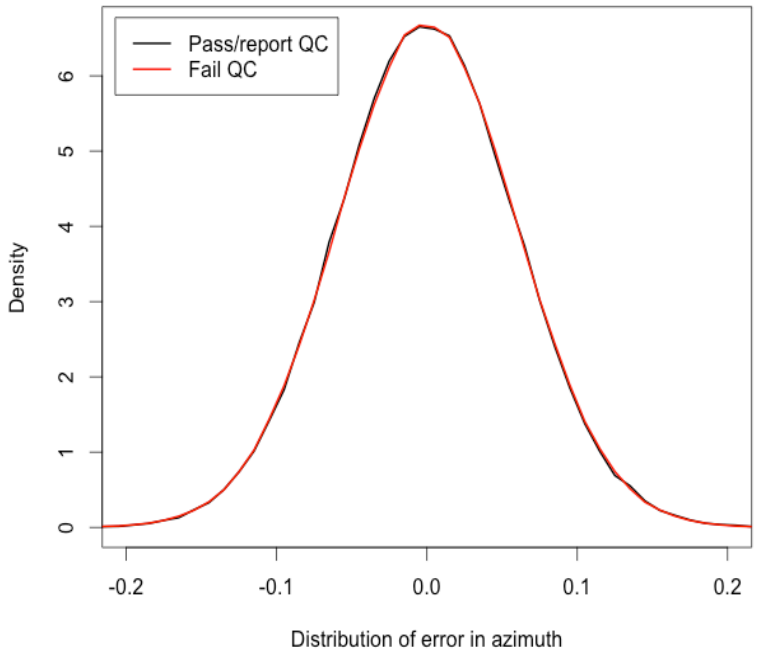
Minimum curvature and beyond :

- Developed more general approaches
- Exploit information ('signatures') in MWD and LWD sensors
- Create a foundation to incorporate Quality Control and Uncertainty

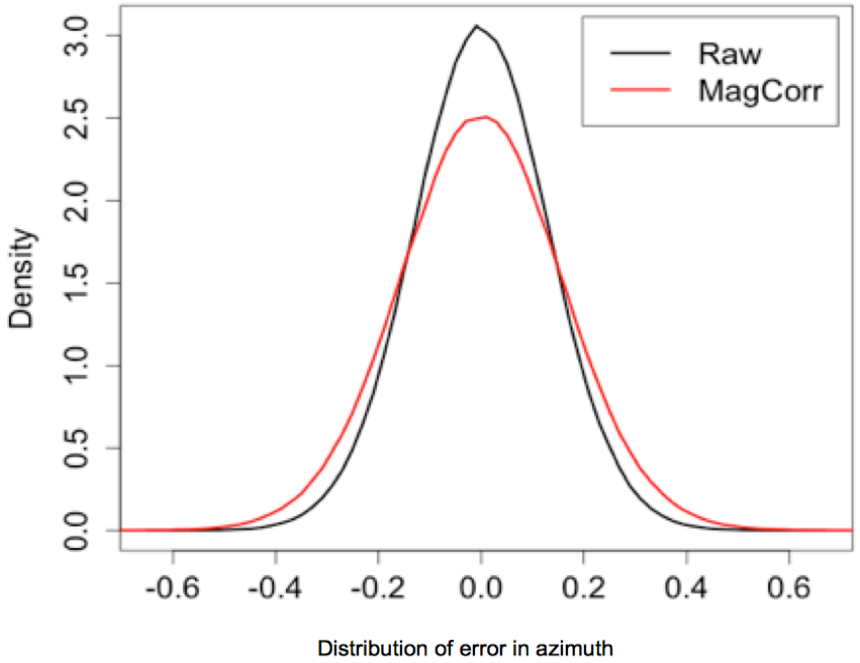
Dynamic Support System for Wellbore Positioning Quality Control
Quality Control

Impact of magnetic corrections and quality control reassessed

- Possible to fail good readings
- Possible to pass bad readings
- Passing QC does not imply improved precision in azimuth



Left Comparison of large set of magnetic readings which pass industry QC (black) vs failed industry QC (red), showing no statistical improvement in azimuthal estimate.



Right Comparison of large set of magnetic readings which have been unprocessed (black) vs processed by industry MagCorr (red), showing reduction in quality due to MagCorr modification.

Dynamic Support System for Wellbore Positioning Quality Control
Magnetic Environment and IIFR

LWD-MWD structures inform magnetic processing

- Tailoring magnetic refinement methods to environment
- Generate model of environment which may not require IIFR

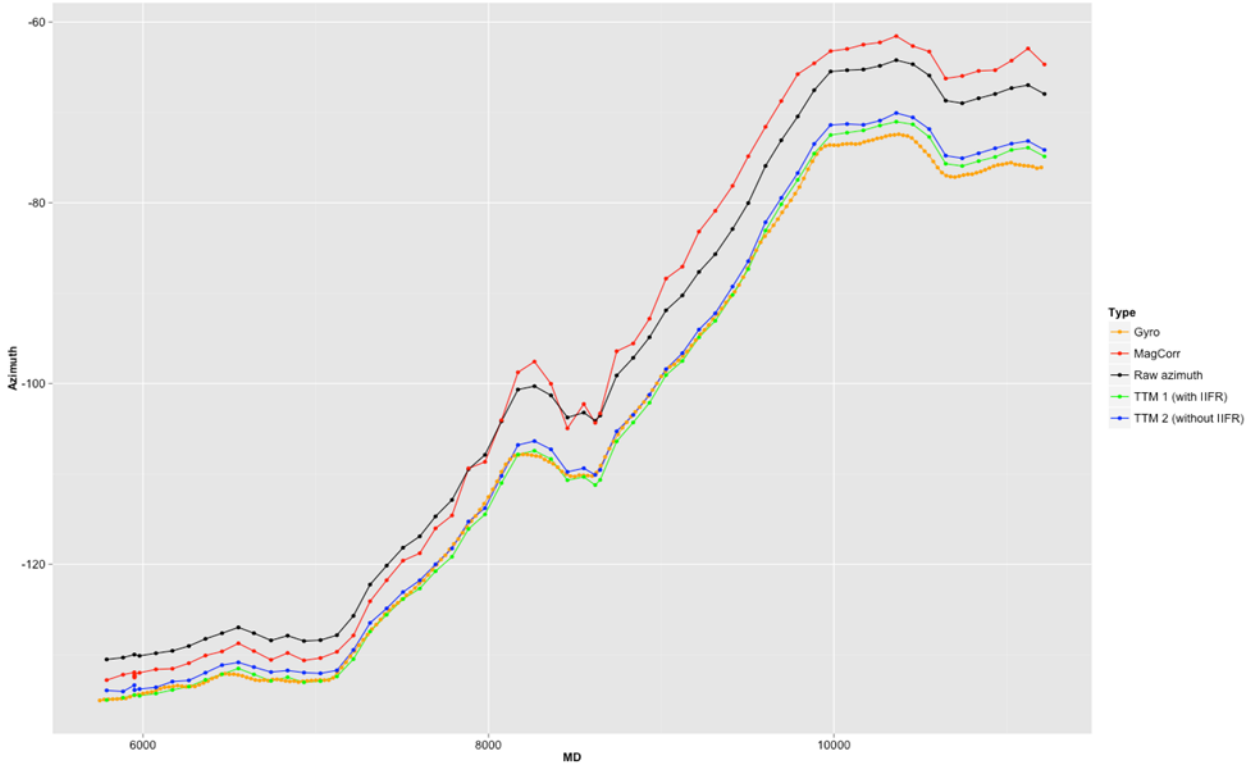


Figure Comparison of azimuthal estimates from high resolution gyro (orange), raw QC-passing magnetic (black), MagCorr corrected (red) and TTM methods TTM-1 (green) and TTM-2 (blue). MagCorr shows poor performance, often worse than raw. TTM methods give significantly improved accuracy, including in the case of TTM-2, which does not use any IIFR data to process magnetic readings.

Dynamic Support System for Wellbore Positioning Quality Control Complex Environments

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Extraction of structure within LWD readings beyond “geological layers”
Identification of structures or “signatures” guided by utility

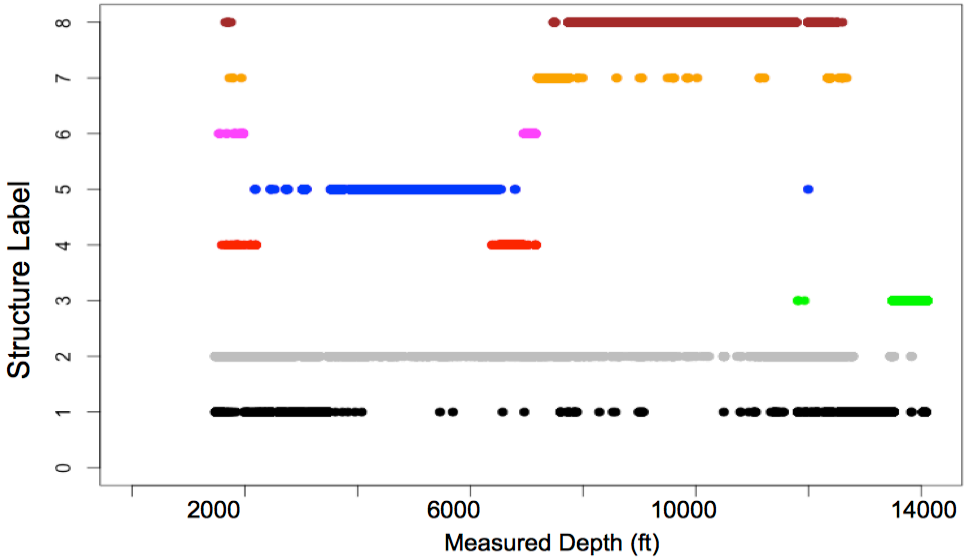


Figure LWD surveys ordered by Measured Depth (MD) and labelled by colour based on hidden structures extracted from LWD dataset. Complex mixing shows structures do not follow MD ordering.

Analysis must be able to handle practical challenges

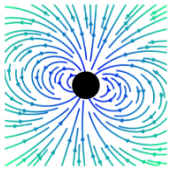
- Industry's frequent use of different tools
- Potential mis-calibration
- Multiple tool runs

Intelligent Wellbore Positioning System Prototype

Intelligent Wellbore Positioning System - Workflow

Sensor Data from BHA
MWD + LWD
Drilling Company

SiteCom WITSML Server
"Real-time"



Nominal Field Values
BGGM + IFR + IIFR
BGS

"Static data" Server

"Drill Simulator"
Historical Surveys
CSV, LAS

Internal Archive
Bespoke format

Deliverable Server (+ Client)

Visualisation Archive
CSV

Deliverable Clients
Browser

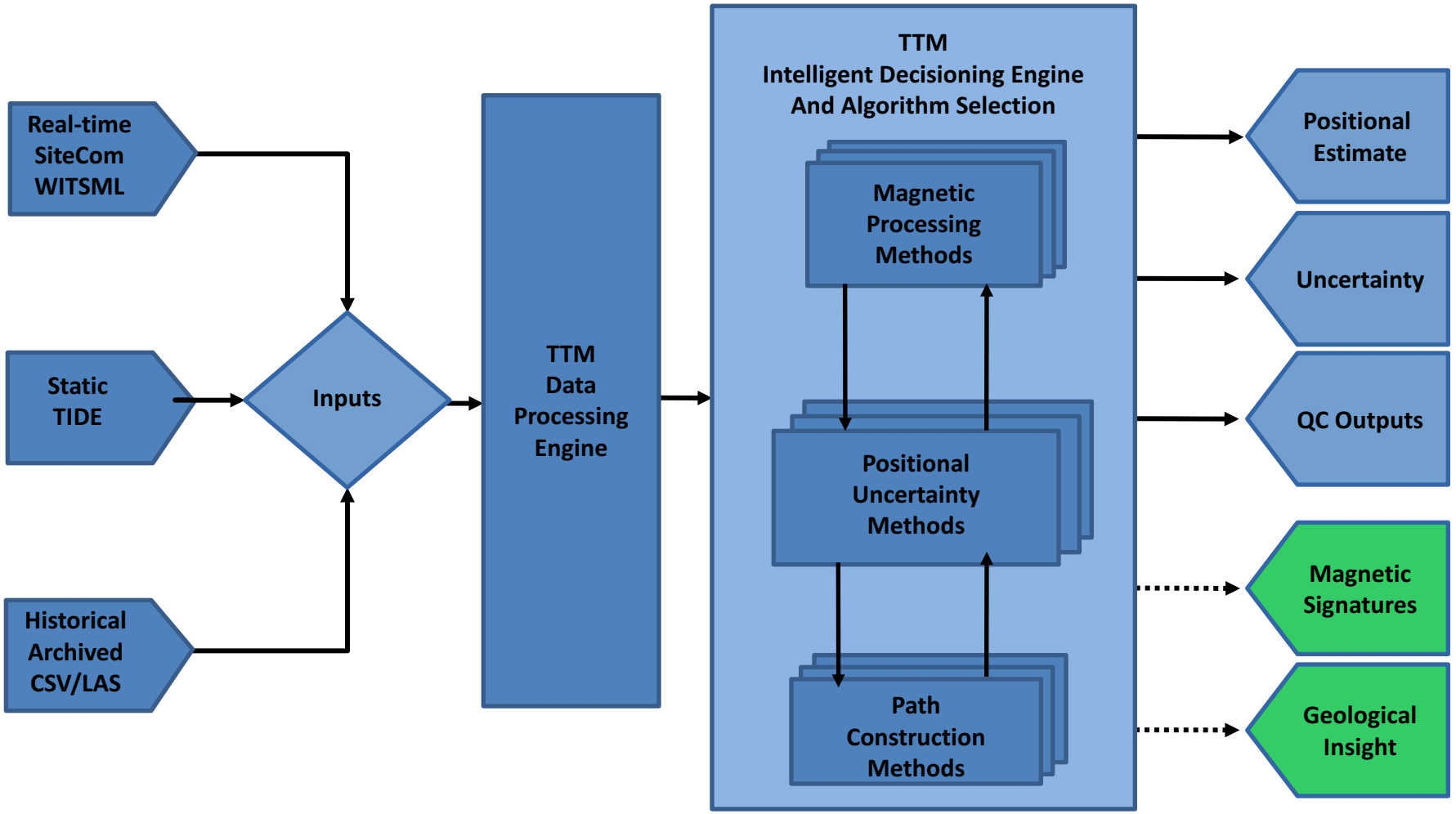
External formats requiring client/libraries for real-time processing

Historical survey formats for off-line processing

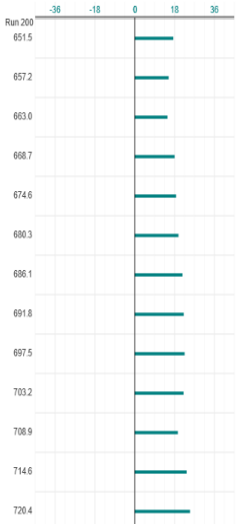
Bespoke proprietary format for internal use only

Simple CSV format for later or external visualisation

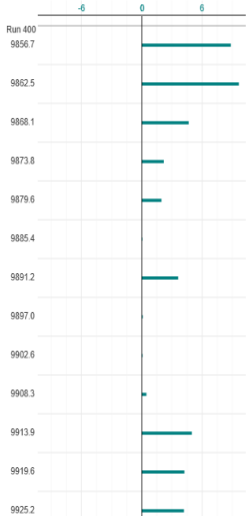
Intelligent Wellbore Positioning System - Engine Workflow



Prototype User Interface
Example Outputs



North	East	TVD	Inclination	Azimuth	Uncertainty	TTM Refined QC	TTM Magnetic QC	SSA Magnetic QC
238.30	44.40	440.00	12.20	45.20	17.46			
240.90	45.20	445.00	12.30	45.10	15.32			
243.50	45.90	450.10	12.40	44.90	14.83			
246.10	46.70	455.10	12.50	44.80	18.02			
248.70	47.50	460.10	12.50	44.70	18.72			
251.30	48.30	465.10	12.60	44.60	19.78			
253.90	49.00	470.10	12.70	44.40	21.61			
256.50	49.80	475.10	12.80	44.30	22.14			
259.20	50.60	480.20	12.90	44.20	22.57			
261.80	51.40	485.20	13.00	44.10	22.07			
264.40	52.10	490.20	13.10	43.90	19.49			
267.00	52.90	495.20	13.20	43.80	23.46			
269.60	53.70	500.20	13.20	43.70	25.00			



North	East	TVD	Inclination	Azimuth	Uncertainty	TTM Refined QC	TTM Magnetic QC	SSA Magnetic QC
541.50	1422.70	8672.00	71.70	156.20	8.85			
546.90	1423.30	8673.80	71.80	156.20	9.66			
552.30	1423.80	8675.50	72.00	156.20	4.67			
557.70	1424.40	8677.20	72.10	156.20	2.19			
563.00	1425.00	8678.90	72.20	156.10	1.95			
568.40	1425.50	8680.60	72.30	156.10	0.06			
573.80	1426.10	8682.30	72.40	156.10	3.62			
579.10	1426.70	8684.00	72.60	156.10	0.09			
584.50	1427.20	8685.70	72.70	156.00	0.07			
589.90	1427.80	8687.40	72.80	156.00	0.46			
595.30	1428.40	8689.10	72.90	156.00	4.98			
600.60	1429.00	8690.80	73.00	155.90	4.24			
606.00	1429.50	8692.50	73.20	155.90	4.19			

Prototype User Interface
Visualisation Screen Description

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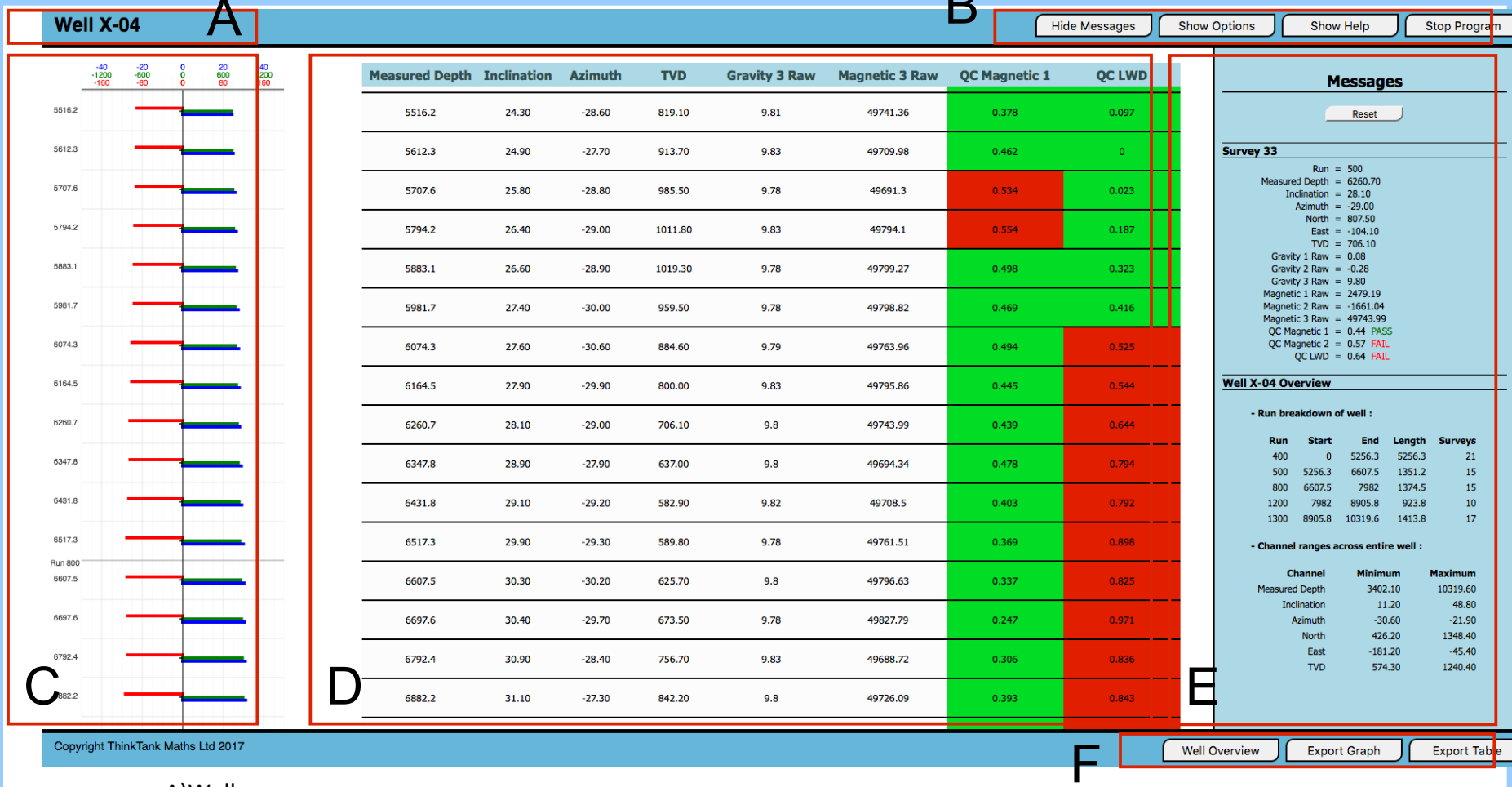
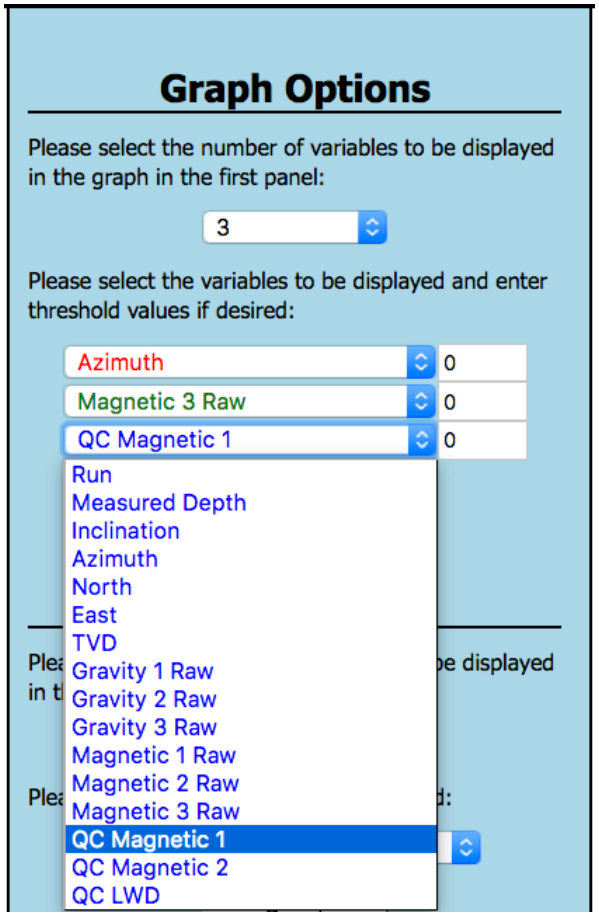
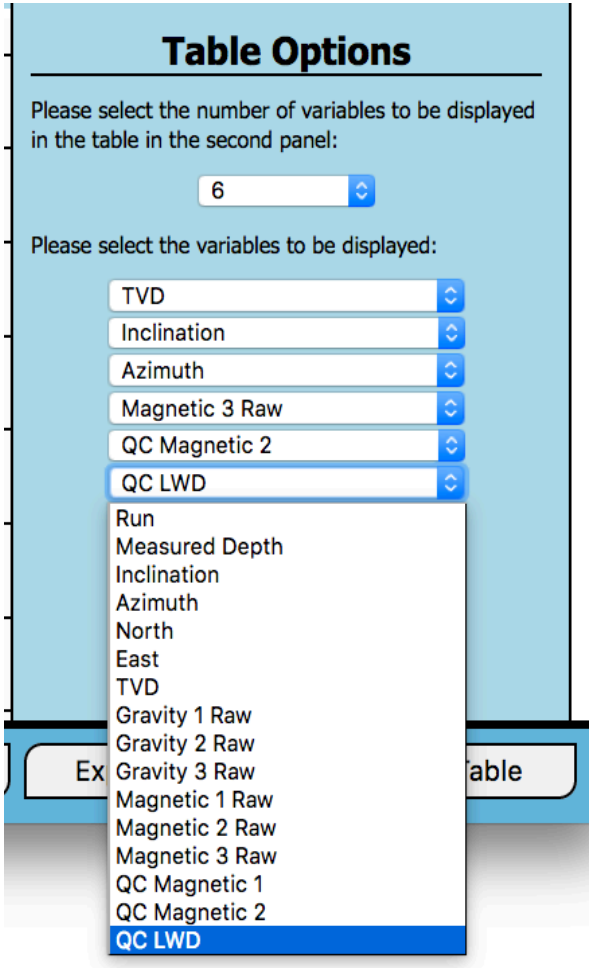


Measured Depth	Inclination	Azimuth	TVD	Gravity 3 Raw	Magnetic 3 Raw	QC Magnetic 1	QC LWD
5516.2	24.30	-28.60	819.10	9.81	49741.36	0.378	0.097
5612.3	24.90	-27.70	913.70	9.83	49709.98	0.462	0
5707.6	25.80	-28.80	985.50	9.78	49691.3	0.534	0.023
5794.2	26.40	-29.00	1011.80	9.83	49794.1	0.554	0.187
5883.1	26.60	-28.90	1019.30	9.78	49799.27	0.498	0.323
5981.7	27.40	-30.00	959.50	9.78	49798.82	0.469	0.416
6074.3	27.60	-30.60	884.60	9.79	49763.96	0.494	0.525
6164.5	27.90	-29.90	800.00	9.83	49795.86	0.445	0.544
6260.7	28.10	-29.00	706.10	9.8	49743.99	0.439	0.644
6347.8	28.90	-27.90	637.00	9.8	49694.34	0.478	0.794
6431.8	29.10	-29.20	582.90	9.82	49708.5	0.403	0.792
6517.3	29.90	-29.30	589.80	9.78	49761.51	0.369	0.898
6607.5	30.30	-30.20	625.70	9.8	49796.63	0.337	0.825
6697.6	30.40	-29.70	673.50	9.78	49827.79	0.247	0.971
6792.4	30.90	-28.40	756.70	9.83	49688.72	0.306	0.836
6882.2	31.10	-27.30	842.20	9.8	49726.09	0.393	0.843

A)Well name
B)Control buttons – Show/Hide “Panels”, Show “Help”, Exit Visualisation
C)Graph – Plot of 1, 2 or 3 user selected output variables for entire well
D)Table – Columned data for user selected variables
E)Panels – Displayed messages/information about selected surveys and display options for graph and table
F)Information buttons – Display well overview, Export table data to CSV and Export graph to PNG

User Interface
Graph / Table Display Options

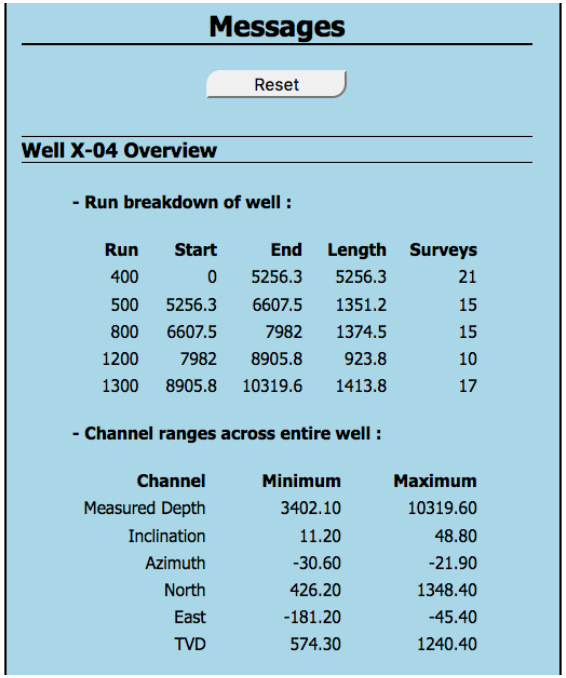




User Interface
Well and Survey Information Messages

Additional information can be obtained on the well overall (right top) and a given survey (left bottom) and is displayed in the “Messages” panel.

The overall well data, via the “Well Overview” button, provides a short summary of the length of each run and density of surveys within each run up to that point in time.



Messages

Reset

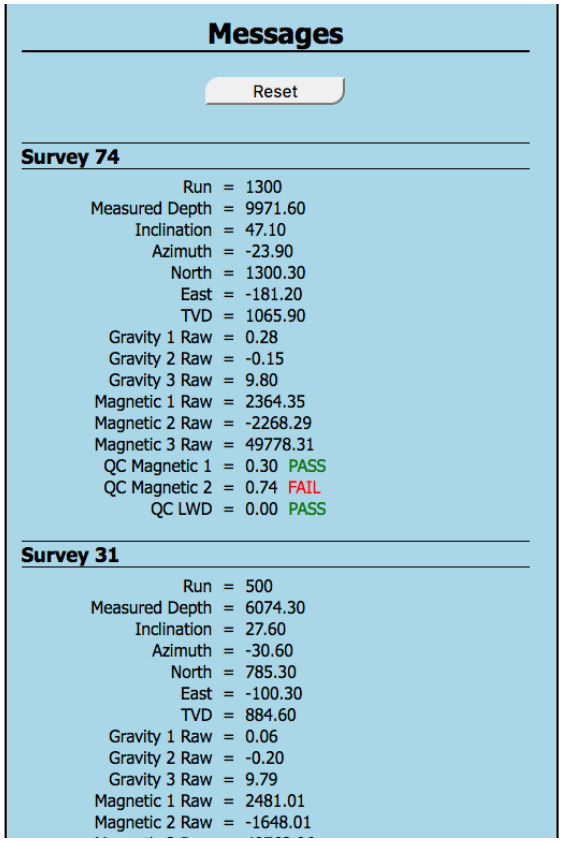
Well X-04 Overview

- Run breakdown of well :

Run	Start	End	Length	Surveys
400	0	5256.3	5256.3	21
500	5256.3	6607.5	1351.2	15
800	6607.5	7982	1374.5	15
1200	7982	8905.8	923.8	10
1300	8905.8	10319.6	1413.8	17

- Channel ranges across entire well :

Channel	Minimum	Maximum
Measured Depth	3402.10	10319.60
Inclination	11.20	48.80
Azimuth	-30.60	-21.90
North	426.20	1348.40
East	-181.20	-45.40
TVD	574.30	1240.40



Messages

Reset

Survey 74

Run	=	1300
Measured Depth	=	9971.60
Inclination	=	47.10
Azimuth	=	-23.90
North	=	1300.30
East	=	-181.20
TVD	=	1065.90
Gravity 1 Raw	=	0.28
Gravity 2 Raw	=	-0.15
Gravity 3 Raw	=	9.80
Magnetic 1 Raw	=	2364.35
Magnetic 2 Raw	=	-2268.29
Magnetic 3 Raw	=	49778.31
QC Magnetic 1	=	0.30 PASS
QC Magnetic 2	=	0.74 FAIL
QC LWD	=	0.00 PASS

Survey 31

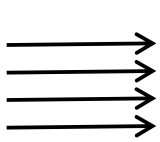
Run	=	500
Measured Depth	=	6074.30
Inclination	=	27.60
Azimuth	=	-30.60
North	=	785.30
East	=	-100.30
TVD	=	884.60
Gravity 1 Raw	=	0.06
Gravity 2 Raw	=	-0.20
Gravity 3 Raw	=	9.79
Magnetic 1 Raw	=	2481.01
Magnetic 2 Raw	=	-1648.01

Information on individual surveys is displayed when a survey’s row in the Table section is clicked. All available information for the survey will be displayed in the “Messages” panel regardless of which data types are shown in the Table.

Trusted Reasoning Architecture (TRA)

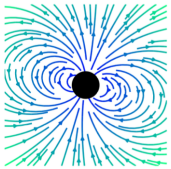
Trusted Reasoning Architecture (TRA) Enabled System Workflow

Sensor Data from BHA
MWD + LWD
Drilling Company



SiteCom WITSML Server
"Real-time"

Internal Archive
Bespoke format



Nominal Field Values
BGGM + IFR + IIFR
BGS

"Static data" Server

Trusted
Reasoning
Architecture
(TRA)

TRA Server (+ Client)

TRA Clients
Browser

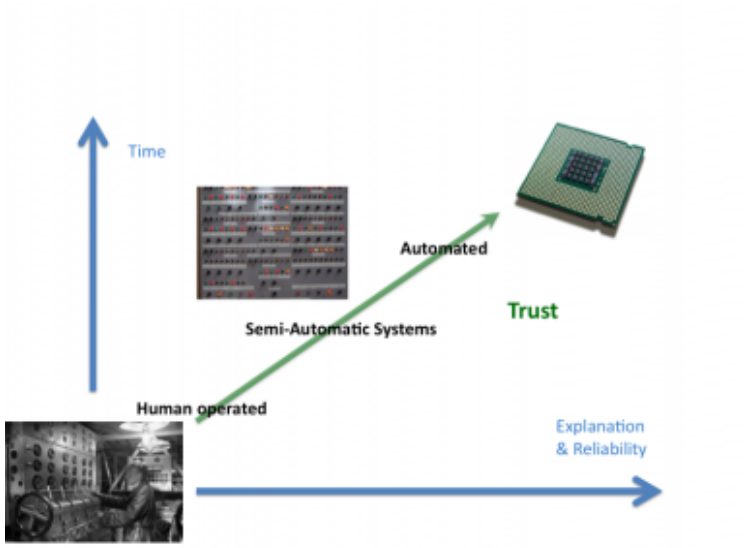
"Drill Simulator"
Historical Surveys
CSV, LAS

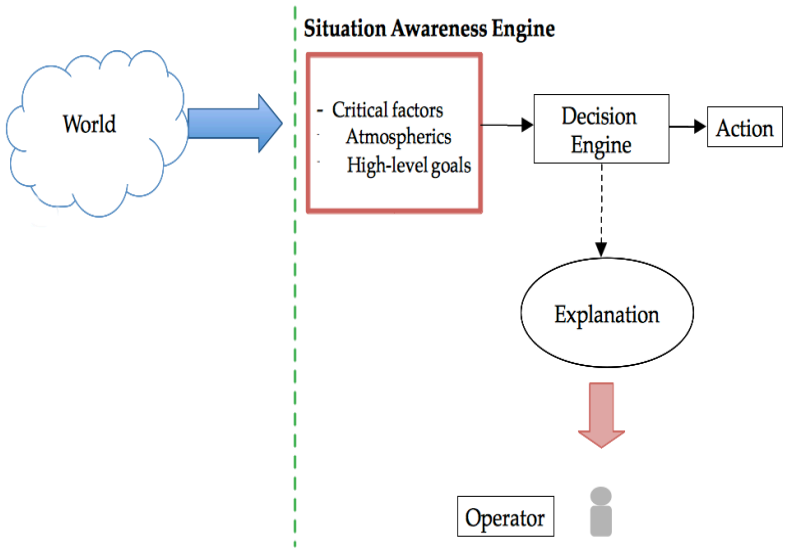
Visualisation Archive
CSV

Decision Support System – situation awareness
Trusted Reasoning Architecture (TRA)

In order to train and refine the system it is necessary to use TTM's *Trusted Reasoning Architecture* (TRA).

Capabilities and insight gained within the highly demanding military domain ("Command and Control" and unmanned aircraft) can be transferred to the Oil and Gas industry in order to provide an intelligent driller decision support system with "man-in-the-loop".

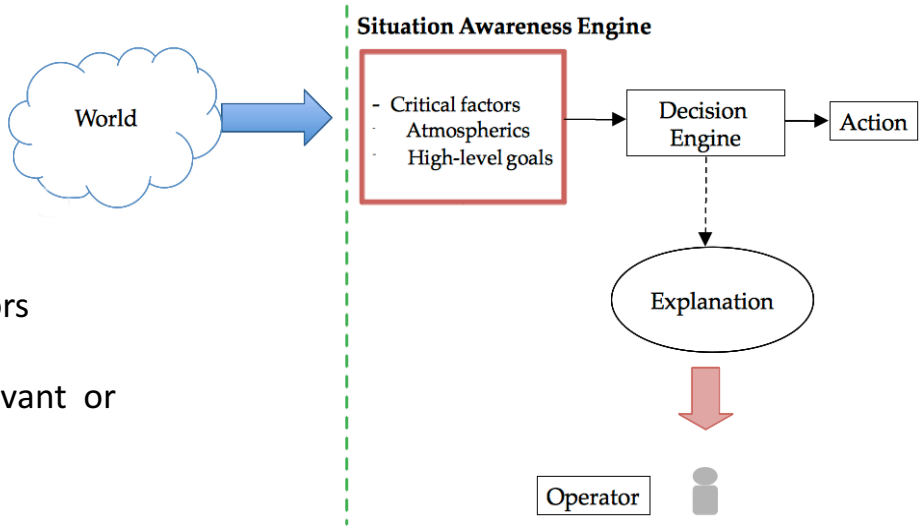




"Drill by Wire" system with numerous potential benefits:

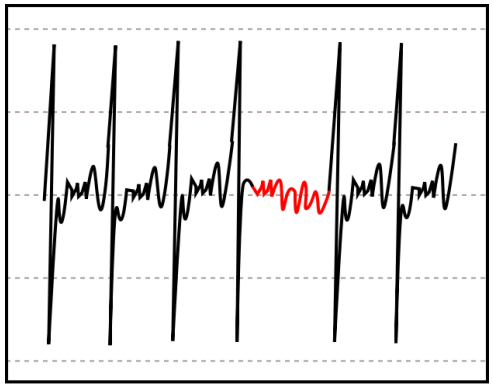
- Continual updating of scenarios and explanatory outputs
- Automated control of steering and drill parameters (WoB, mud pressure, RoP etc) – well stability prediction
- Refined quality control - eg distinguishing between broken sensors, being off-plan and sensor interference
- Automatic cataloguing of new events (to prevent undesired situations from reoccurring)

Trusted Reasoning Architecture
Atmospherics and Anomalies



Improved communication of information essential

- "Atmospherics" drawn from multiple sensors
- Explainable actions lead to increased trust
- Avoid overwhelming operator with irrelevant or "raw" data



Future Developments

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Collision Avoidance Procedure

Through the continued development and refinement of magnetic field processing and novel LWD directionality methods identification of signals indicative of collision risks :

- Offset active wells
- Ghost wells
- Broken or stuck equipment left in an abandoned and plugged well
- Unknown obstructions, man-made or natural, which could pose a risk to the drill

Well Planning

Automated Directional Drilling Support

Leakage Detection and Mud Losses

Well Stability While Drilling (Preventing “Troubles” While Drilling)

Deliberate wellbore interception (relief well planning)

Geology Insight

Subsidence Prediction

Misused trendy techniques…

- Statistical analysis (Analytics)
- Neural networks
- CFD (computational fluid dynamics)
- Deconvolution techniques
- Monte Carlo simulations

…and *flawed* thinking

- System over-simplification
- Assumed linearity
- Bayesian inference
- Gaussian distribution
- Mechanical functionality
- Direct correlation
- Artificial equilibria, …

A New Perspective

Thank you

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