ERROR MODEL MAINTENANCE COMMITTEE

- Andy McGregor

46th General Meeting
October 12th, 2017
San Antonio Texas, USA

Wellbore Positioning Technical Section

ISCWSA
The Industry Steering Committee on Wellbore Survey Accuracy (ISCWSA)

Speaker Information

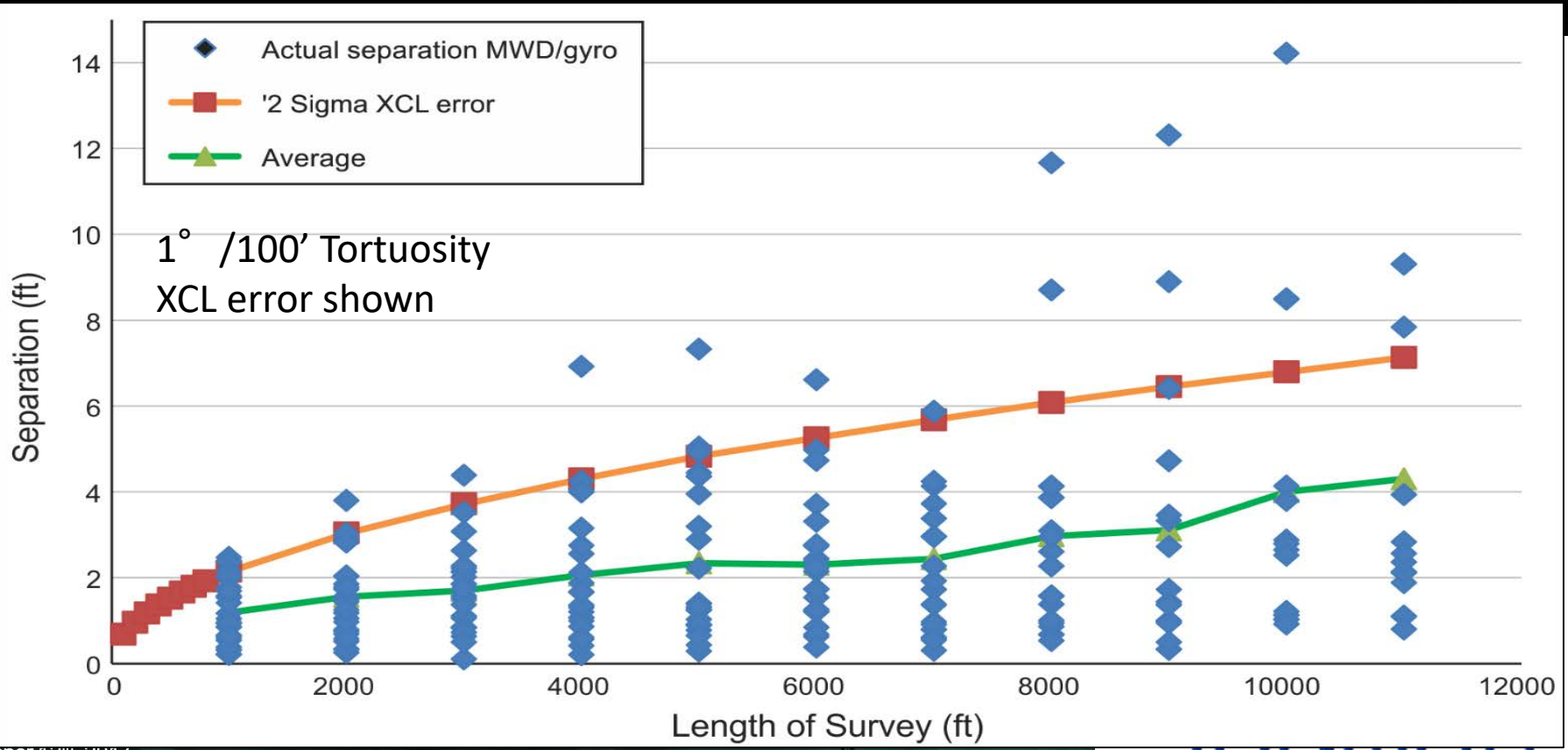
- Andy McGregor
- Wellbore Positioning Consultant
- AJC

- October 10th 2017

Long Course Lengths Models

- Jerry Codling worked on effect of survey interval
- SPE-187073-MS
- Accepted into the ISCWSA Model – now rev5
- OWSG models will also be updated
- Supersedes all previous version which considered the well profile perfectly characterized
- Documentation and diagnostic data to be provided
- Minor amendments needed for inc only models

yro


Actual separation MWD/gyro
'2 Sigma XCL error
Average
1° /100' Tortuosity
XCL error shown
Separation (ft)
Length of Survey (ft)
0
2
4
6
8
10
12
14
0
2000
4000
6000
8000
10000
12000

Long Course Lengths Models

xcl 0.167 max(DLS, const T),

Based on analysis of continuous gyro data

Will help cover the situation where a few surveys have failed QC, side-tracking, old surveys

Also includes some of Stockhausen effect at shorter intervals based on ‘average BHA performance’ in the original dataset.

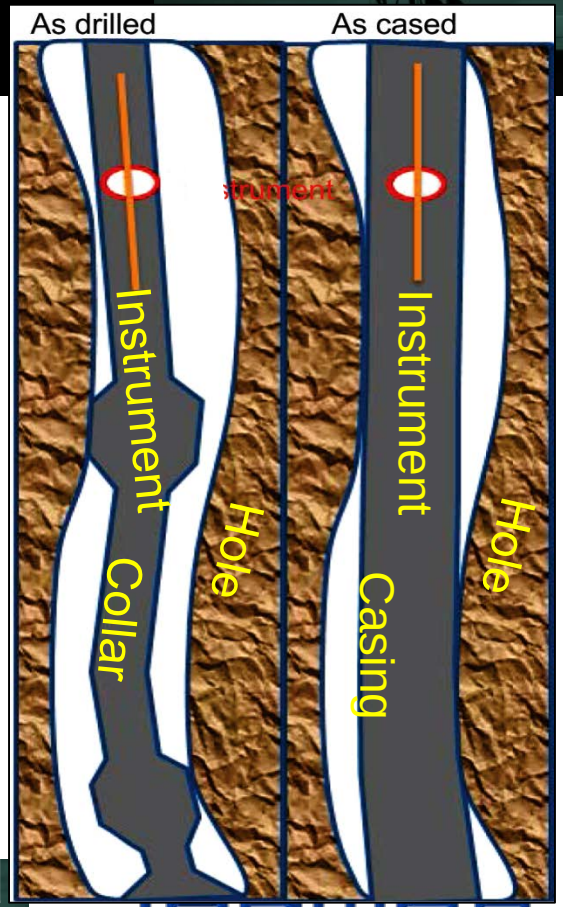
But caveat remains that is you introduce systematic drilling practices and do not survey frequently enough to observe these, then you could still be outside the ellipsoid

Misalignments

- Rev4 values too conservative?
- Sizes were increased and propagation kept random
- We discuss larger random term or splitting into random and systematic terms
- Difference in misalignment between tool offset in the BHA and BHA offset in the hole

- MWD – Collar to hole size over 40 ft.
- Gyro – Casing Connector to hole over 40 ft.
- Table of maximum angle from misalignment…

Type	Hole Size (in.)	Casing Size (in.)	Gauge Conn. (in.)	Collar Size (in.)	Casing Len. (ft.)	Angle Gyro (°)	Angle MWD (°)
Casing	26	20	21	9.5	40	0.60	0.98
Casing	23	18.625	19.625	9.5	40	0.40	0.81
Casing	17.5	13.375	14.375	9.5	40	0.37	0.48
Casing	16	13.375	14.375	9.5	40	0.19	0.39
Casing	12.25	9.625	10.625	8	40	0.19	0.25
Casing	8.5	7	7.677	6.5	40	0.10	0.12
Tubing	6	2.875	3.668	—	40	0.28	—
Tubing	8.5	3.5	4.5	—	40	0.48	—



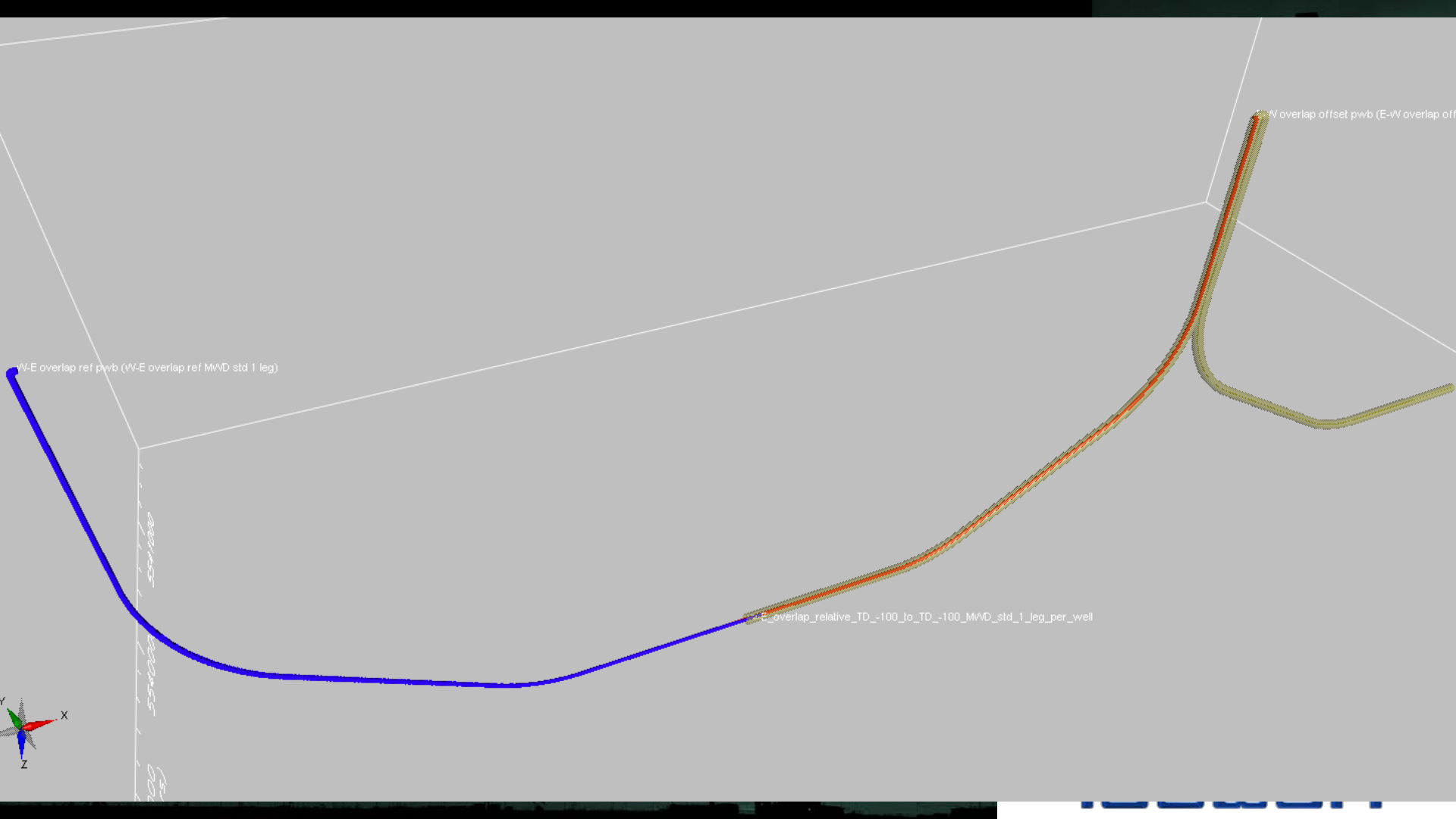
Documentation / Website

- Definition document done
- Spreadsheet examples done
- Need to go on website

- Searchable content
- Provide models in cloud based, machine usable formats?

Correlation of Error Sources

- Anti-collision method favouring combining covariances
- Current combined methods simply add covariance matrices and implicitly assume all errors are uncorrelated.
- Noted that this was not strictly correct for geo-magnetic reference terms
- Over optimistic in some scenarios


W overlap offset pwb (E-W overlap off
W-E overlap ref pwb (W-E overlap ref MWD std 1 leg)
E_overlap_relative_TD_-100_to_TD_-100_MWD_std_1_leg_per_well
Y
X
Z

Simple Method for Handling Correlations

- Analysed a series of wellplans on varying headings
- Only the global mag reference terms change
  - DECG, DBHG, MDI, MFI
- Varied correlations
- Result for that the combined covariance matrix for each source is a linear combination of the fully correlated and uncorrelated solutions

Simple Method for Handling Correlations

- For two wells, A and B usual combined covariance is
- $C_{A,B} = C_A + C_B s$
- This changes to
- $C_{A,B}^{Correlated} = C_{A,B} - \rho_{mag} \sum_{i \in MagRef} \left(E_{A,i} E_{B,i}^T + E_{B,i} E_{A,i}^T \right)$

Where for example:

- $E_A^{DECG} = \sum_{leg} \sum_{station} e_{l,k}^{DECG} + e_k^{*DECG}$

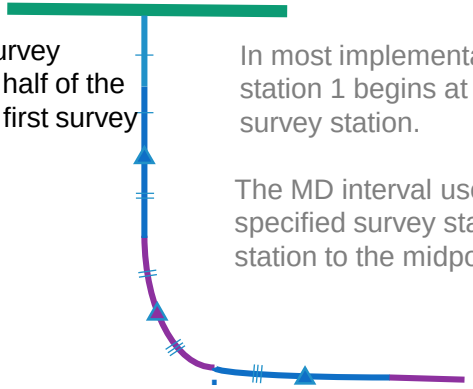
Work To Be Done

- Maths needs to be checked
- Write up and add to error model documentation
- Passed back to anti-collision meeting to decide how they want to handle this
- Evaluate and present worst case
- User identify when magnetic reference sources are the same
- Infer from the error models applied

Surface Tie-On

- Anti-collision test data set showed differences in surface tie-on
- Some software assumed inc and az at slot to be perfect.
- Hence no error accumulation on first half survey interval below slot
- Other software extended errors at first downhole point back to surface
- Not so much of problem if first survey is only 100ft down, but more obvious if there is a long gap to first survey
- Agreed to carry first point errors back to surface
- Can equally be handled by adding a dummy point
- Error accumulation is from well reference point i.e. not necessarily drill floor.

This means there is no downhole survey uncertainty associated with the first half of the interval between surface tie-on and first survey station.



In most implementations, the MD interval associated with station 1 begins at mid point between the surface tie-on and the survey station.

The MD interval used to calculate the uncertainty vector for a specified survey station is the midpoint from the previous station to the midpoint from the next station.

Surface tie-on, Harry Wilson

Geomag Look Up Tables

Currently different models with BGGM, Hi-Def, IFR term values for geomagnetic reference

Some vendors providing more detailed values – global lookup tables and field specific IFR values

Landmark consider pull these directly from vendor websites

Still need current models for planning evaluation

Need to consider visibility of web terms and ability to exchange with other software and users

Rotating Models
Sources

Heritage Values	Modified Heritage Values	Numerical Analysis of Simulation Data	Design Requirements Generated to Target MWD Std. Accuracy
•DRFR •DSPS •DSTG •ABZ •ASX, ASY, ASZ •MBZ •MSX, MSY, MSZ •DECG •DECR •DBHG •DBHR •AMIL •SAG	•XYM1 •XYM2 •XYM3 •XYM4	•AN1, AN2 →lateral shock & vibe •ANZ →axial shock & vibe •CA2, CA2 →centripetal accel •DSC →depth shift compensation	•AAXY →Accel XY attenuation from LP filter •AMXY →Mag XY attenuation from LP filter •PSD →XY phase shift btwn accels & mags •EDDY →XY interference from eddy currents

Tool Validation

Error model designed to give in-situ error magnitudes

Not easy to directly decompose errors to determine whether a given tool performs to the model in the shop

How to map 24 terms calibration values into 12 term error model values

What tests should MWD manufacturer perform to demonstrate his tool complies with the model

Group going to work on this