Improved BHA Sag Correction and Uncertainty Evaluation Brings Value to Wellbore Placement

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Summary

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  - BHA misalignment definitions
  - Current modelling limits
  - Aim of the study
- New Model & Results
  - Introduction
  - Sag & Horizontal Misalignment corrections & residual errors
- Operational Implementation
  - Applications
  - Case study
- Conclusion & Perspectives

Introduction

ISCWSA Presentation & Error model

Ø ISCWSA produces / maintains wellbore surveying error models for the industry

Ø Error sources :

- § Magnetic field uncertainties
- § Magnetic compass errors
- § Gyrocompass errors
- § Tool misalignment errors
- § Along-hole depth errors

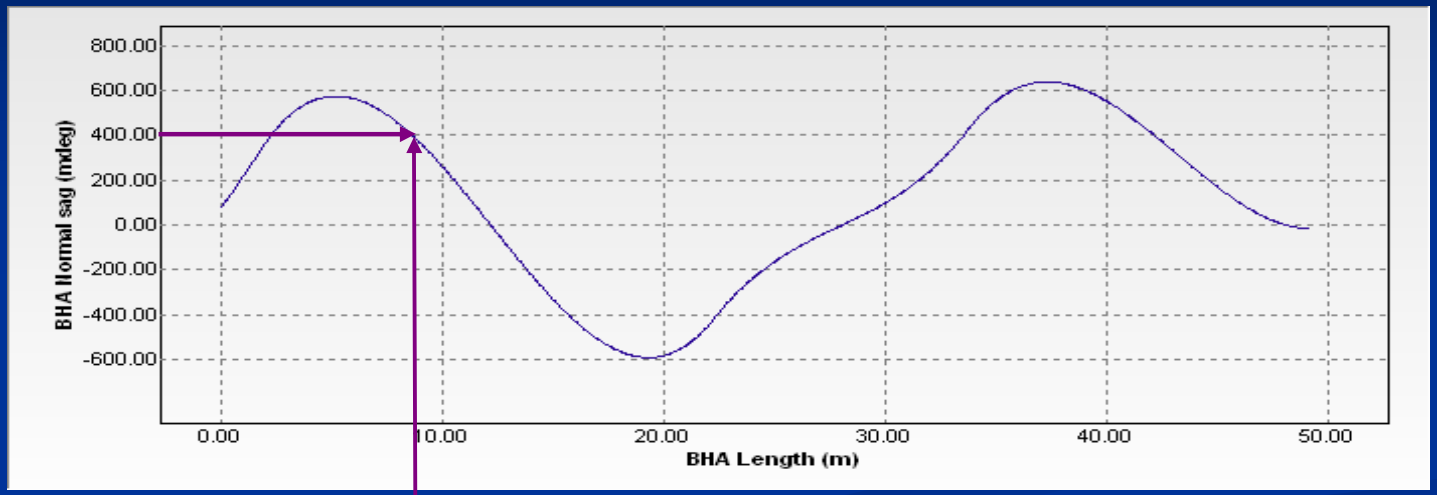
Ø Error terms :

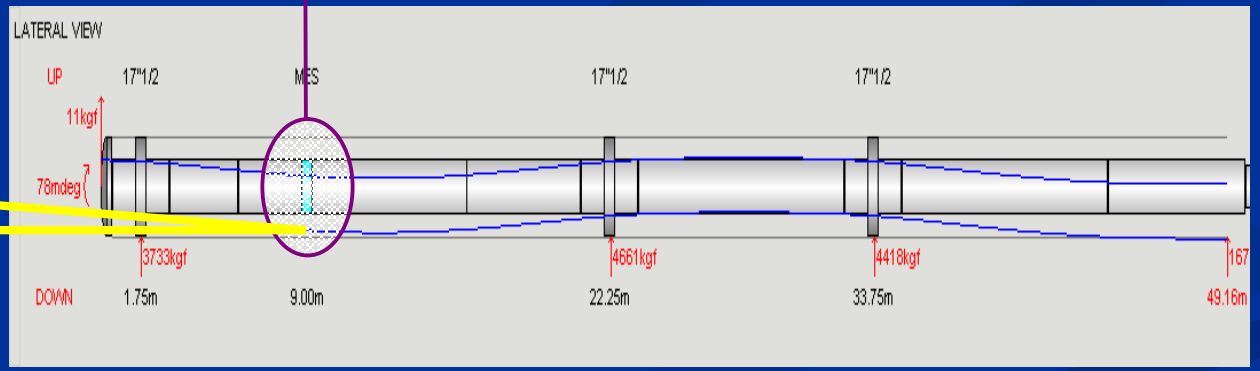
- § Name
- § Mean value
- § Magnitude, as a one s.d
- § Weighting function (D, I, A)
- § Propagation mode (R, S, W, G)

Ø BHA SAG is a tool misalignment error, subject of this presentation

Introduction

SAG definition





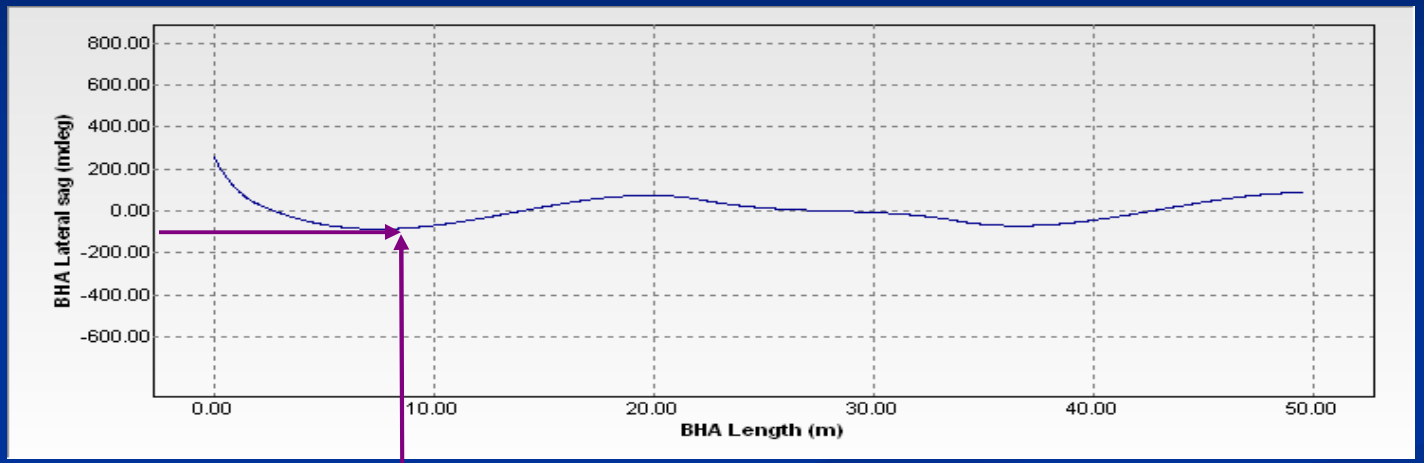
Measured inclination

Sag Error

True inclination

Introduction

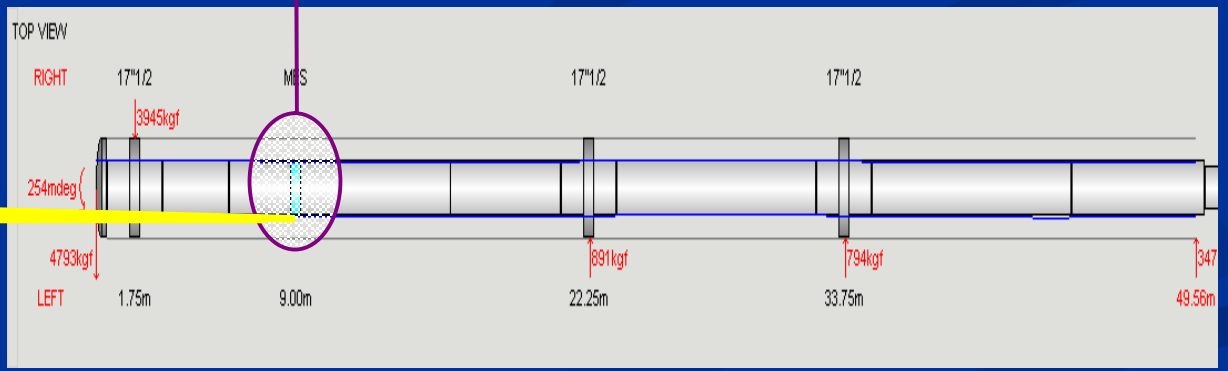
Horizontal misalignment definition



Horizontal misalignment Error

Measured azimuth

True azimuth



Introduction

Current sag modelling limits

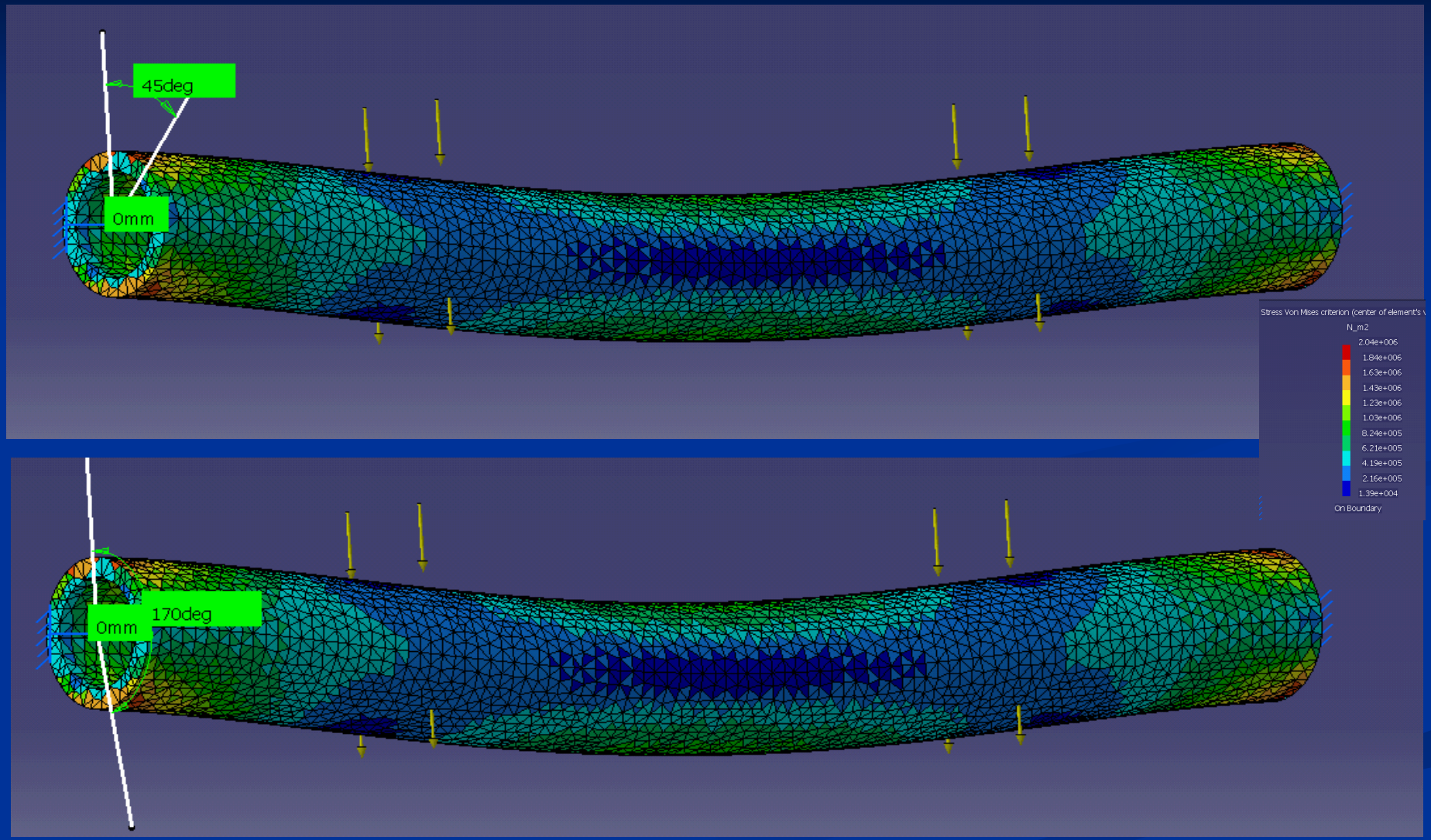
Without correction, sag error is given a magnitude of 0.2°
The weighting function *(0, sin I, 0)* describes the gravity effect but :

- Should we accept that BHA distortion is only due to gravity?
- Should we believe that a BHA with a bent sub has no sag in a vertical well?
- Are we underestimating the BHA sag error term for vertical wells?
- Are we overestimating the BHA sag error term for horizontal wells?

With correction, sag error is given a magnitude of 0.08°

- Based on a simplistic 60% sag correction efficiency statement
- The residual error, linked to input parameters, cannot be constant
- Should the residual error obey to the weighting function *(0, Sin I, 0)*?

Introduction



Introduction
Aim of the study

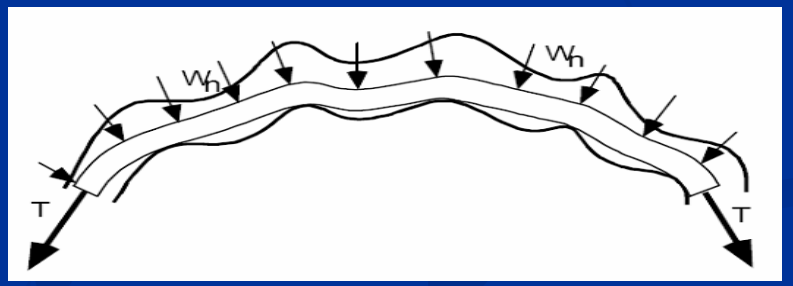
- **Motivation**
  - BHA sag is predominant in the inclination global error
    - Representing up to 80% of the TVD wellbore position uncertainty
  - Some control is needed on the sag correction process for validation of TVD uncertainty
  - Recognized limits of current Industry sag and horizontal misalignment modelling

- **Aims**
  - Clarify and quantify parameters affecting BHA sag
  - Propose a first model based on a complete methodology
  - Evaluate sag & horizontal misalignment correction
  - Evaluate residual errors.

New Model & Results

Introduction of the New Model

- A 3D BHA model featuring :
  - A unique analytical rigid solution for high volume computation
  - Real drill-string & BHA / hole interaction contact management
  - 3D trajectory reconstruction
  - All types of BHAs



- The following assumptions were done :
  - No WOB - the survey is taken off bottom
  - No friction - the BHA is not rotating
  - Continuous rigidity throughout element connections
  - No temperature effect on elements mechanical properties

New Model & Results

Modelled BHAs

BHA	Size	Type
1	17½"	MOTOR + VGS
2	17½"	MOTOR + VGS
3	17½"	ROT HOLD
4	17½"	ROT BUILD UP
5	17½"	ROT BUILD UP
6	12¼"	MOTOR + VGS
7	12¼"	MOTOR
8	12¼"	ROT HOLD + VGS
9	12¼"	ROT HOLD
10	12¼"	ROT BUILD UP
11	12¼"	ROT DROP OFF

New Model & Results

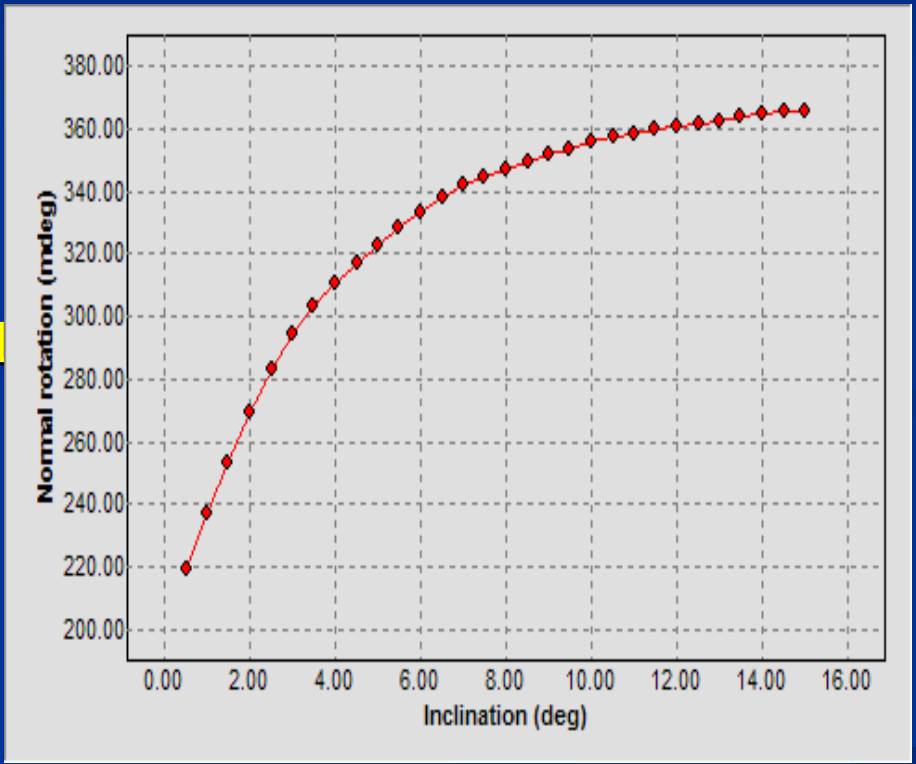
BHA Configurations for corrections

Parameters	Min	Max	Step	Number
Bent Angle (°)	0.6	1.8	0.6	3
TFO (°)	0	315	45	8
VGS Diameter (inch)	16.25 / 11.75	17 / 12.25	0.25	4
Inclination (°)	30	90	10	7
Build/Drop (°/30m)	-5	5	5	3
Turn (°/30m)	-5	5	5	3
Mud Weight (SG)	1.1	2.1	0.5	3
OVG (inch)	0.25	0.75	0.25	3
Sensor position (m)	2	5	1	4
ID MWD (inch)	2.5	4	0.5	4
		Total configurations		870 000

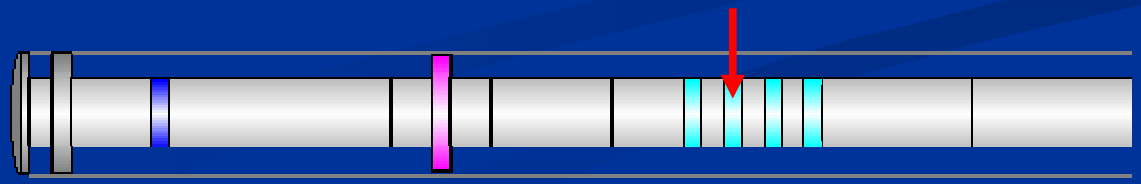
New Model & Results

BHA Sag correction

- Example of Hole overgauge effect
- Sag does not always evolve as sin I **No General ru**
- Sag exists for BHA with bent-sub in near vertical wells

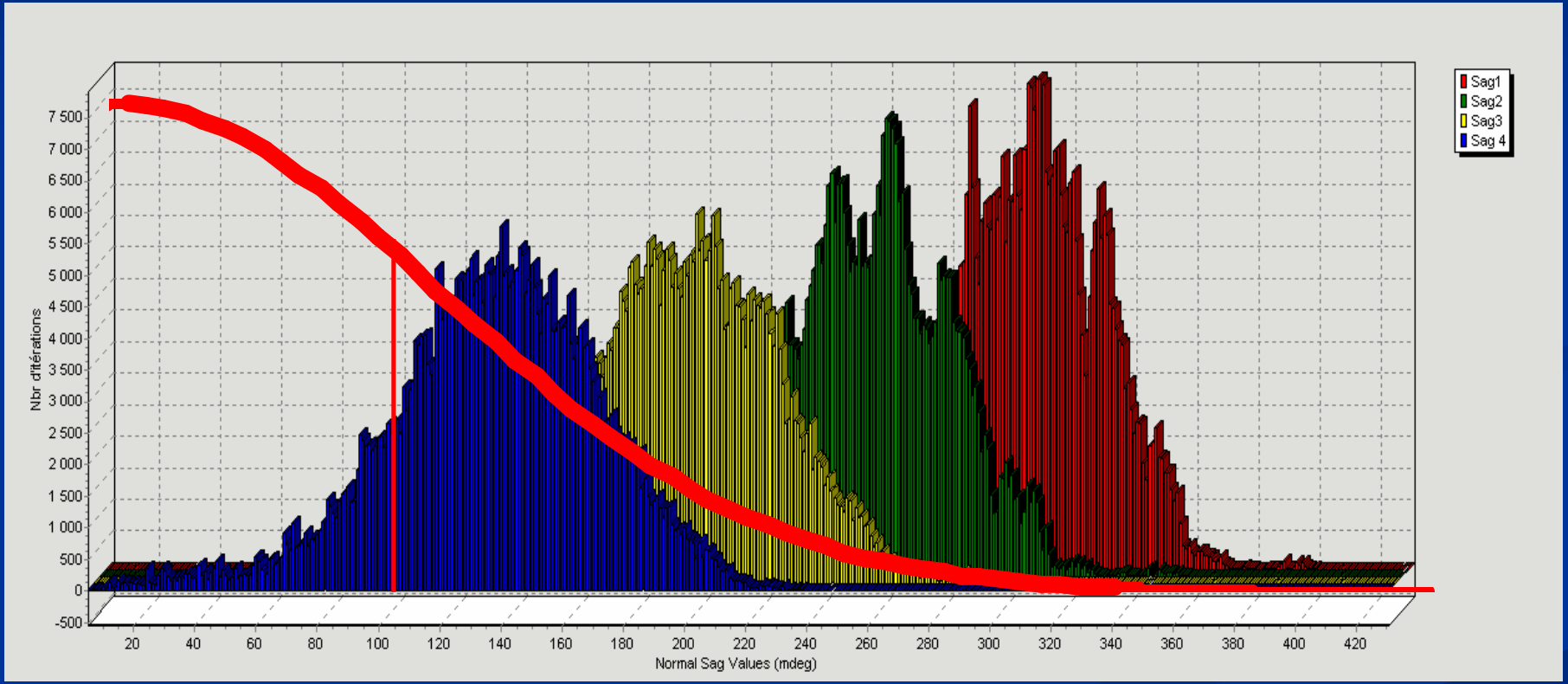


17½" BHA



New Model & Results

Sag correction - all 12¼" BHAs



§ Results are shown for a chosen inclination of 30°

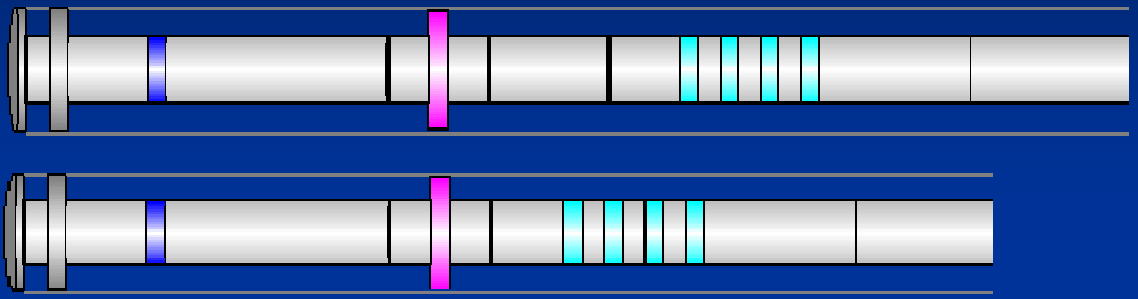
§ The Red curve represents the Industry Sag modelling at same inclination

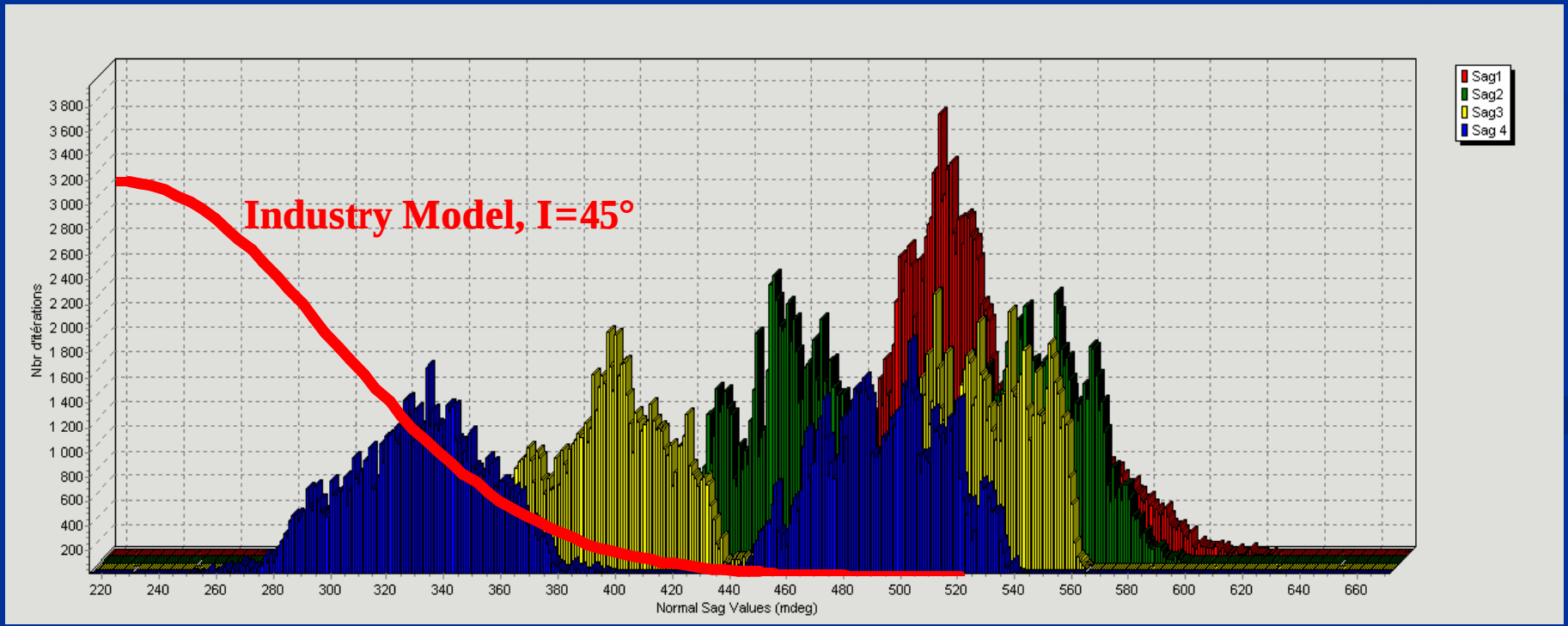
New Model & Results

Sag correction - 17½" BHA

17½" BHA 1

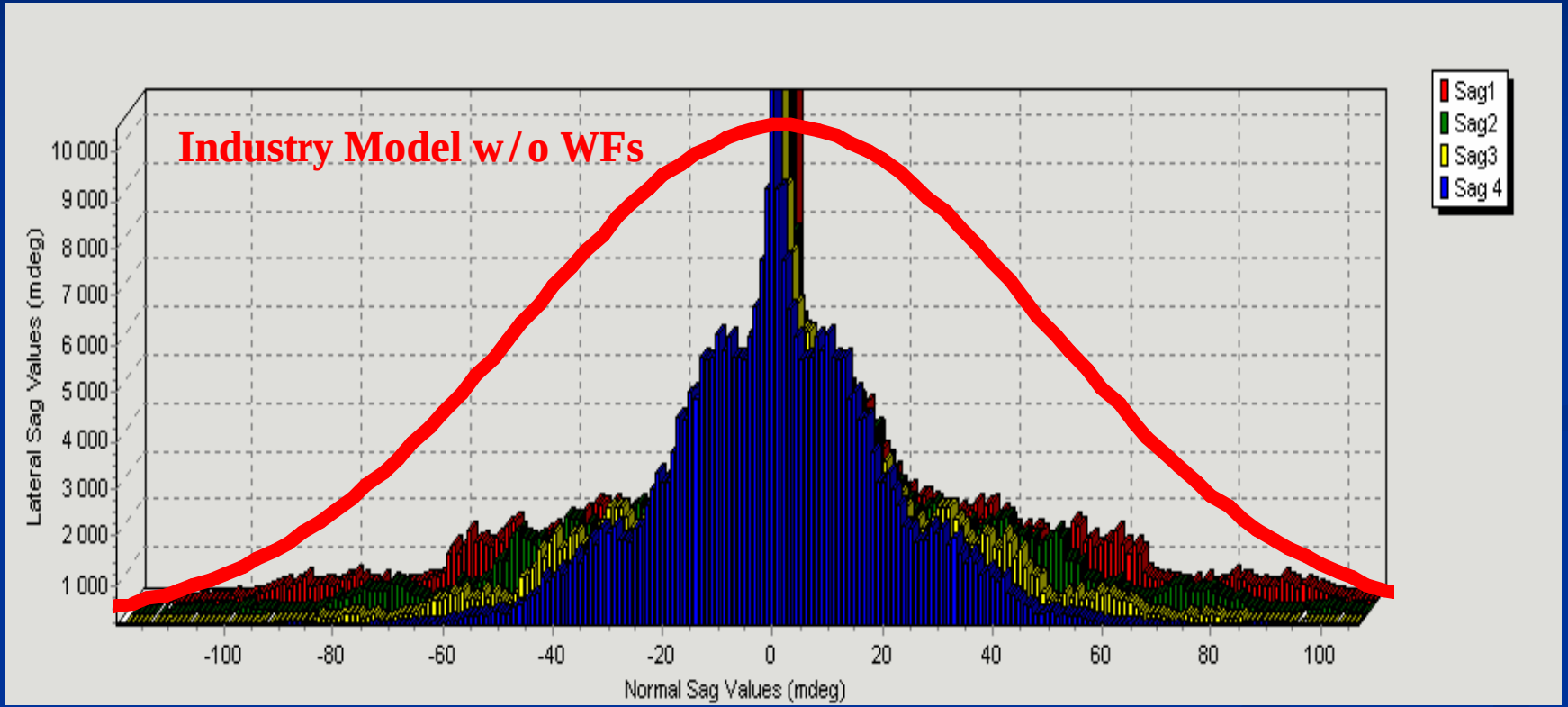
17½" BHA 2





New Model & Results

Horizontal misalignment correction – All BHAs



§ The horizontal misalignment correction ranges + / - 0.12°

§ The Industry error term is well modelled with a mean value of 0 and a magnitude of 0.04° but the weighting function should be (0, 0 ,1) Not Tool Face dependent

New Model & Results

Residual errors - Computation

Input parameters follow a normal law and are independent.

- **For each parameter μi :**
  - **μi0 = the expected value**
  - **σi = the standard deviation**
  - $\frac{\partial Fsag}{\partial mi}$ **= the weighting function**

- **For each survey, the residual error is the Root Sum Square of all errors contribution:**

$$s\ \text{Residual Sag error}\big|_{m10,m20,\ldots,mn0}(s_1, s_2, \ldots, s_n) = \sqrt{\sum_{i=1}^{i=n} si^2 * \frac{\partial Fsag}{\partial mi}\Big|mi0^2}$$

New Model & Results

Residual errors - Summary

Parameters	σ input Error (±)	Sag Error	Hor. Misalig. Error
Bent Angle (°)	0,10	10-3	4.10-4
Bent Housing position (in)	1,0	10-5	10-5
Sensor position (in)	2,0	2.10-3	10-4
TFO (°)	5,0	2.10-4	10-3
OVG (inch)	0,125	2.10-3	3.10-3
Inclination (°)	0,50	3.10-4	2.10-4
Build/Drop (°/30m)	0,25	10-4	2.10-4
Turn (°/30m)	0,25	10-4	10-3
Mud Weight (SG)	0,05	10-3	10-5
ID MWD (inch)	0,25	2.10-3	10-4
	σ Residual Error	0,0038	0,0035

Operational Implementation

Benefits

- **This new methodology can lead to :**
  - **Precise sag & horizontal misalignment correction**
  - **Reduced residual errors**
- **But requires :**
  - **A good knowledge on the system**
  - **Full data set**

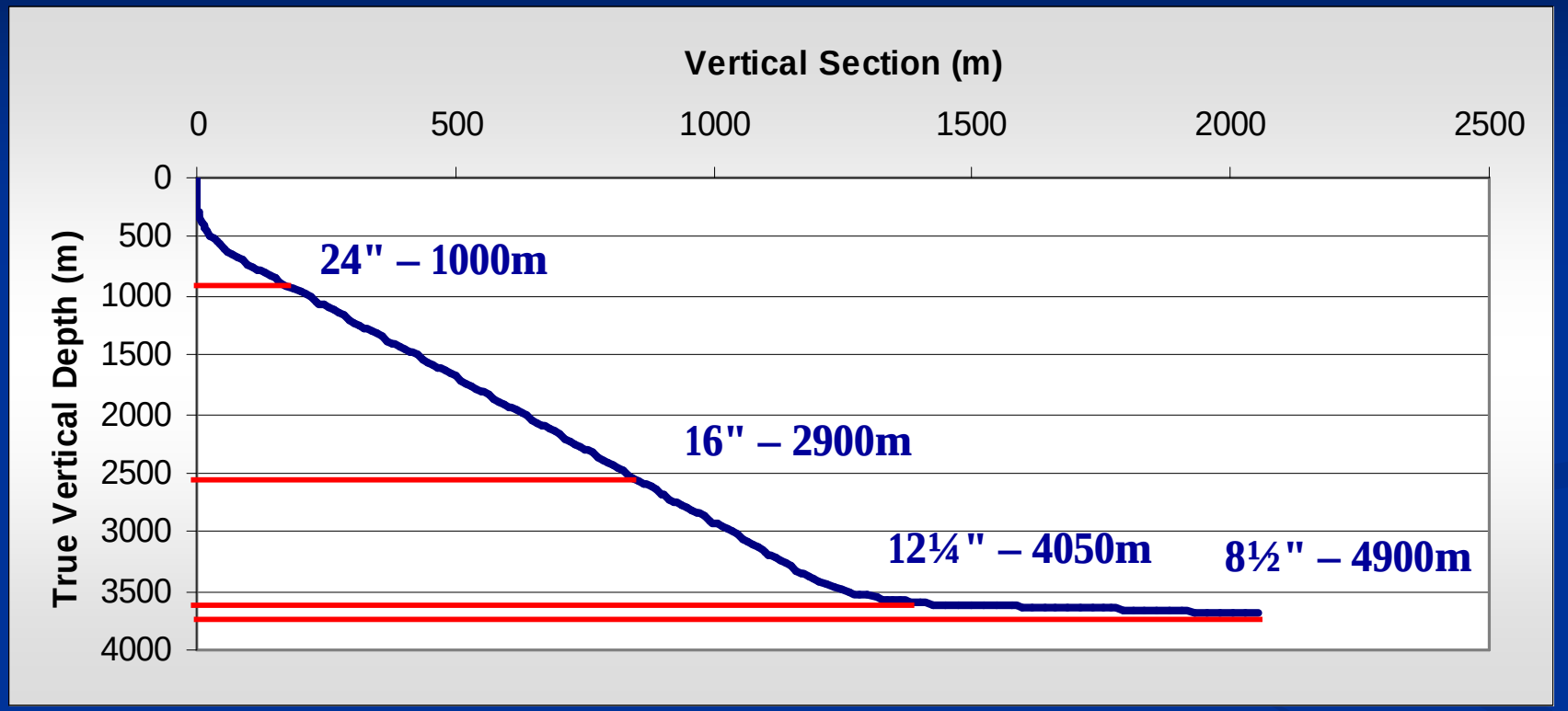
Ø ***It is implemented in a directional drilling BHA Management software with all the required information.***

Operational Implementation
Applications

- **Pre engineering**
  - Design BHA with reduced sag effect
  - Matching target sizing and TVD uncertainty estimates
- **While drilling**
  - Sag & horizontal misalignment corrections & uncertainties applied near to real time (operations support centre)
  - Enhanced target hitting and reservoir navigation
- **Post analysis**
  - Enhanced well position and uncertainties definition
  - Construction of a robust earth model

Operational Implementation

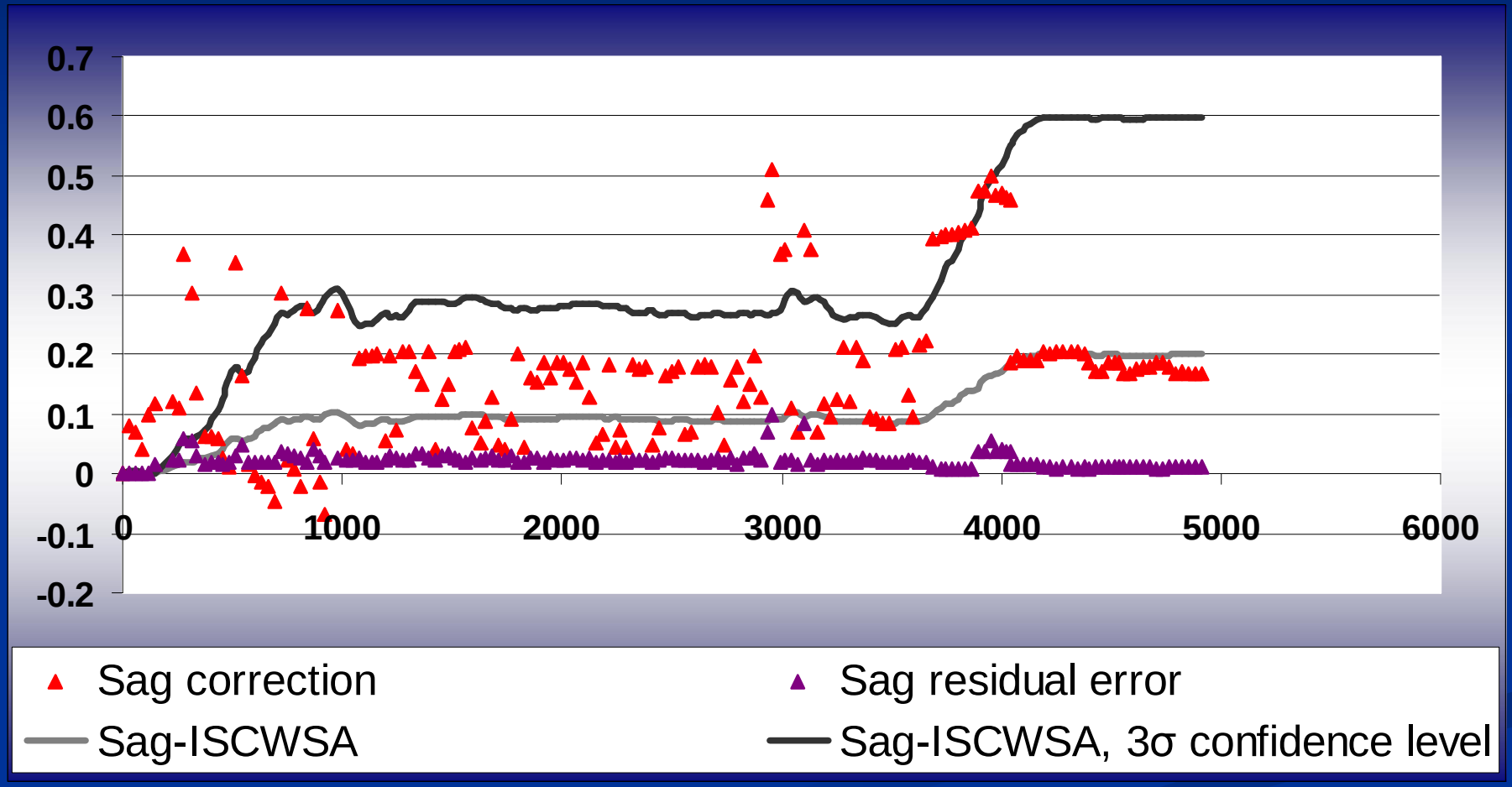
Case study - Presentation



Dia.	BHAs	BHA Type
24"	1	Steerable Motor
16"	3	Steerable Motor
12¼"	4	Steerable Motor
8½"	3	Steerable Motor

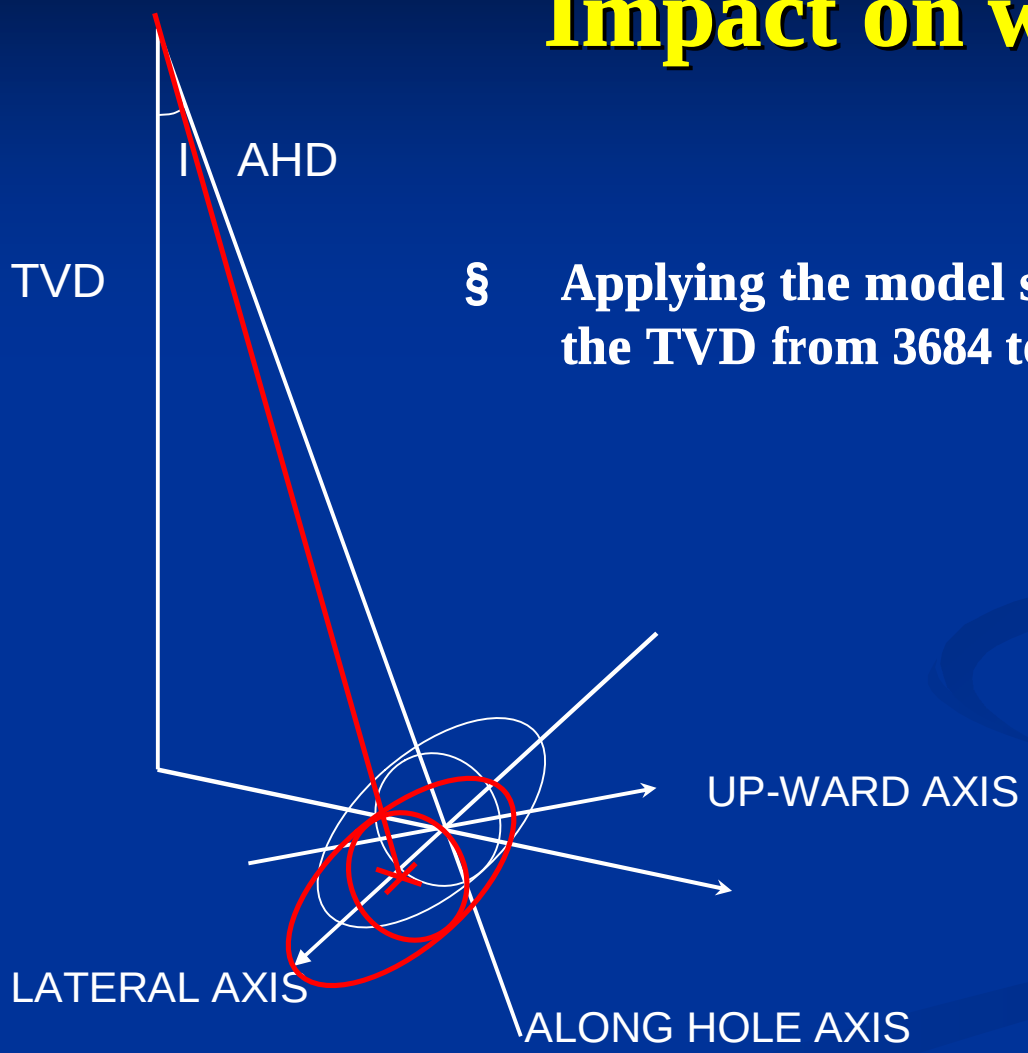
Operational Implementation

Case study - Results



Operational Implementation

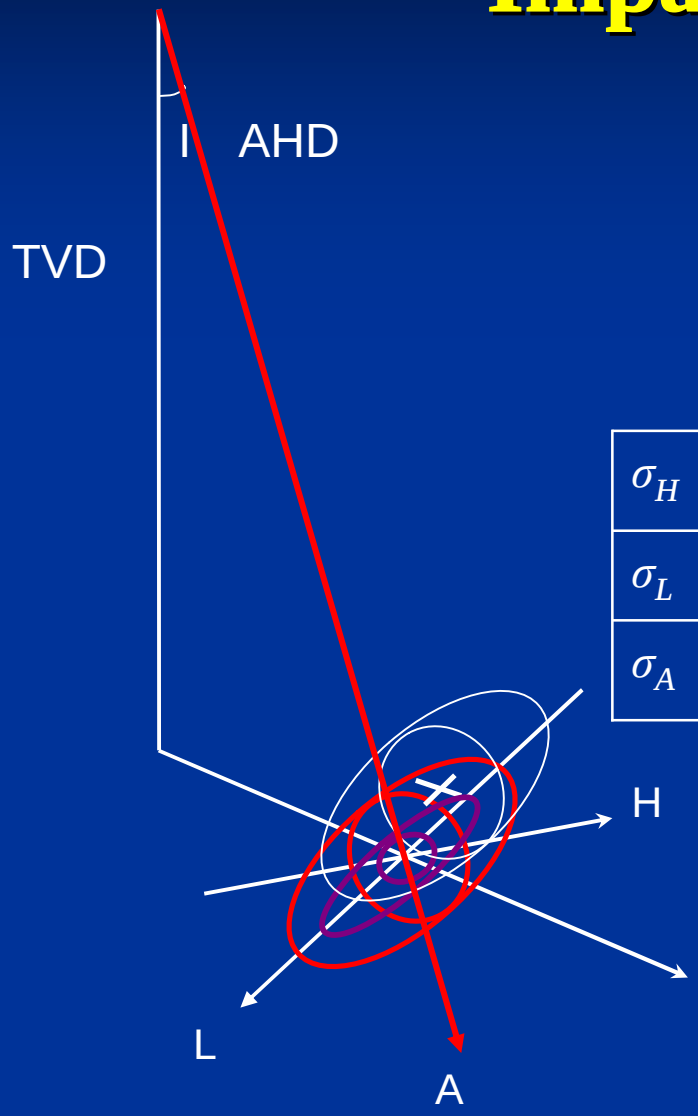
Impact on well positioning



- **Applying the model sag correction repositioned the TVD from 3684 to 3689.5m**

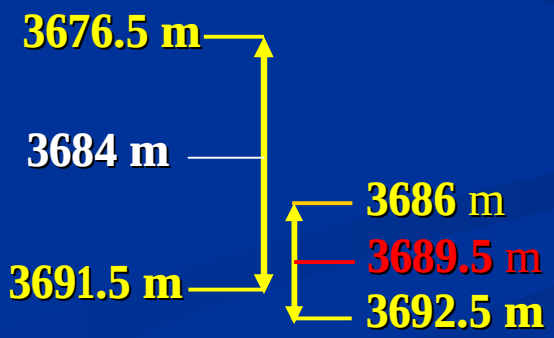
Operational Implementation

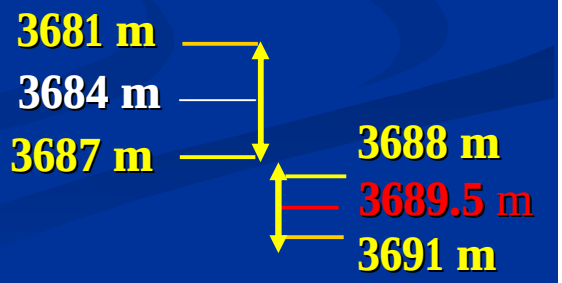
Impact on uncertainty reduction



§ **Applying the sag model reduced the E.O.U by 50%**

	Current Industry Single leg	New Model Single leg	Current Industry Multi leg	New Model Multi leg
σ_H	7.55	3.20	3.08	1.71
σ_L	32.17	30.41	11.69	11.07
σ_A	7.10	3.17	5.02	4.35





Conclusion

New Model Improvement

	BEFORE		NOW
Sag correction	No sag correction	0°	Computed
	Sag correction	Black Box	
Sag error	No Sag correction	0.2° [0, sinI, 0]	Computed Typical: 0.004°
	Sag Correction	0.08° * [0, sinI, 0]	
Hor. Misali. correction	0		Computed
Hor. Misali. error	0.04°		Computed Typical: 0.004°

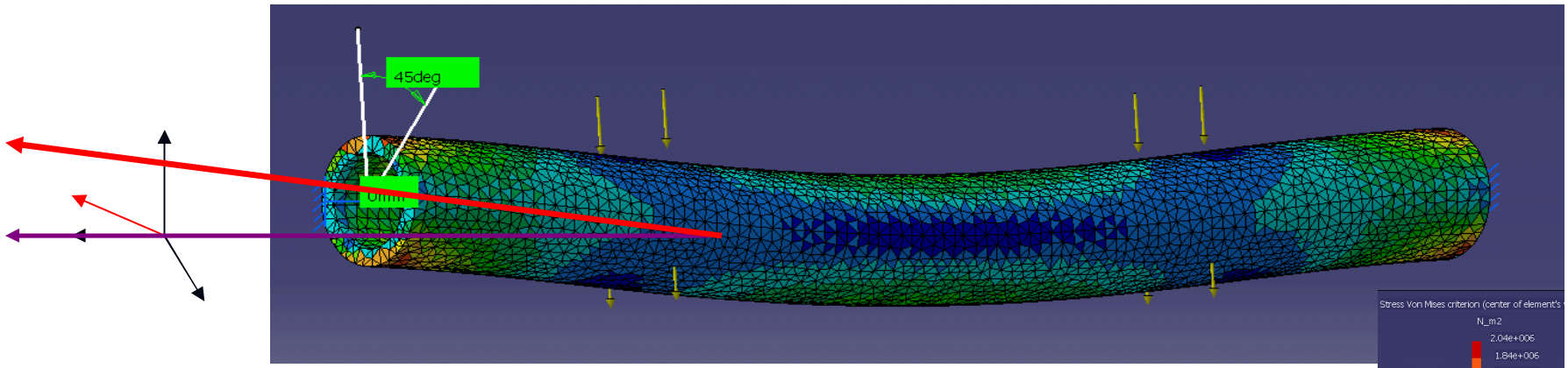
Conclusion & Perspectives

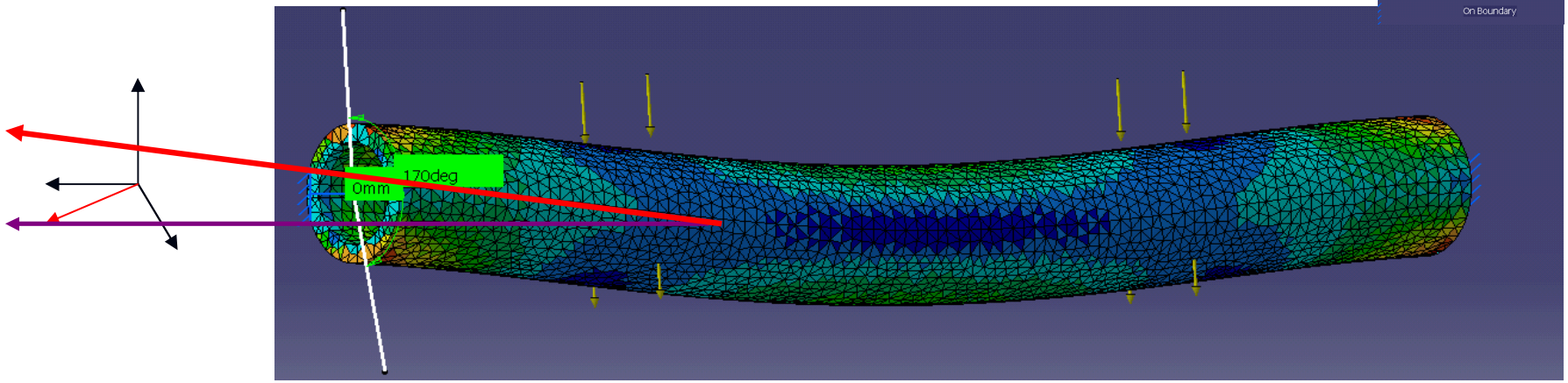
SAG Correction & Residual Error

What to remember

- Sag correction & residual error depend on the borehole trajectory, BHA design and settings
- Horizontal misalignment correction & residual error can be treated like BHA sag
- Residual error can be evaluated with regards of the input system
- Each survey has its own sag correction and residual sag error
- Case studies show Industry error model may underestimate sag effect
- Methodology described is easy to implement in actual model*
- Good sag correction leads to accurate well positioning
- Good residual error evaluation leads to realistic E.O.U

IT BRINGS VALUE TO WELLBORE PLACEMENT


45deg
0mm
Stress Von Mises criterion (center of element's
N_m2
2.04e+006
1.84e+006
1.63e+006
1.43e+006
1.23e+006
1.03e+006
8.24e+005
6.21e+005
4.19e+005
2.16e+005
1.39e+004
On Boundary


170deg
0mm