The Evolution of Real-time Torque & Drag Analysis from Manual Local Usage to Automated Cloud-based Analytics

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Agenda

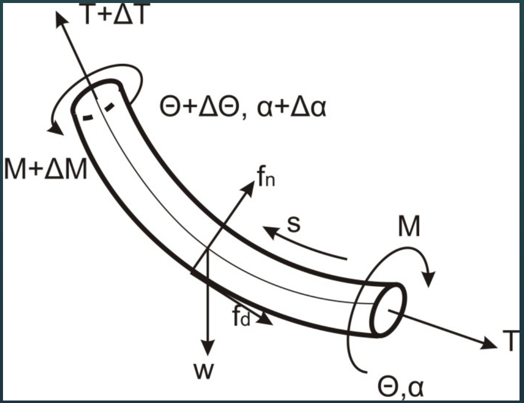
- Physics-based T&D Model
- Value of Real-Time T&D Analysis
- Key Requirements
- Evolution of RTTD Methods
- Automated Cloud-based Analytics

Physics-based T&D Model

Assumptions

- Static equilibrium
- Wellbore friction causes drag and torque
  - Lumped parameter friction factor
- Soft string
  - Drillstring in contact at all tooljoints
  - Neglect bending stiffness + radial clearance
- Buckling
  - Separate “bolt on” calculation

Governing Equations



$$F_n = [(F_t \Delta\alpha \sin\bar{\theta})^2 + (F_t \Delta\theta + W \sin\bar{\theta})^2]^{1/2} \ldots$$

The equation for normal force leads immedia equations for the tension increment:

$$\Delta F_t = W \cos\bar{\theta} \pm \mu F_n, \ldots$$

and for the torsion increment:

$$\Delta M = \mu F_n r. \ldots$$

SPE 11380-PA Johancsik et al. 1984 “Torque and Drag in Directional Wells – Prediction and Measurement”
• The classic paper on T&D by Exxon

Value of Real-Time T&D Analysis

Enhance ROP

- Monitor/adjust transfer of weight and torque to bit
- Avoid drillstring buckling
  - WOB transfer, sliding, drillpipe or casing wear
- Improve downhole MSE calculation

Reduce NPT and ILT

- Detect deteriorating hole conditions
  - Cuttings buildup, hole instability, impending packoff
- Avoid high total stress on drillstring
  - Twistoff, fatigue
- Optimize wiper trips and hole treatments

1989: Early Vision of Value

Table 9 Diagnostics for Well Bore Friction Interpretation

DRILLING PROBLEM	DIAGNOSTIC						POSSIBLE REMEDIES
	DRAG	FRIC	MUD PROPERTIES	STABILIZER PLACEMENT	HYDRAULICS	OTHER	
Thick filter cake/ differential sticking	Gradual increase to over 5% while drilling	Gradual increase while drilling	High fluid loss High percentage of low gravity solids			High differential pressure	- Work pipe at connection (back ream if using top drive) - Wiper trip - Condition mud and wiper trip
Cuttings build up in annulus	Gradual increase to over 5% while drilling	Gradual increase while drilling	Low yield point Low gel strengths		Low annular velocity	High hole angle Low percentage of cuttings returned to surface while drilling Very high ROP	- Increase flow rate - Circulate off bottom - Pump a high viscous pill - Condition mud - Ream high angle hole section - Control drill
Stabilizers hanging up	Sharp increase while drilling to over 5%	Sharp increase while drilling		Stabilizers above the MWD are located in sandstone or hard stringer (as indicated by MWD gamma ray or resistivity)			- Work pipe (back ream if using top drive) - Short wiper trip so that BHA passes through tight hole section

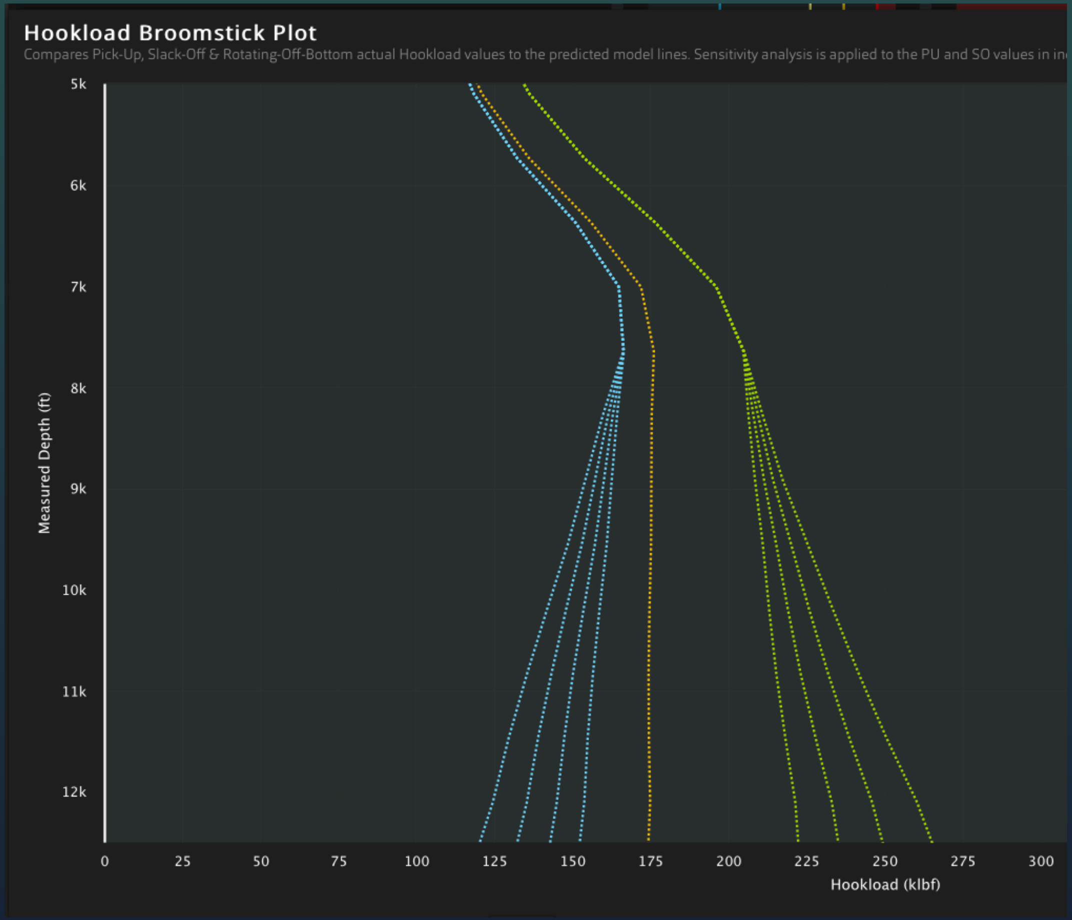
SPE 18649 (1989) Falconer et. al. “Applications of a Real Time Wellbore Friction Analysis”

Future Value: Automated Drilling

- SPE Drilling Systems Automation Technical Section (DSATS)
- Real-time knowledge and control of the drillstring
- Who would leave here today in a driverless car?
- Who's ready for their rig to be completely automated?

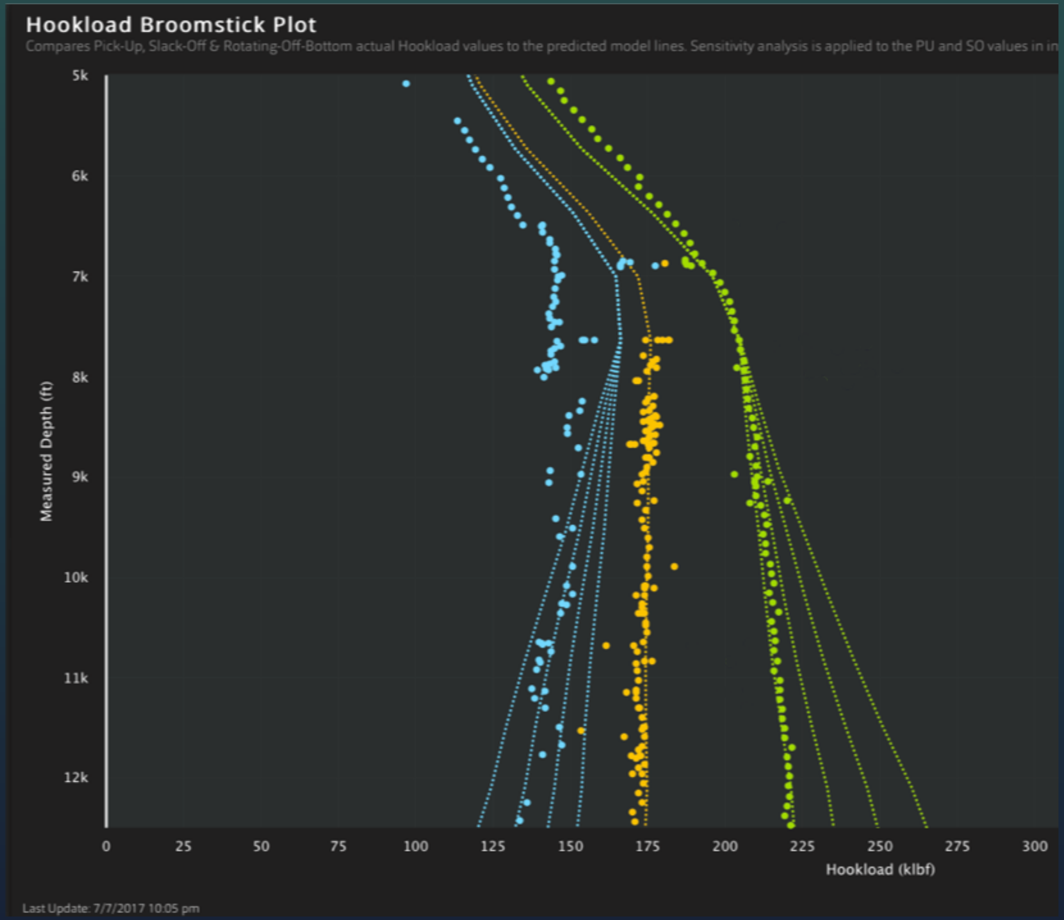
Key Requirements
Physics-Based Model

- Data input
  - Manual vs Automated
- Rig activity specific
  - PU, SO, ROB, Wash up/down, Ream up/down, etc.
- Normal conditions
  - Models must be calibrated but not over done
  - When to calibrate?
  - Continual knobbing masks NPT

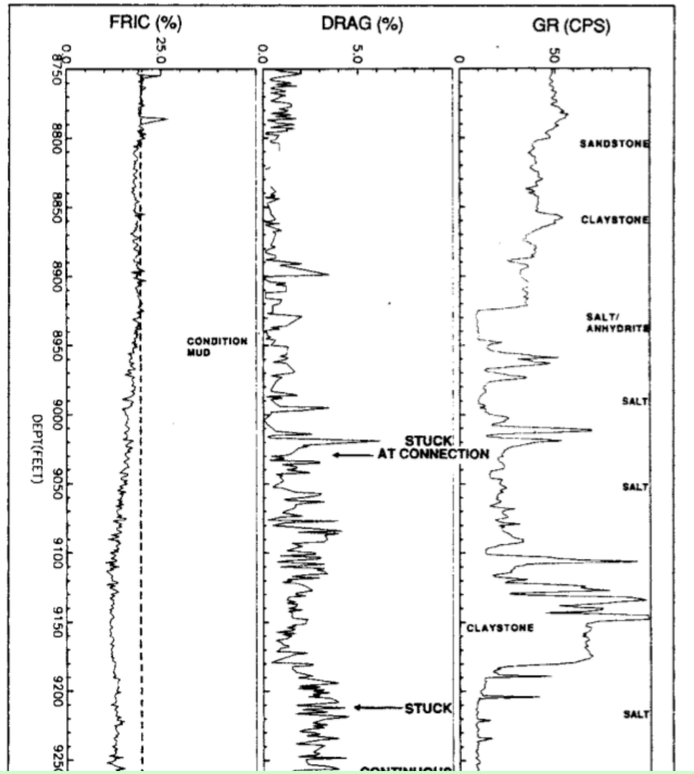


Key Requirements (2)
Data Capture and Rig Activity Detection

- Rig activity detection
  - Manual vs automated
- Data capture
  - Manual vs automated
  - Rig activity specific
  - Drilling and connection practices complicate auto detection
- Smart filtering allows capturing "right" data for different activities
  - Add wash up/down and ream up/down to conform to rig's drilling practices rather than other way around



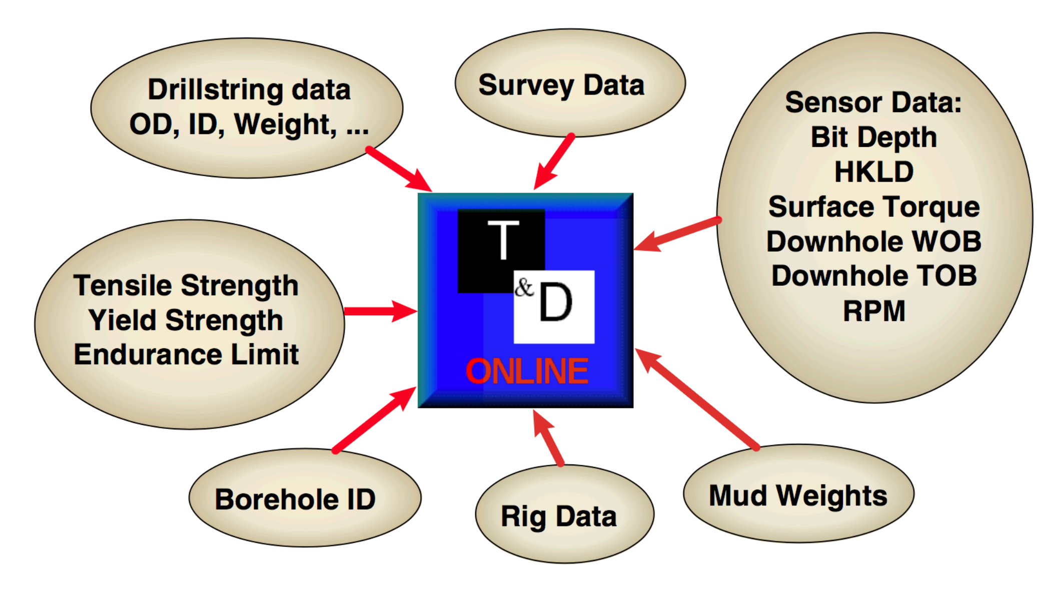
Evolution of RTTD Methods
1987: Friction Factors Logs

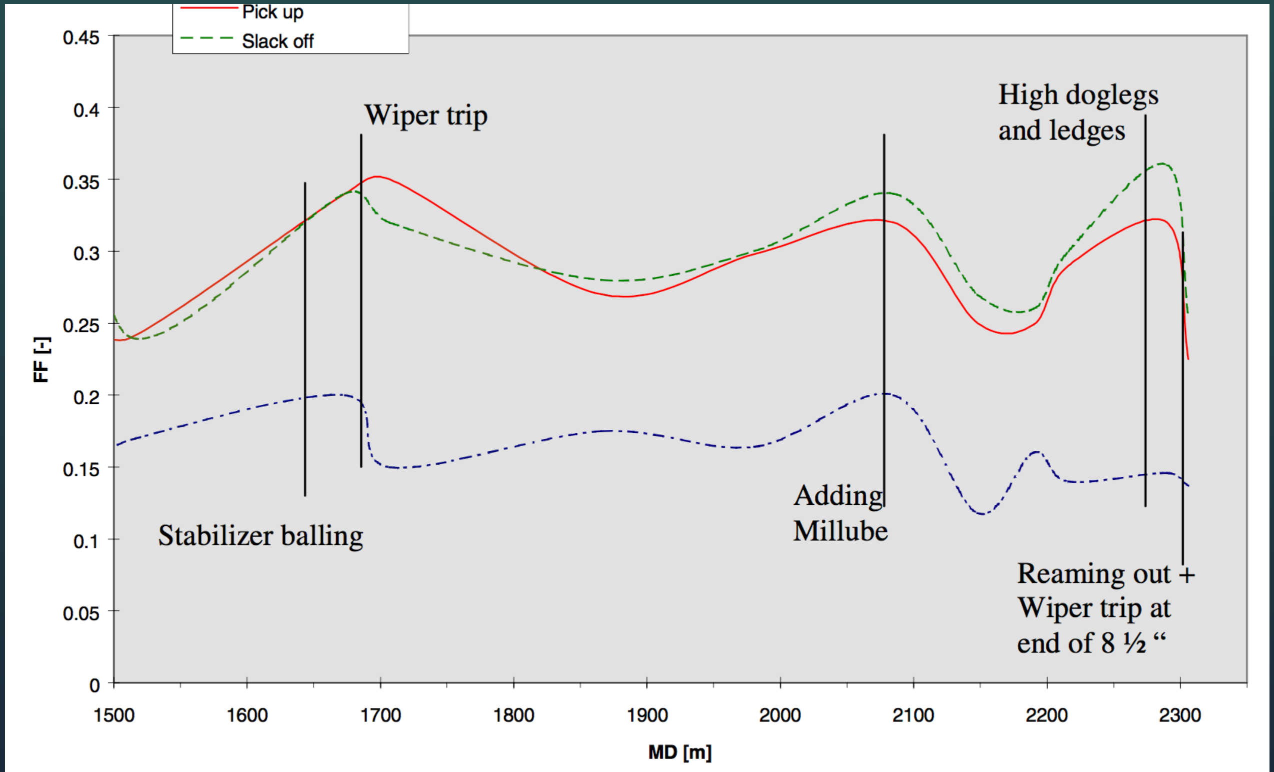


SPE 16114 (1987) Lesage et. al.
"Evaluating Drilling Practices in Deviated Wells with Torque and Weight Data"

- "Sharp increase in rotating friction factor is a warning sign of a drilling problem."
- Detect differential sticking and buckling
- Limitations of approach
  - Required downhole WOB/TOB tool
  - Long computational time on mainframe
  - Heavy manual manipulation to detect rig activity, input data, process results

2000: Enhanced NPT Detection

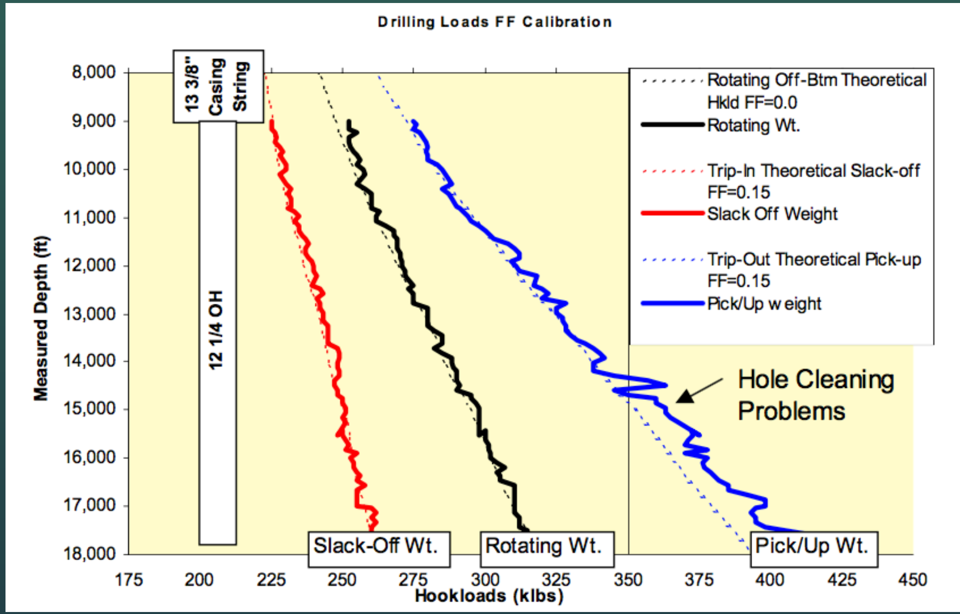


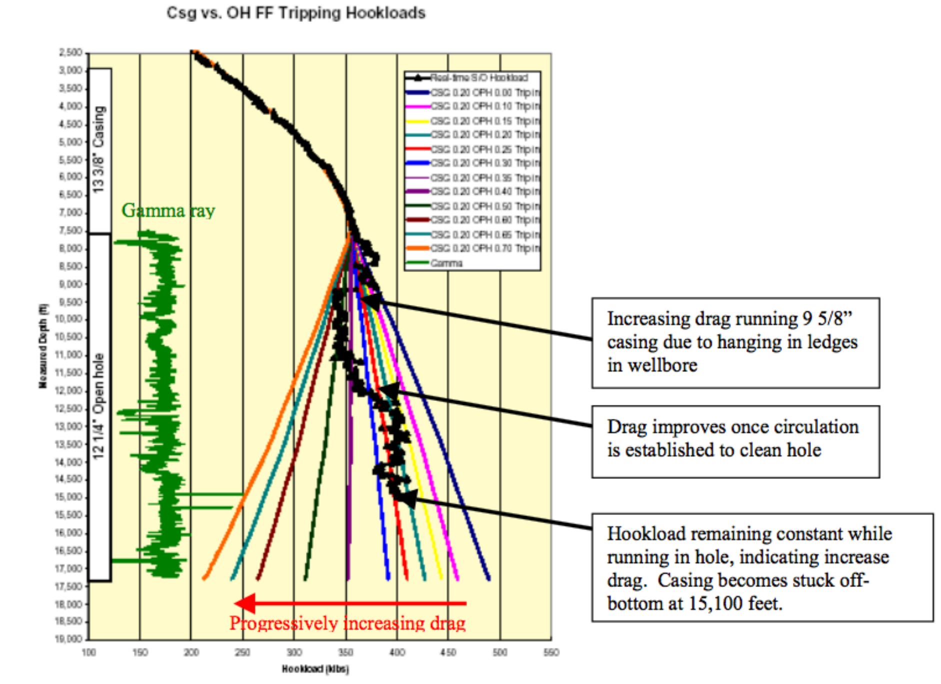


SPE 62784 (2000) Vos and Rieber "The Benefits of Monitoring Torque and Drag in Real Time"

2003: Broomstick Plots

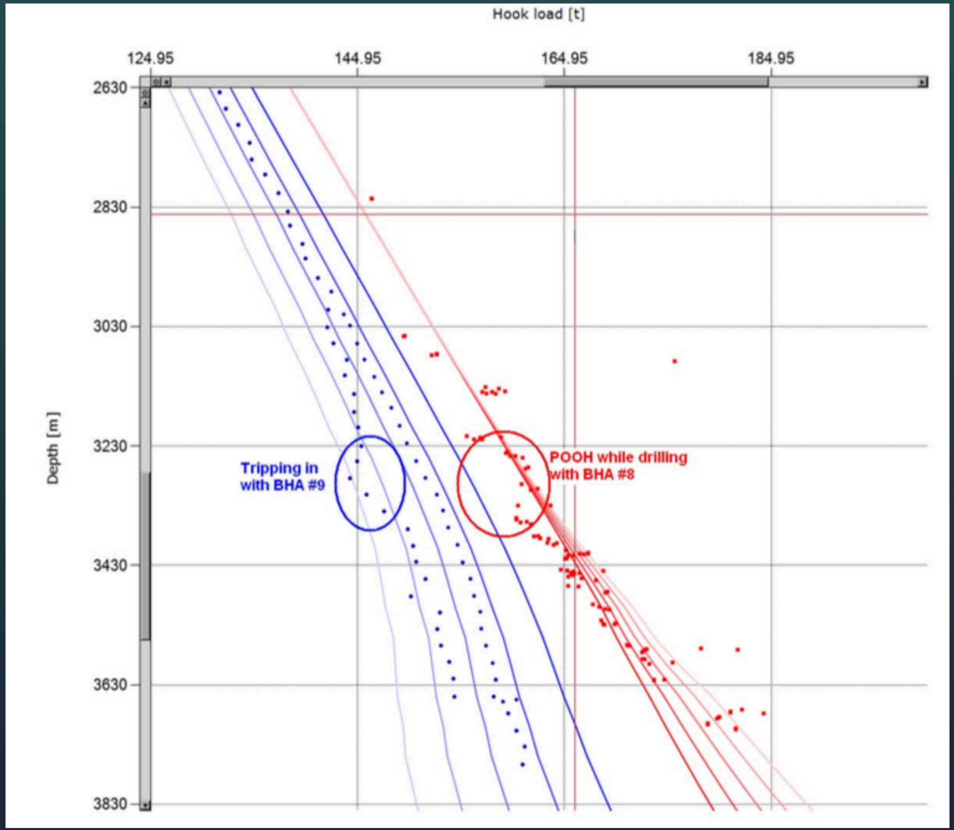
- Improved visualization to monitor hole conditions in real time at rig site
- Surface measurements recorded by driller
- Modeling in town and sent to rig for each hole section





AADE-03-NTCE-24 (2003) Lenamond "A Graphical Hole Monitoring Technique to Improve Drilling in High-Angle and Inclined Deepwater Wells in Real Time"

2008: Automated Rig Activity Detection

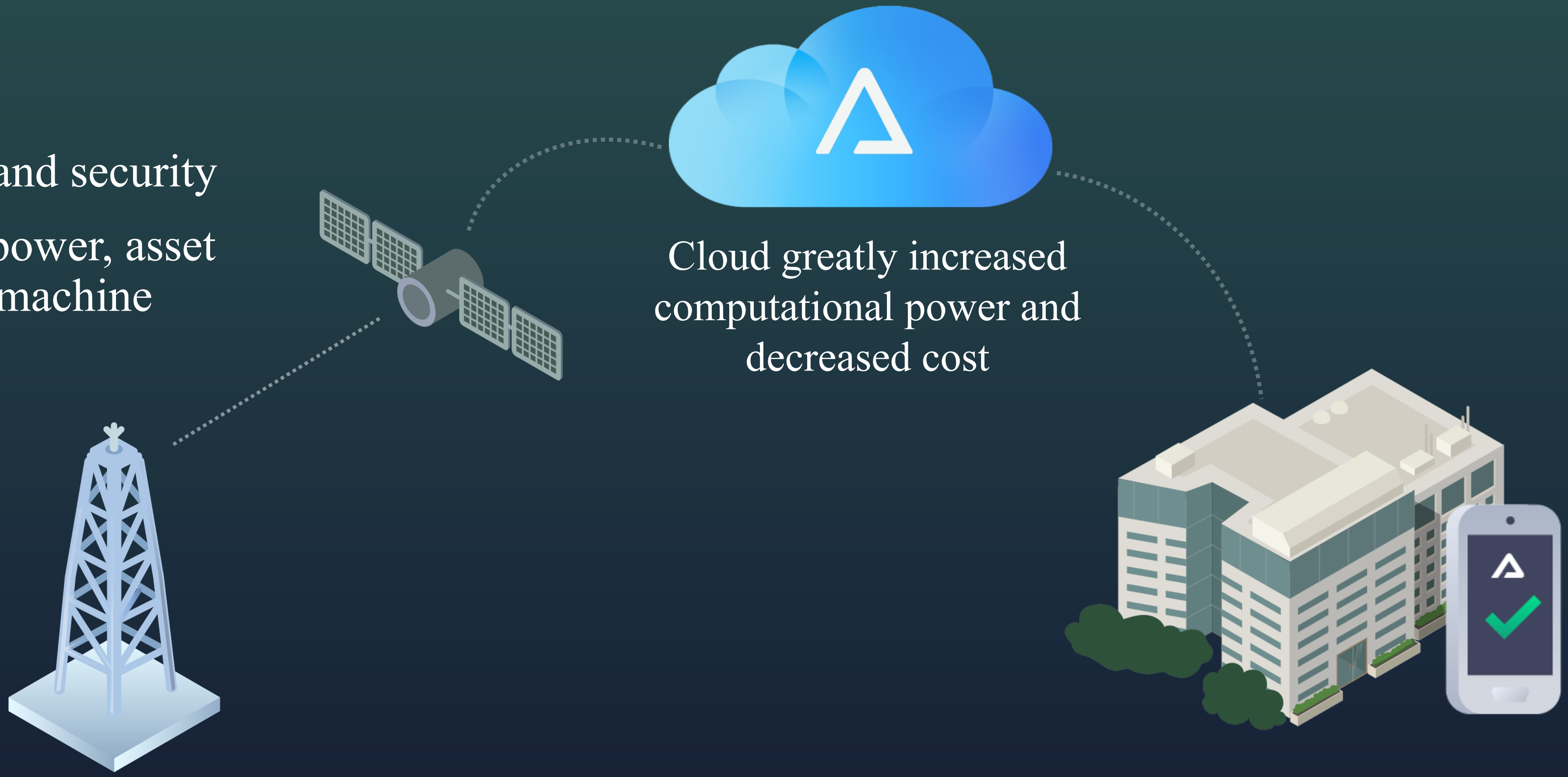


SPE 112565 (2008) Kucs et. al. "Automated Real-Time Hookload and Torque Monitoring"

- Optimization engineer runs T&D software to develop models
- Output to Excel files with 5 friction factors and different operations
- Results in 3 Excel files POOH, RIH, ROB
  - Valid for one wellbore geometry, one BHA, one mud weight
  - Files input into RT T&D monitoring tool for visualization
- Major advancement through automated rig activity detection
  - But model predictions were manual that prevented real-time updates

Enter Cloud-Based Analytics

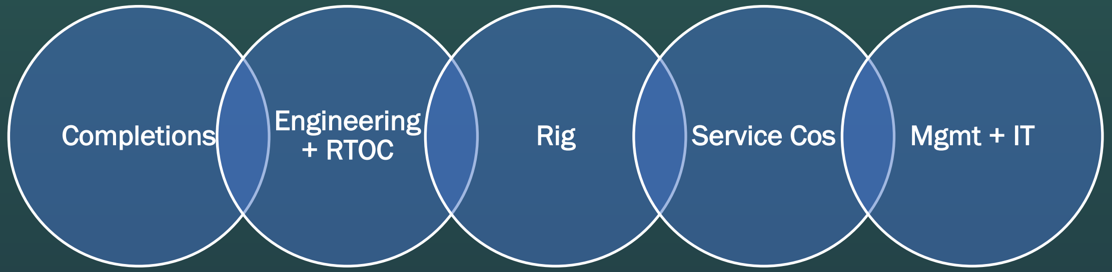
- Fast response to business needs
- Instant scalability
- Third-party API access
- Improved data sharing and security
- Significant computing power, asset health monitoring, and machine learning

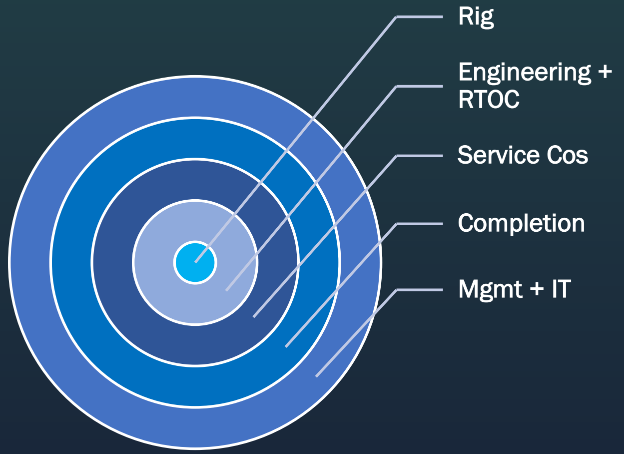


Benefits for Cloud RT T&D

- Mobility for users
- Common view for entire team
  - Collaborative decision making
- Updates to global operations at the same time
  - Configuration control
  - New features and enhancements
- Experts' knowledge shared via algorithms & real-time community chat

Silos

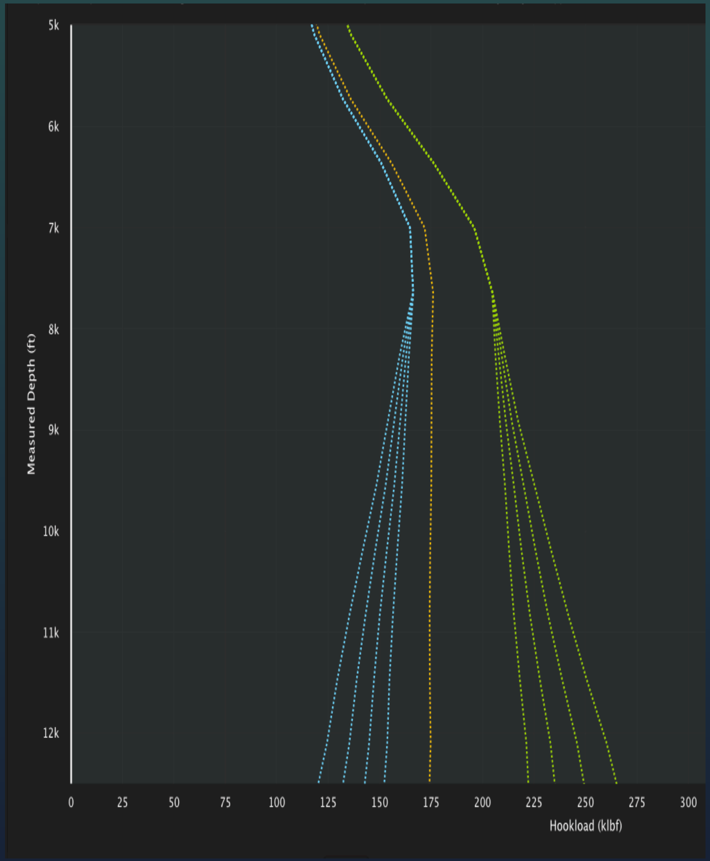




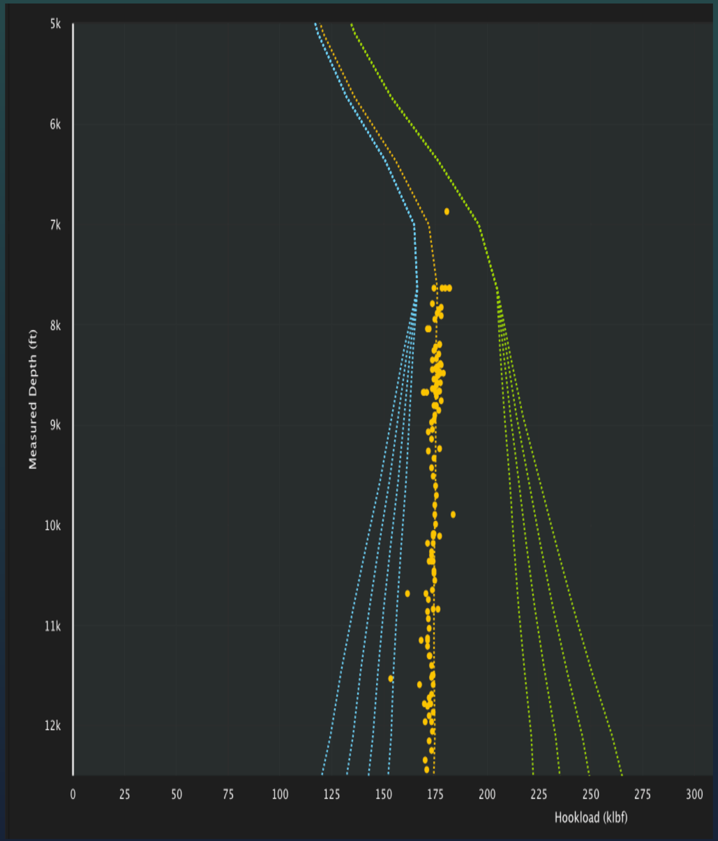
Collaboration

Hookload Broomstick – Static Local

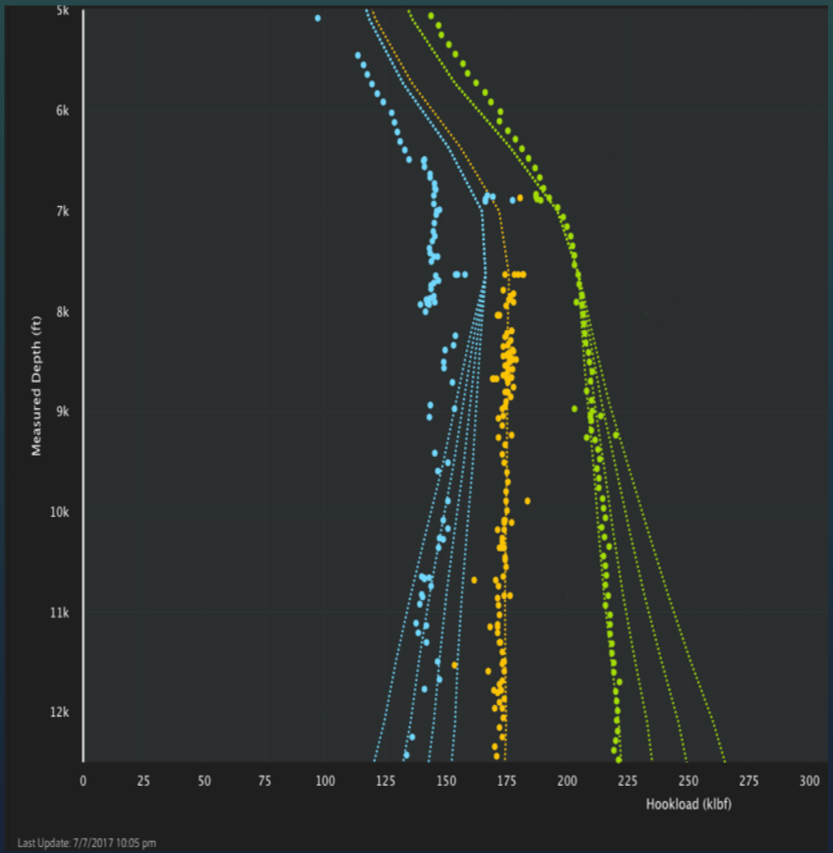
Model Values



Model vs Actual ROB

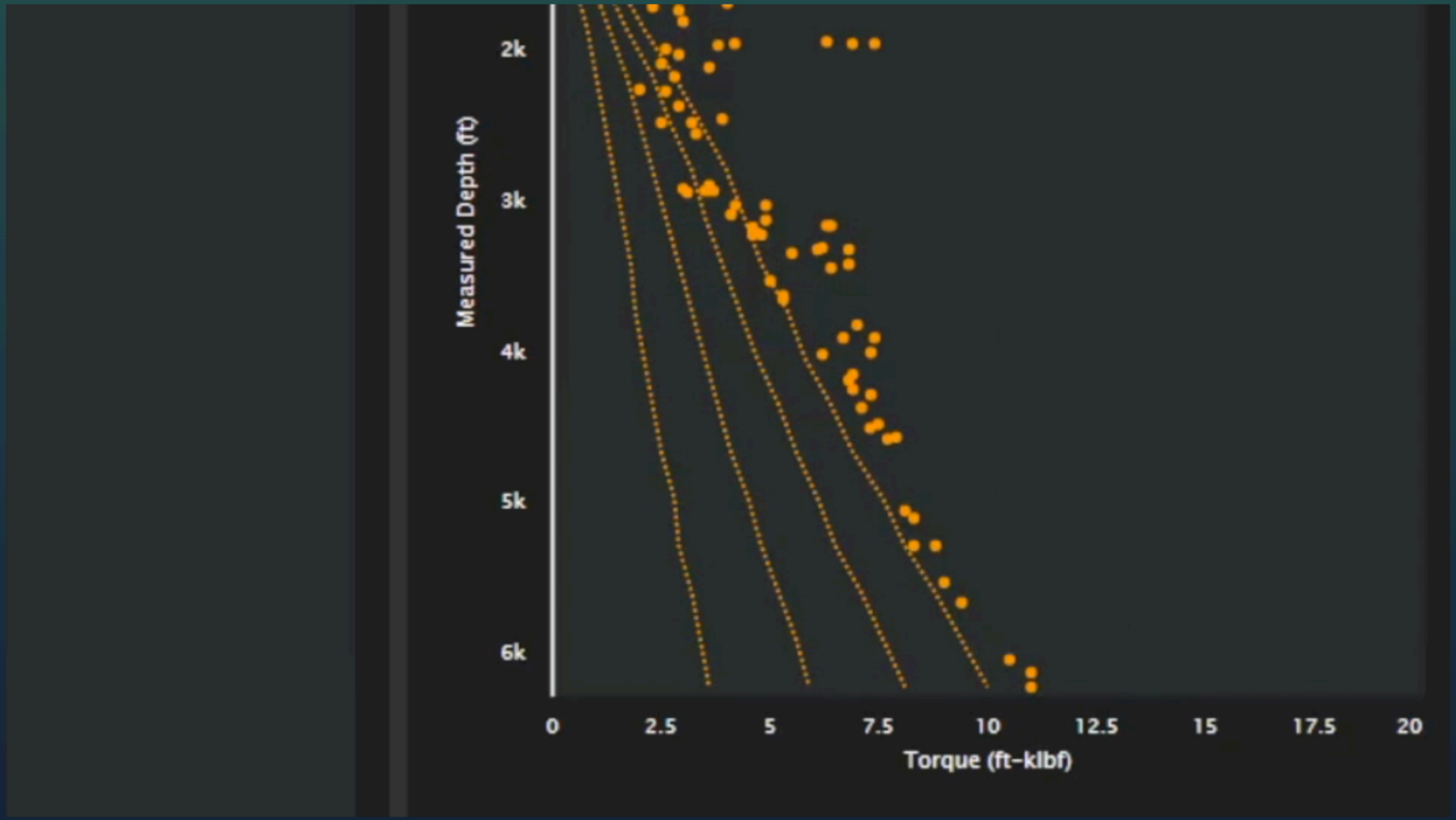


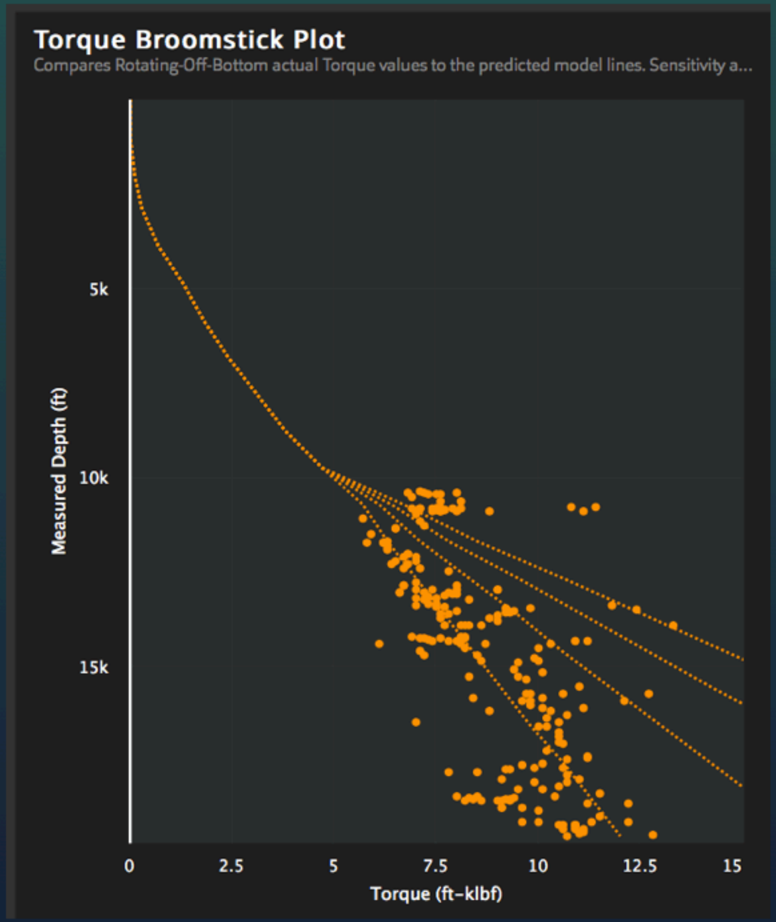
Model vs Actual ROB, PU, SO



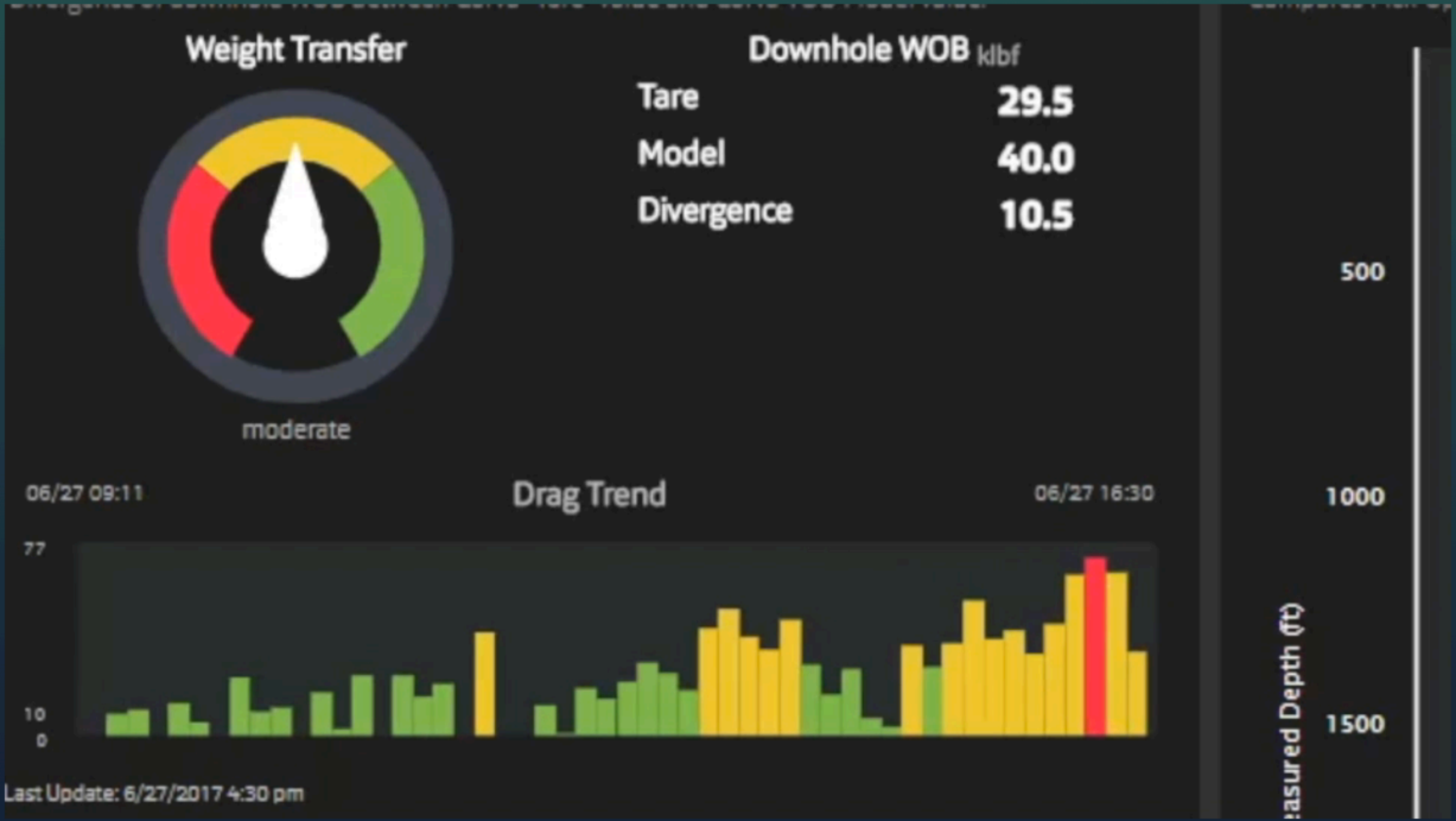
Hookload Broomstick in Real Time

Torque Broomstick in Real Time

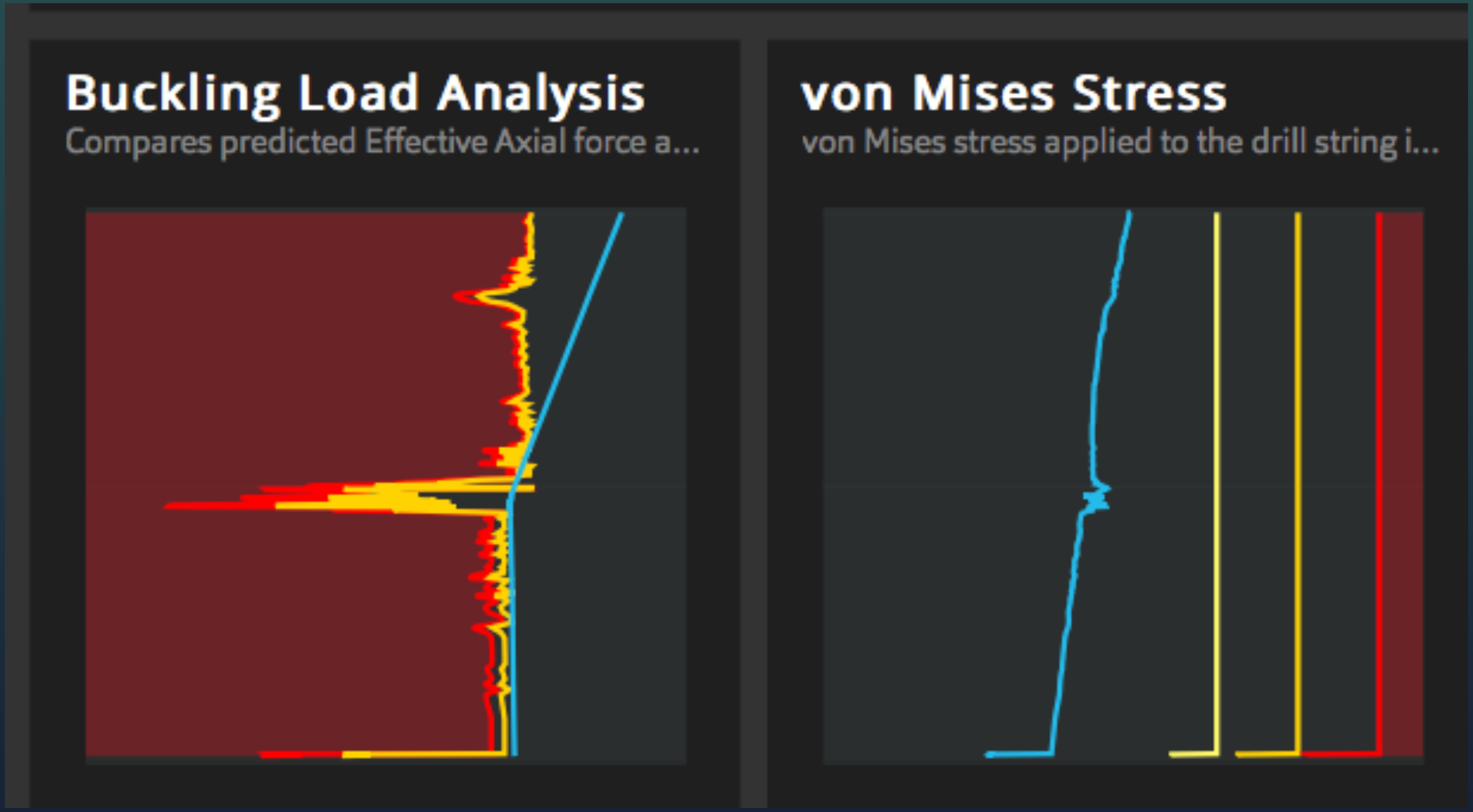




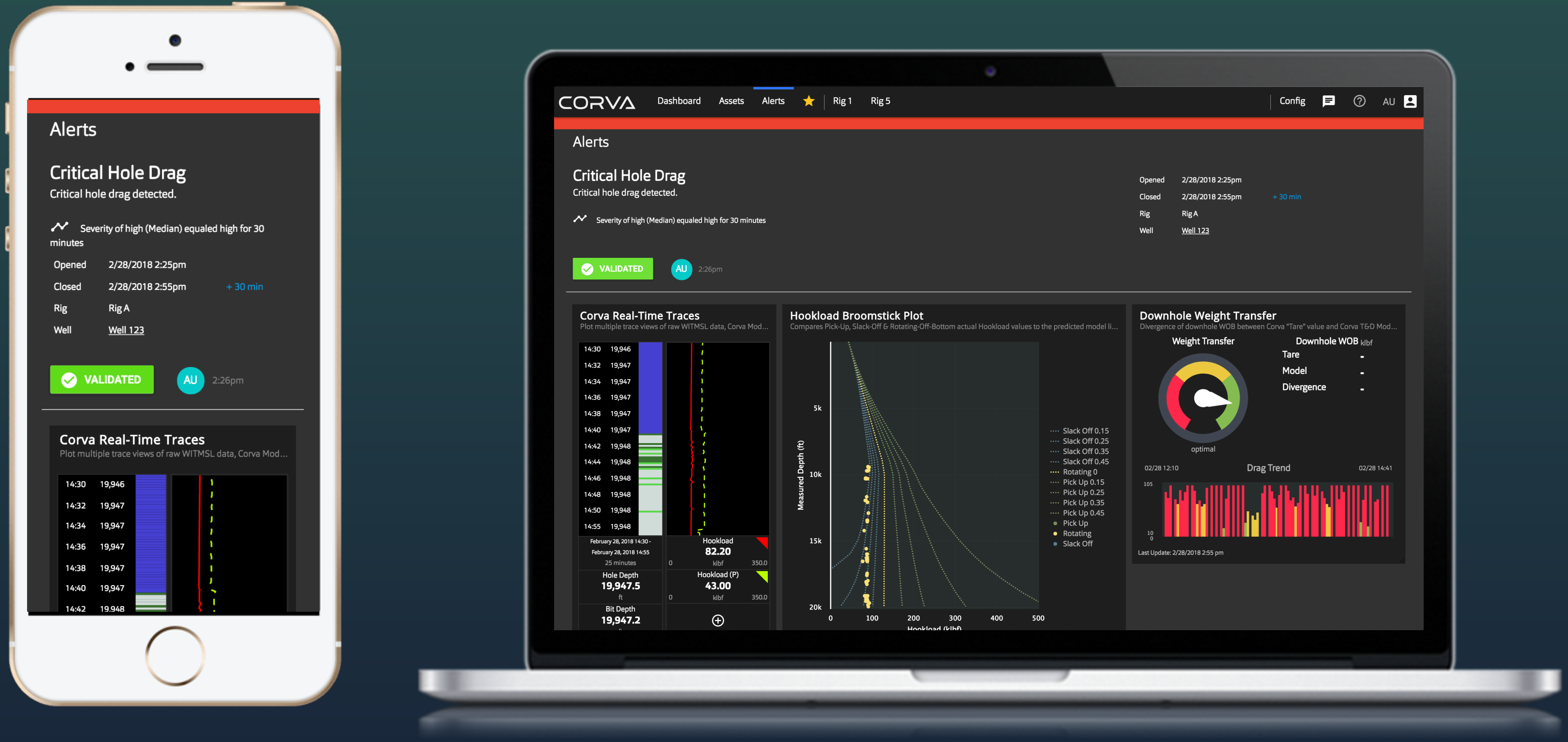
Weight Transfer and Drag Trend



Buckling Load and von Mises Stress



Automated Validated Alerts



Alerts monitored 24/7 and **validated** before disbursement to subscribed users to avoid any false positives

Summary: Real-Time Torque & Drag Using Automated Cloud-based Analytics

- Value to help optimize ROP and avoid NPT
- Requires automated model predictions, rig activity detection, and data capture
- Broomstick plots, buckling loads, and stresses generated without user intervention
- Alerts for suboptimal conditions sent automatically to specific users after validation
- Cloud computing allows common view for community awareness and collaborative decisions
  - Simultaneous updates to all global operations
  - Experts' knowledge shared via algorithms & real-time community chat
  - Cloud analytics display data and results that fits with today's engineers familiarity with similar apps on web and mobile devices

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