General Survey Quality, Survey Errors, and Survey QC Process

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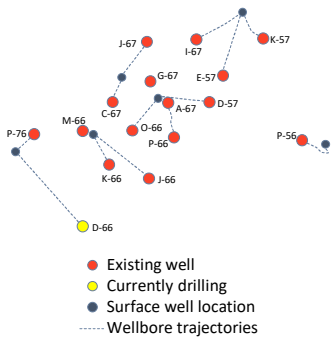
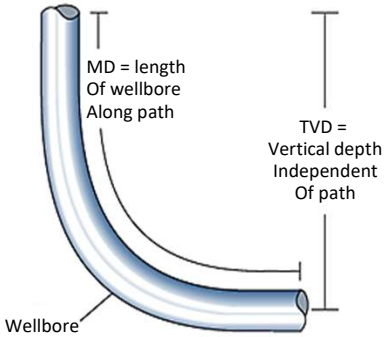
Agenda

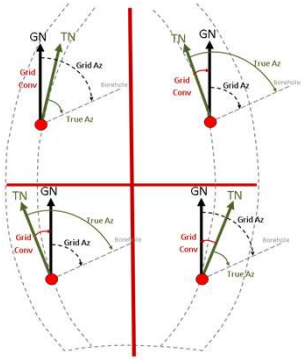
- Introduction to Surveys
- Error Model and Uncertainty
- Industry Standard Survey Correction Services
- Survey QC Process

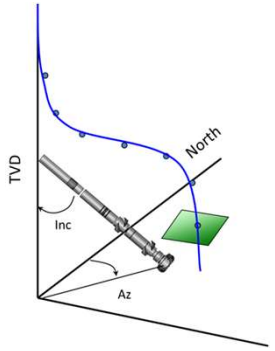
What is a Survey?

Measurements of			
Surface Location start point	**Depth** measured from a datum	**Azimuth** aligned to a North ref	**Inclination** from vertical



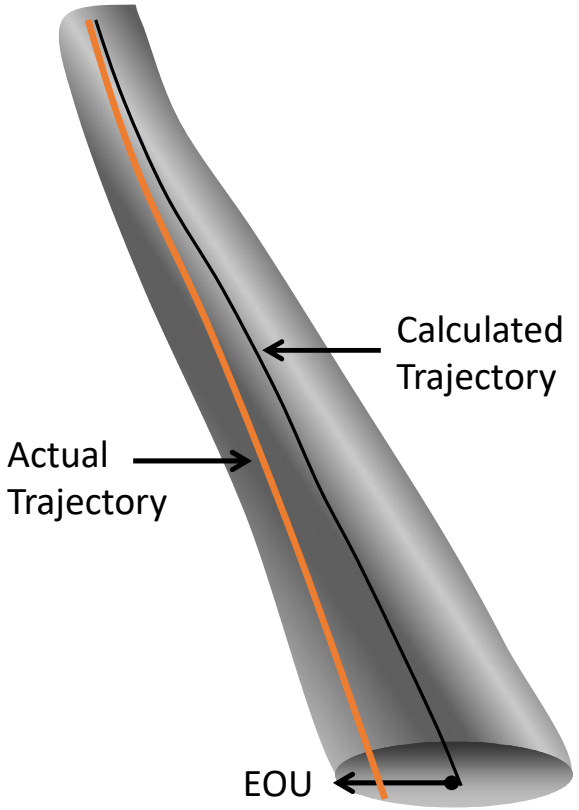






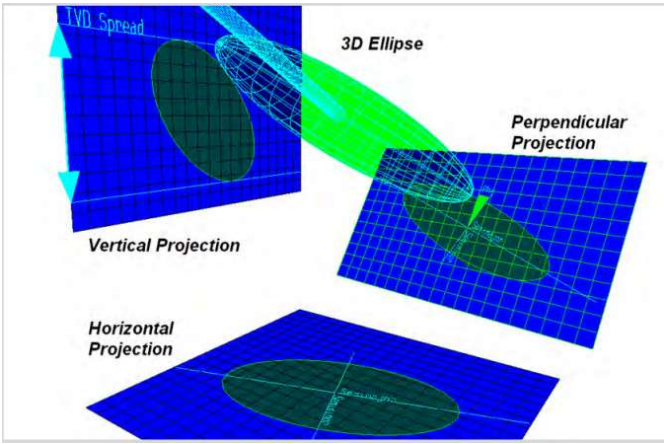
Surveying Position Uncertainty

- The calculated path is perceived as being the true location of the well. When, in fact, the well can be anywhere inside the Ellipse of Uncertainty
- Geological positioning and Anti-collision analysis requires reliable estimates of position uncertainty



Ellipse of Uncertainty

- Error Model
  - ISCWSA defined mathematical framework for modelling the Wellbore Surveying Uncertainty
  - Defines Error Terms and Propagation Mathematics
- Instrument Performance Model (IPM)
  - aka Position Uncertainty Model (PUM) or Tool-Code
  - IPM defines magnitudes of error terms based on actual measurement equipment.
  - Service providers best positioned to provide
  - ISCWSA maintains a set of generic IPM's available for use.
- Surveys + Error Model + IPM = Ellipse of Uncertainty
  - Accumulated Errors on a Statistical Basis

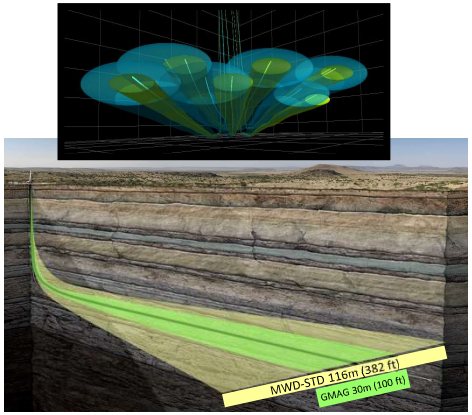


https://www.iscwsa.net/

Error Model Assumptions and Limitations

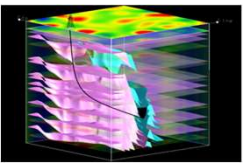
- The model only applies to surveys run under normal industry best-practice procedures which include (from *Definition of ISCWSA Error Model*):
  - rigorous and regular tool calibration
  - a maximum of 100ft survey intervals
  - field QC checks, such as total magnetic field, gyro drifts, total gravity field and magnetic dip angle on each survey measurement
  - the use of non-magnetic spacing for MWD surveys according to industry norms
  - for MWD, surveys taken in a magnetically clean environment away from casing and adjacent wells.
- Does not estimate Gross Errors!

Why Uncertainty?



Lateral

Vertical



- Global model
- Crustal anomaly
- Solar disturbance

Reference

- Drill-String
- Cross-Axial
- External

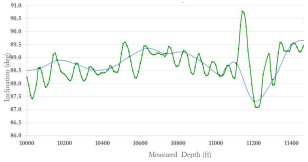
Environment

Tool

- Sensor accuracy
- Calibration

Calculation

- Minimum curvature assumption and limitation of Survey frequency

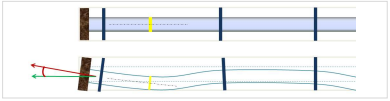


Reference

- GARM Model

Environment

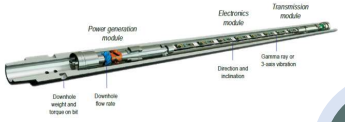
- Tool misalignment SAG
- Drill-pipe stretch



Tool

- Sensor accuracy
- Calibration

Survey Correction Options



HRGM | IFR1 | IFR2 | MS | SAG | Dual-Inc | Depth | Short Interval

Reduce Lateral Uncertainty

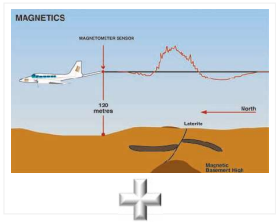
HRGM IFR1 IFR2

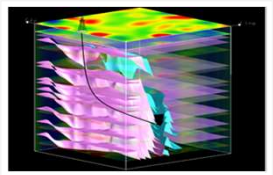
Reference

Model Accuracy Improvement

- IGRF
- HRGM
- IFR1

Aeromag Survey



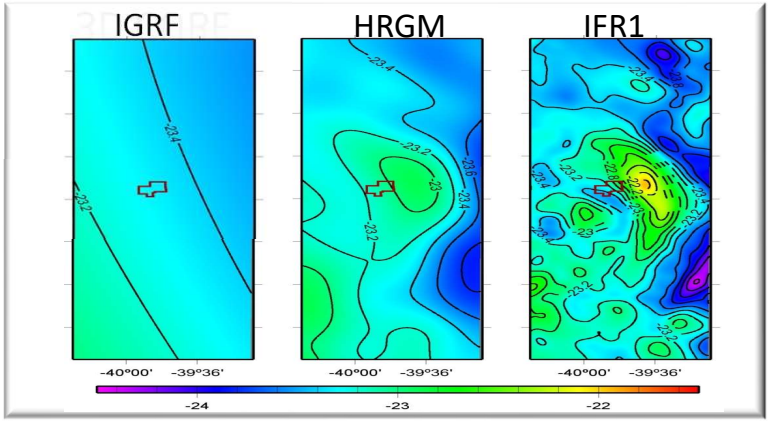


3D CUBE

Satellite Data

Reduce Declination Uncertainty

Improve Multi-Station Solution Accuracy



Reduce Lateral Uncertainty

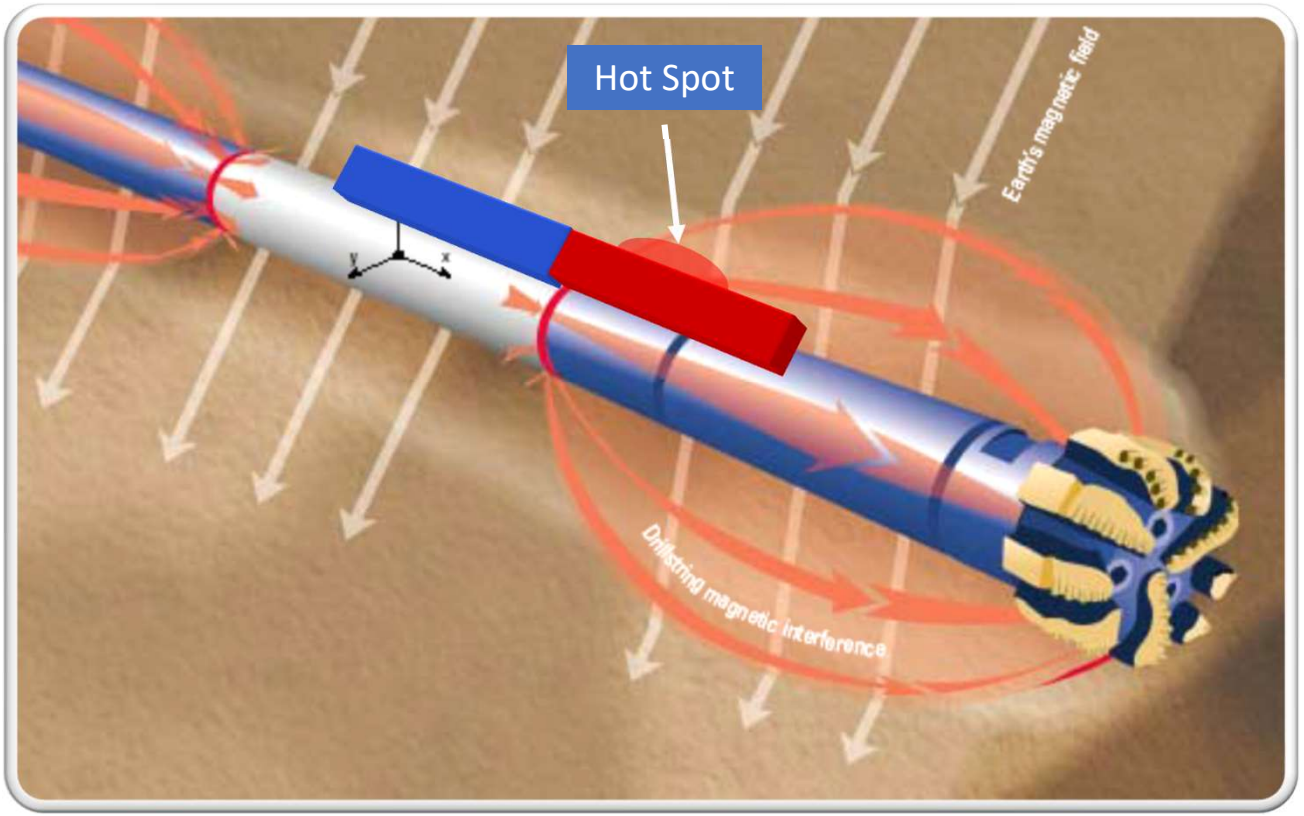
MS

Multi-Station Correction

- Drill String Interference
- Tool Calibration
- Characterizes BHA Magnetic Signature
- Requires variation in Trajectory and Tool Face

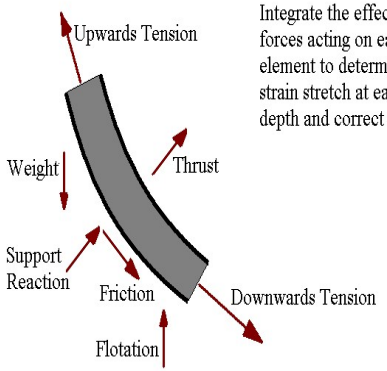
Reduces Azimuth Error

Environment Tool

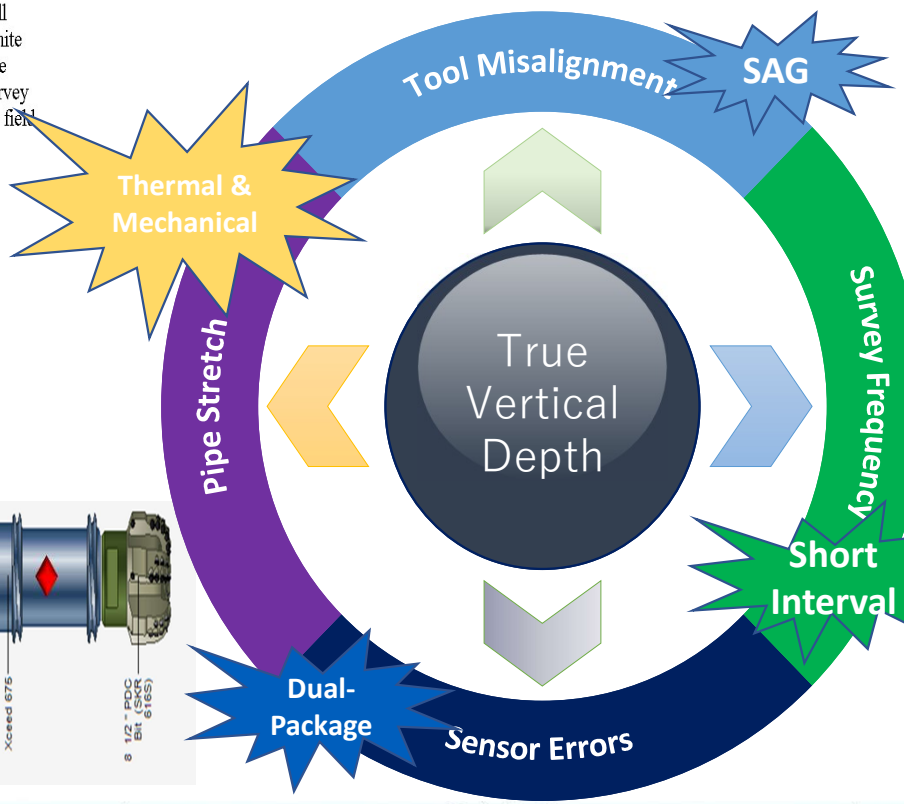


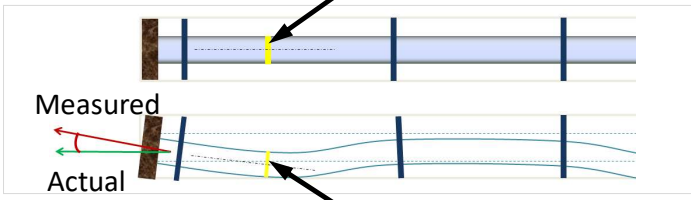
Reduce Vertical Uncertainty

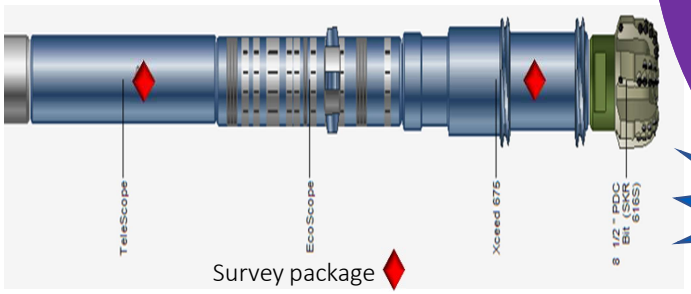
SAG | Dual-Inc | Depth | Short Interval

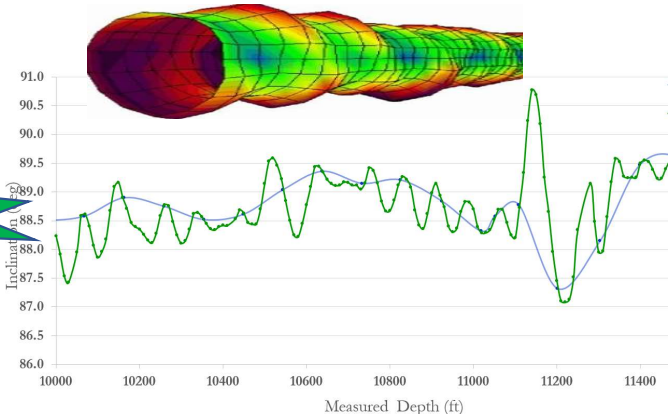


Integrate the effect of all forces acting on each finite element to determine the strain stretch at each survey depth and correct in the field



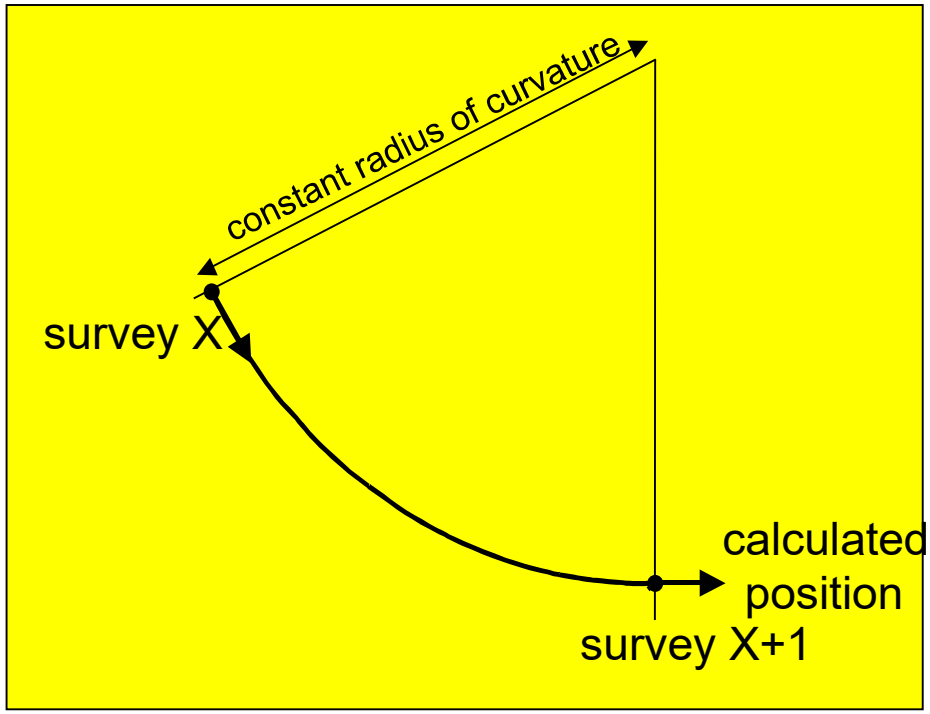


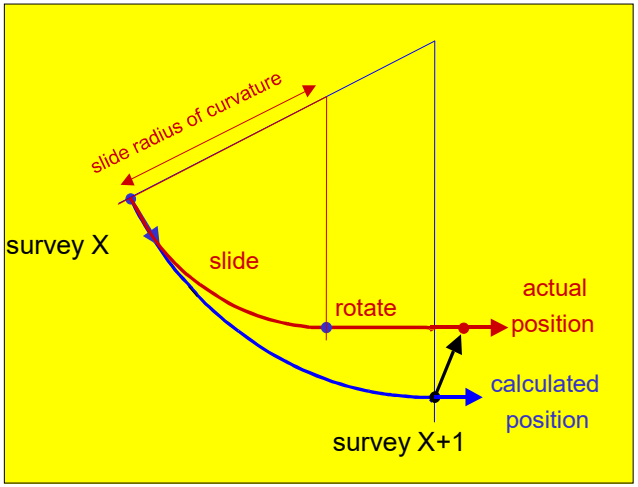


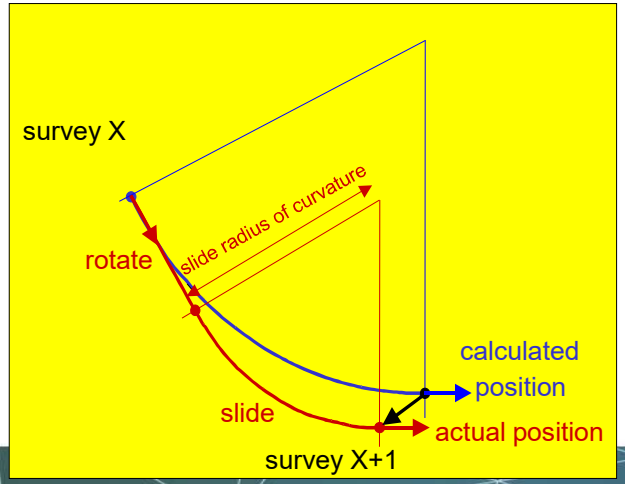


Minimum Curvature Assumptions

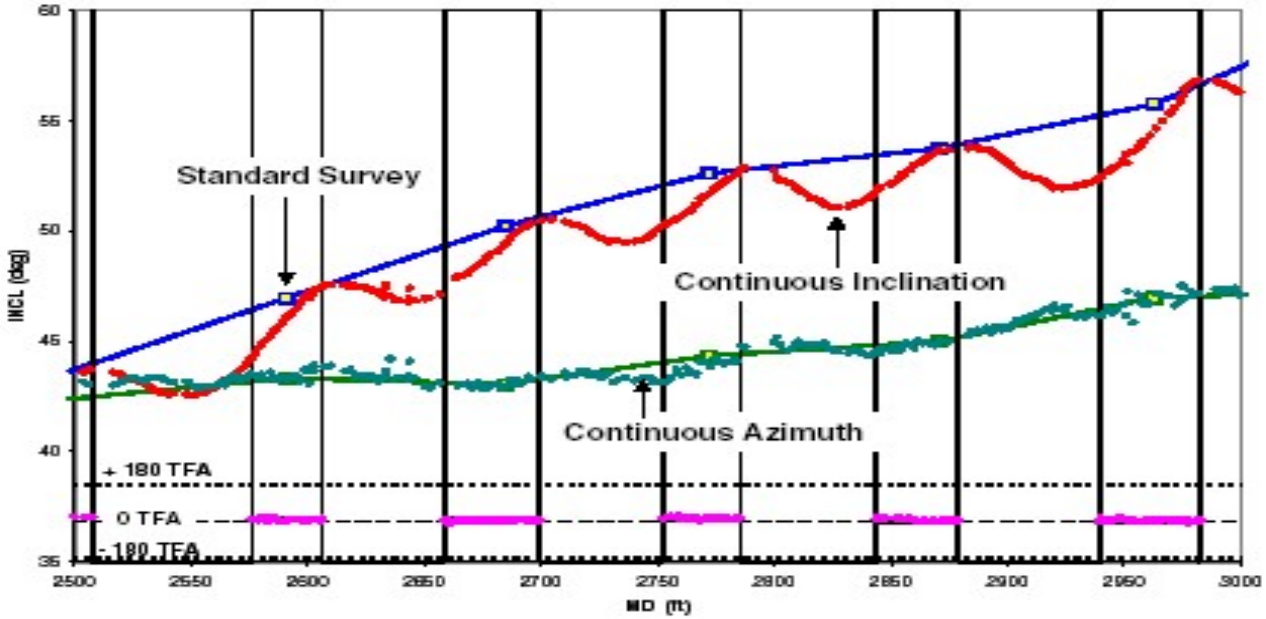
Steering, Slide and Rotate and DLS

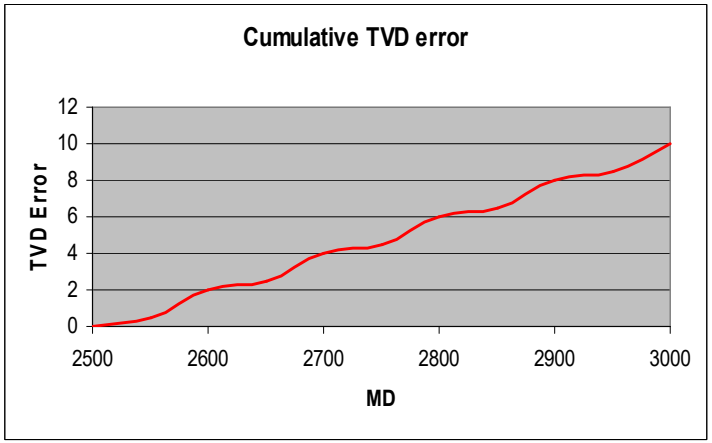






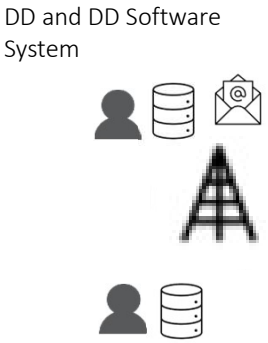
Short Interval Survey Case Study from continuous data





SPE Papers 79917/109972 – CVX/SLB

Survey QC

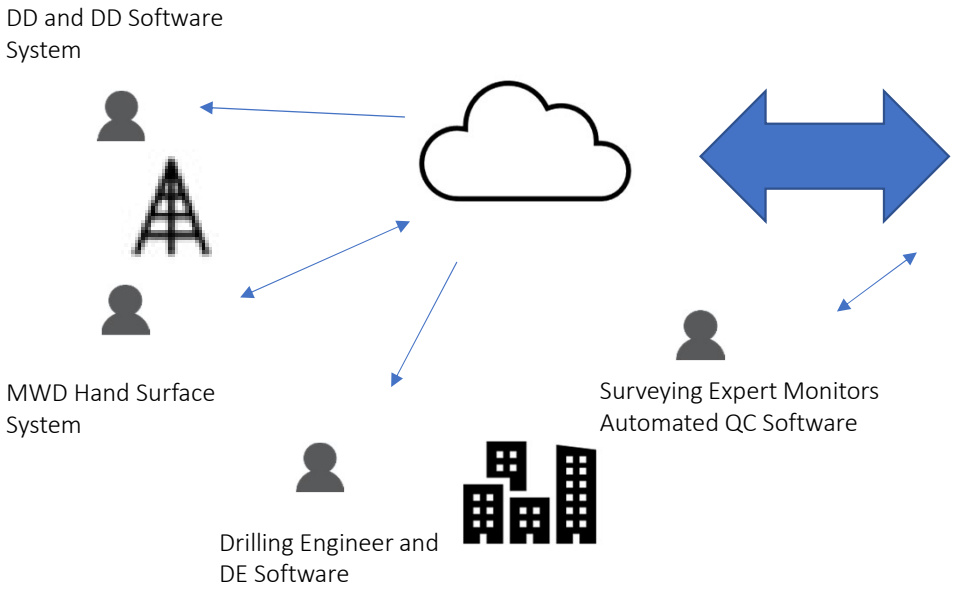


- **Add Surface Location and Global Reference Values from Well Plan**
- **Compare downhole survey with Field Acceptance Criteria set by service provider**
- **Escalate if questions**

- **Compare Surface Location with Plan**
- **Calculate Reference Values – IFR if needed**
- **Filter for trends in Total Field, Dip, Gravity**
- **Compare with Field Acceptance Criteria based on Survey Program Target Tool-Code**
- **Remove Gross Outliers**
- **Run Multi-Station Solution checking for drillstring interference size and uncertainties**
- **Compare Benchmark and Checkshots surveys if available**
- **Compare drillstring interference with expected interference based on BHA design**
- **Compare Well Plan and BHA tendencies with Actual Trajectory for unrealistic surveys**
- **Provide back final QC'd Surveys.**
- **Done in Batches – Takes 5-45 minutes**

Manual Data Transfers
High Risk of Gross Errors
Multiple "Definitive" Data Sets

Survey QC - Automation



Machine to Machine Data Transfer
Eliminate Gross Errors
One Definitive Data Set

- **Automatic QC Software Initiated: Surface Location, Well Plan, BHA and Survey Program Entered**
- **Surveys Streamed to Software, for each station:**
- **Calculate Reference Values**
- **Filter Surveys for trends in Total Field, Dip, Gravity**
- **Compare with Field Acceptance Criteria based on Survey Program Target Tool-Code**
- **Run Multi-Station Solution checking for drillstring interference size and uncertainties**
- **Compare Benchmark and Checkshots surveys if available**
- **Compare drillstring interference with expected interference based on BHA design**
- **Compare Well Plan and BHA tendencies with Actual Trajectory for unrealistic surveys**
- **Make final QC'd Surveys available**
- **Each Survey done in less than a minute**

Conclusion

- Reliable Estimates of Positional Uncertainty is important
  - Anti-Collision
  - Geological Positioning and Spacing
- Answer Products are available to address Positional Uncertainty
  - Lateral improvement with IFR Upgrades and Multi-Station Corrections
  - Vertical improvement with SAG, Short Interval Surveys, Dual-Inc, and Depth
- Survey QC Automation reduces risk of Gross Errors.
  - Eliminates manual data transfer
  - Improve QC'd Survey delivery time and rate

Questions?