Webinars

Transparency in Measurements

John Macpherson, Baker Hughes
Paul Pastusek, ExxonMobil
Michael Behounek, Apache
Richard Harmer, Schlumberger

Based on SPE 174874, 189626 and 194082

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John Macpherson

Michael Behounek

Paul Pastusek

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Agenda

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	PRESENTERS
• Introduction	
• Adopting an Open Measurement Framework – With examples from drilling mechanics and dynamics	John Macpherson
• Resolving rig data quality issues	Michael Behounek
• Creating open source models, test cases and data	Paul Pastusek (depending on connectivity) or John Macpherson
• Questions	

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Introduction

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Motivation

Systems automation consumes digital data

Challenge

Without reliable known data automation systems are inherently unstable.

The problem is compounded when users do not own or control the measurements systems, as is required for interoperability.

Way Forward

Thus, it is important to:

Take steps to ensure that measurement systems are transparent,

understand the quality and reliability of the measurements being used in drilling automation,

build on verified models and test cases.

This webinar will explore significant work in this area, based on three published SPE papers.

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PART 1

ADOPTING AN OPEN MEASUREMENT FRAMEWORK: DRILLING MECHANICS AND DYNAMICS EXAMPLES

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Based on SPE 174874 • A Framework for Transparency in Drilling Mechanics and Dynamics Measurements

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Part 1 – A measurement framework for transparency

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1. Confusion in drilling dynamics, with examples

Which leads to …

2. A need for data transparency and Metadata

Which leads to…

3. Clarity in drilling dynamics, with examples

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Why an open measurement framework is needed to bring transparency

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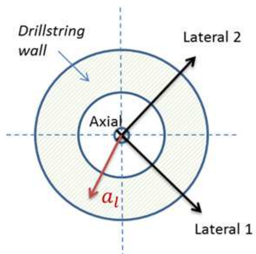
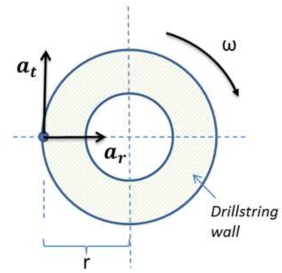
What we might report



Translational motion of the collar center

What we might measure



Combined rotational and translational motion

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Why an open measurement framework is needed to bring transparency

Company A makes and describes measurements

Company B makes and describes measurements

Company C makes and describes measurements

Company X develops algorithms to interpret and use measurements

Transparency is required!

1. No reliable data is no data
2. No data means no Automation

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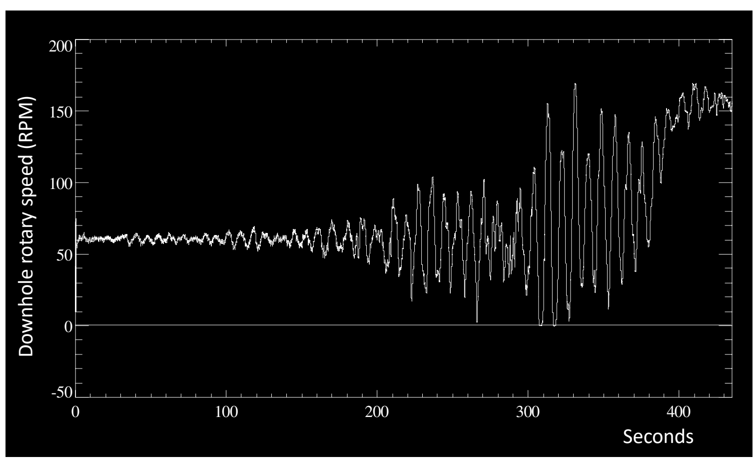
Data Confusion in Drilling Dynamics: Stick-Slip Example

- Rotary speed from x and y magnetometers
- 435 seconds of 100 Hz data bandwidth 42.6 Hz (-3dB), cutoff at 50 Hz (-72 dB)
- Initial rotary speed 60 RPM
- Full stick-slip at 310s
- Rotary speed raised to 155 which mitigated stick-slip
- Torsional Oscillation period 7.72 seconds



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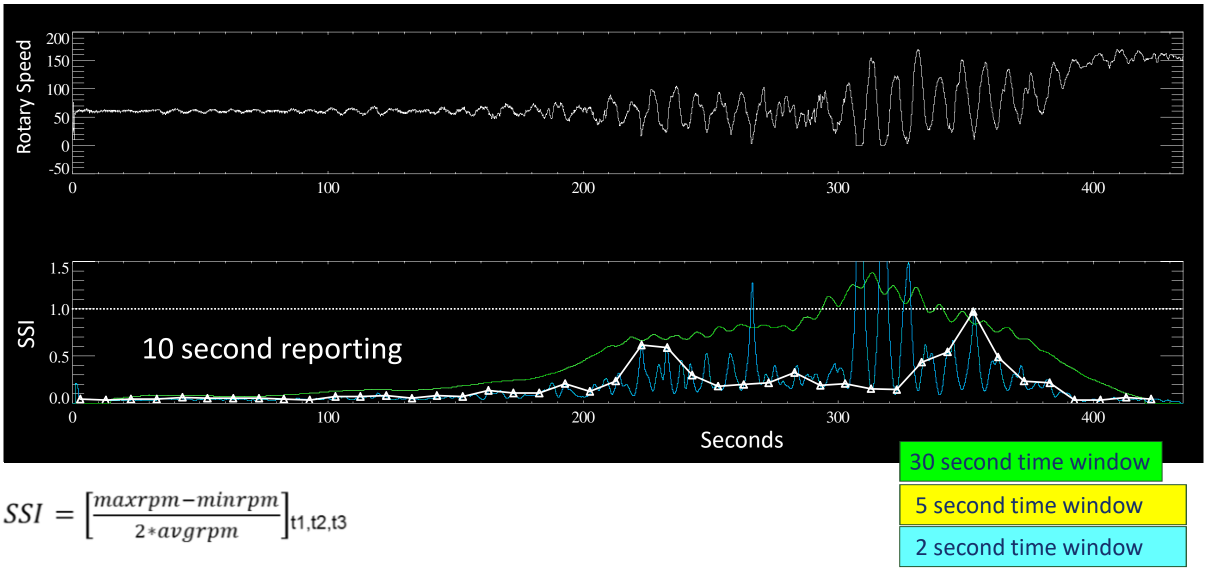
Data Confusion in Drilling Dynamics



$$SSI = \left[\frac{maxrpm - minrpm}{2 * avgrpm}\right]_{t1,t2,t3}$$

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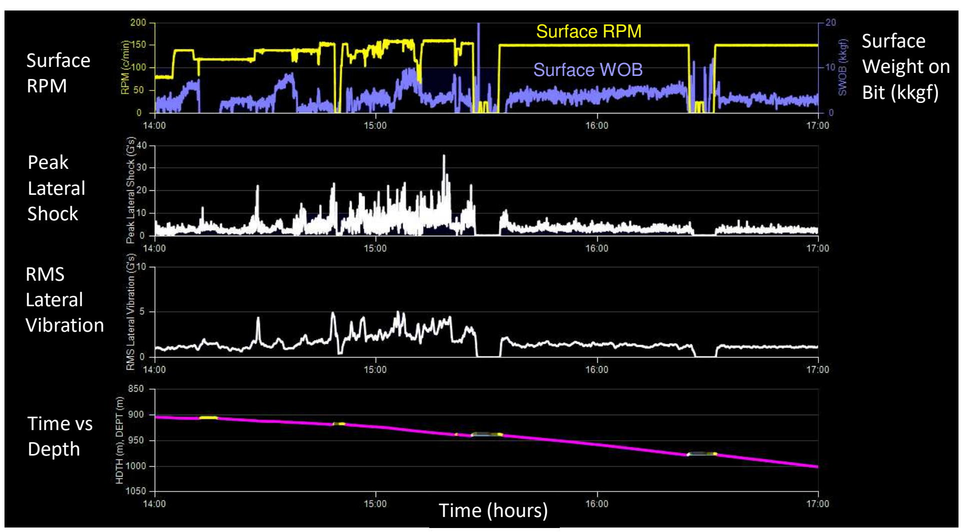
Data Confusion in Drilling Dynamics

Accelerometer Processing Example

- Peak lateral shock (2000 Hz bandwidth)
- RMS lateral vibration (150 Hz bandwidth)



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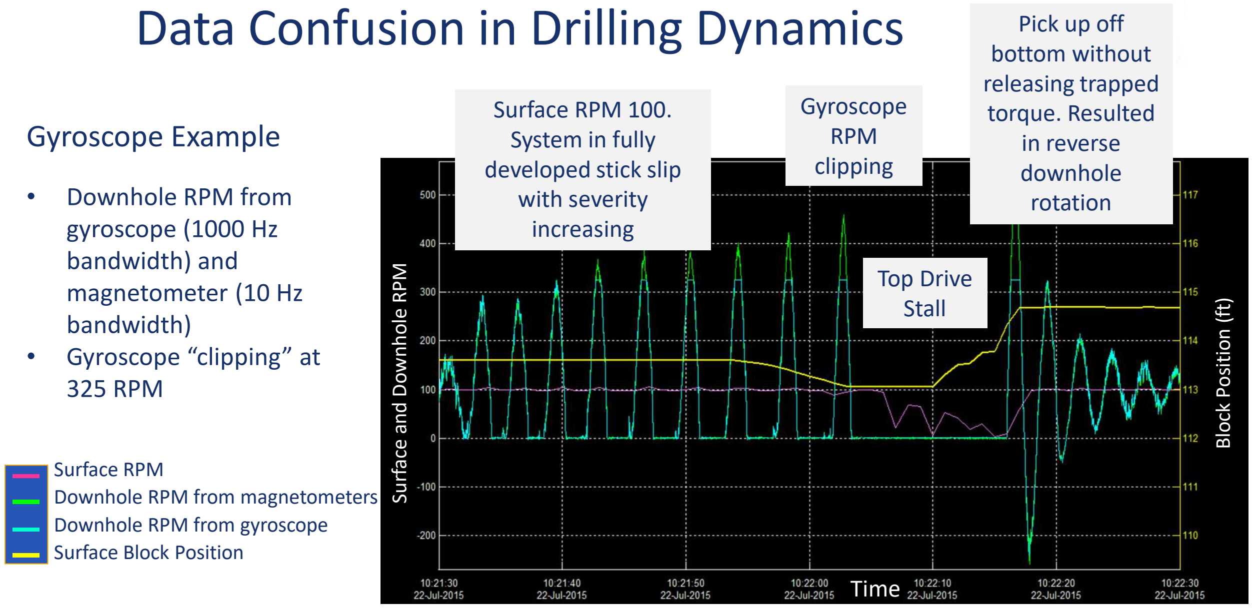
Data Confusion in Drilling Dynamics

Gyroscope Example

- Downhole RPM from gyroscope (1000 Hz bandwidth) and magnetometer (10 Hz bandwidth)
- Gyroscope "clipping" at 325 RPM



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Measurement Standards

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Objectives (a) Deliver quality data, (b) Ensure trust in dynamics data

- Consistent orientation and definition: axial, lateral, tangential, radial
- Consistent definition of drillstring motions and loads
- Information on sensors and measurements
- Details on data processing
- Details on diagnostics and computations

→ Metadata describing the data

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Metadata

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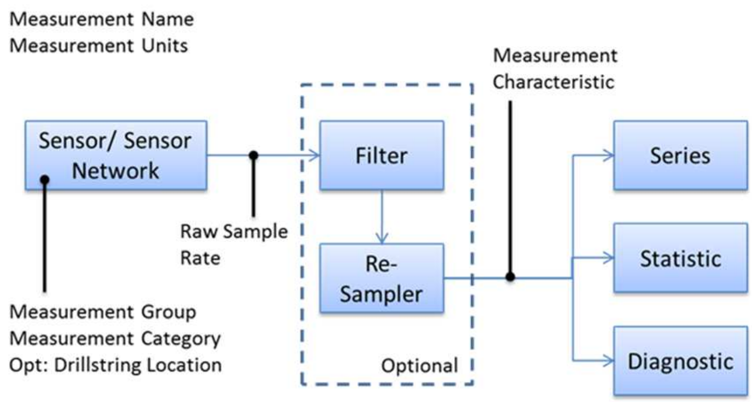
- Metadata describes data
- Built on a model of the data acquisition process



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Metadata

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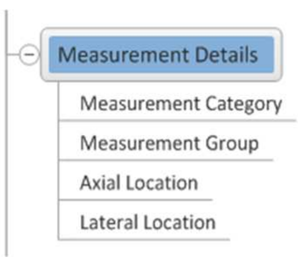

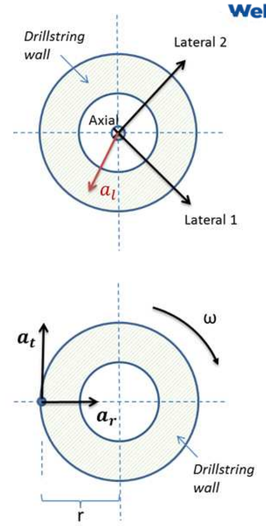

- **Category**: acceleration, velocity, displacement, force, bending moment, torque, pressure, …
- **Group**: Bit, BHA, along-string, surface sub, …
- **Axial location**: distance from bit
- **Lateral location**: radial distance of measurement

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Metadata

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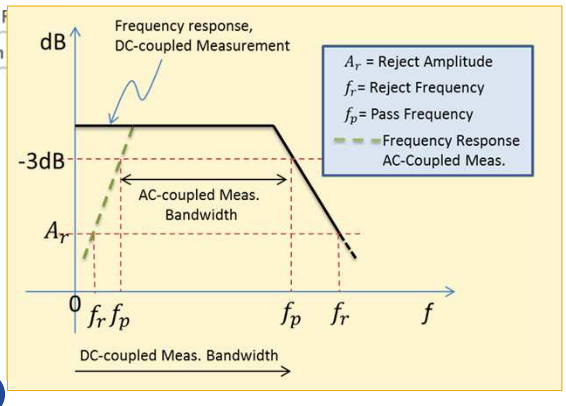
- Measurement Characteristics
  - Output Sample Rate
  - Raw Sample Rate
  - Gap Length
  - Gap Percentage
  - Maximum Range
  - Minimum R
  - Resolution



Peak Lateral Acceleration	
Units:	g
Category:	DC-coupled acceleration
Type:	BHA
Axial Location:	20m
Lateral Location:	0.0mm
Output Rate:	0.2 Hz
Raw Sample Rate:	1,000 Hz
Range:	+/- 62.5g
Resolution:	0.0019g
Bandwidth:	-3db@160Hz

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What can be achieved with good data?

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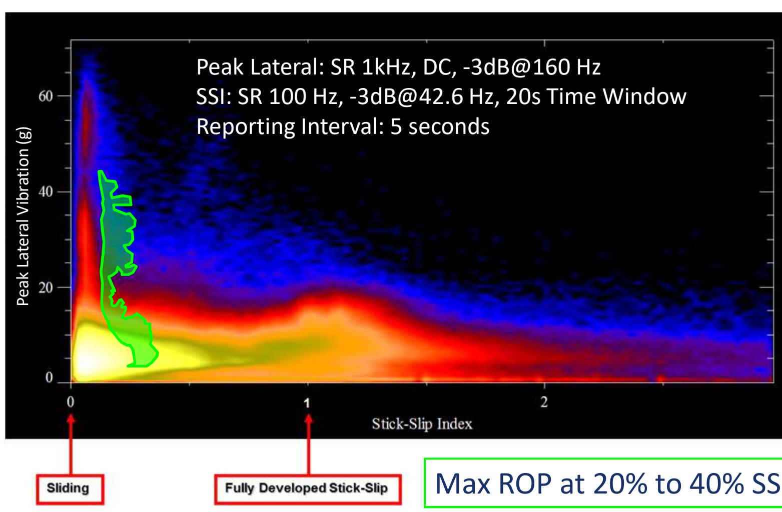
- Large downhole data set study
- 262 bit runs

- Shows "average" relationship between torsional and lateral behavior



Max ROP at 20% to 40% SSI

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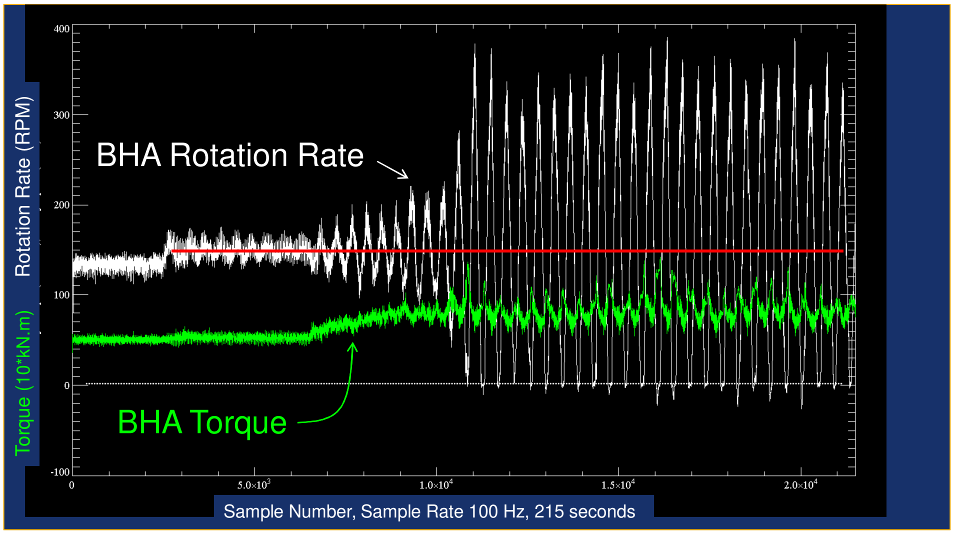
What can be achieved with good data?

Stick-Slip Event

- Downhole Measurements
- Sample Rate: 100 Hz
- Bandwidth: 0 to 42.6 Hz
- Raw Meas. Sync: < 0.5ms



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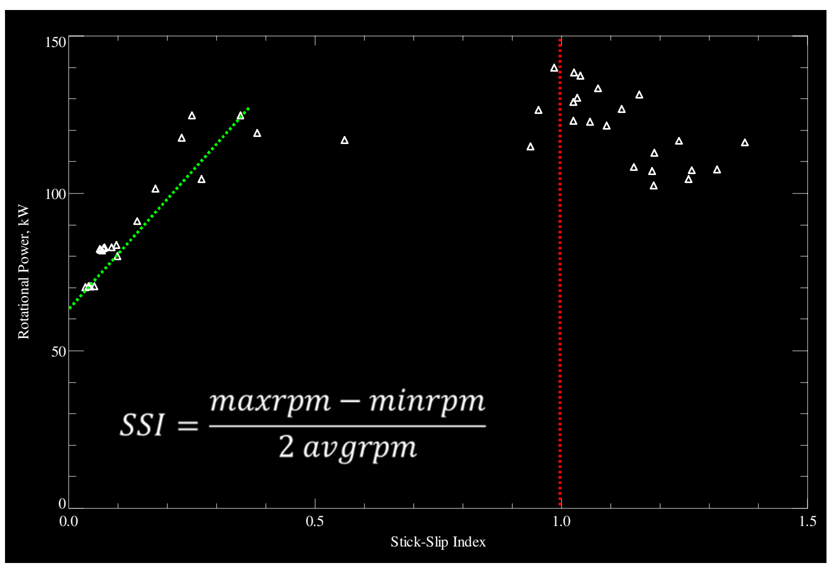
What can be achieved with good data?

- Rotary Power (TRQ * RPM) in BHA
- 5 second average window
- Power increases from 60 to 125 kW before system looses stability and stick-slip develops



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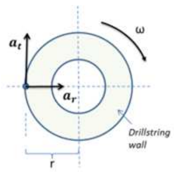
What can be achieved with good data?

Stick-Slip Event

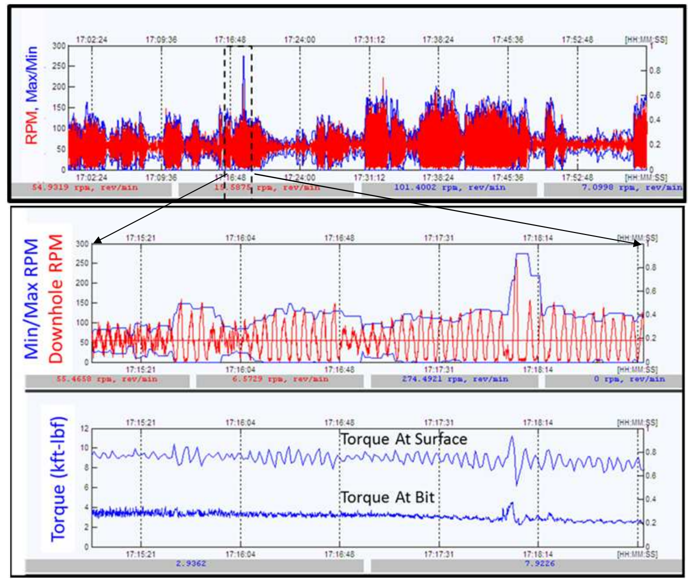
Downhole Measurements
- Sample Rate: 50 Hz
- BHA RPM from radial accelerometers

$$\omega^2 = a_r/r$$



Surface Measurements
- Sample Rate: 1 Hz
- BHA RPM envelope estimated from surface torque and string model

Ref: SPE/IADC 163420



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Part 1- Summary

1. Dynamics measurements can deliver significant value (efficiency, cost, safety) by providing understandable diagnostic data
2. Measurement transparency is needed so that confidence is established
3. Transparency is established through metadata describing the data
4. Intellectual property (trade secrets) are preserved since information on *how the measurement is made* is not part of the metadata
5. Adoption of this framework will resolve the current state of confusion and uncertainty, enable all parties to develop monitoring, advising and control applications that use these data, and help lower well costs + improve borehole quality.

Part 2

RESOLVING RIG DATA QUALITY ISSUES

Based on SPE 189626 • Operator's Group, Rig Contractors, and OEM/Service Company Work to Solve Rig data Quality Issues

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Part 2 – Resolving Rig Data Quality Issues

The quality of drilling measurements is increasingly important due to the following factors:

- Speed of drilling operations influencing the need for prompt safety-critical decisions
- Reuse of drilling data for optimization purposes and decision support tools
- Increase in the number of systems passing data from one system to another
- New industry needs, such as the automation of rig operations

The industry has reached a point where there is a need to systematically manage data quality

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Steps to Address the Issue

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Operators Group for Data Quality formed in 2014

- Education on drilling and completions data quality issues
  - Technical papers and articles
  - Industry speaking engagements
- Industry engagement efforts for change
  - Qualification of 10 key measurements
  - Data Quality Contract Addendum example
  - Foster Operators, Rig Contractors, OEM/Service companies working together to advance data quality in work processes

API Efforts

- OGDQ leading API effort to build “Specification for Field Verification of Key Rig Measurements” under SC8 Subcommittee on Drilling Structures & Equipment
- API Q2 “Specification for Quality Management System Requirements for Service Supply Organization for the Petroleum and Natural Gas Industry”

IADC

- New efforts in ART and Maintenance sub-committees

Drilling by the numbers demands better numbers – It’s Not Always the Sensor

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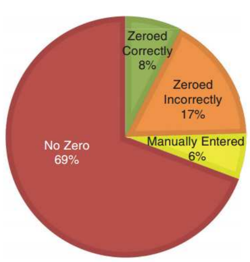

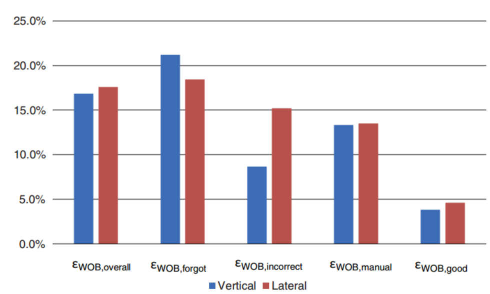

Based on a Pason study of data from 40 wells, the biggest source of errors in the weight on bit measure was a failure by the driller to push a button that recalibrates the number to zero when pipe is added to it.

Weight on bit errors (from left): the average, the level when the driller forgot to zero it, the level when the calculation was done incorrectly, the error when the data were entered by the driller, and the error if it was consistently done correctly.

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SPE 189626 • An Algorithm to Automatically Zero Weight on Bit and Differential Pressure and Resulting Improvements in Data Quality • C. Neufeldt, et al

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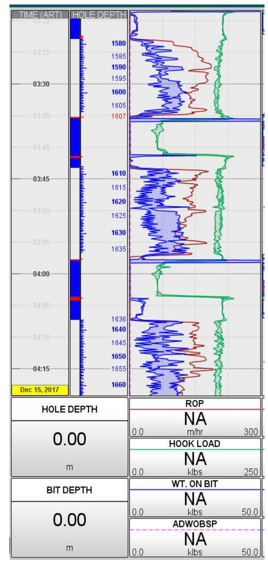
Current State Data Quality Example

AC rig drilling horizontal wells in shale with multiple hookload (HL) sensors feeding EDR, autodriller (AD), Historian. Issues:

1. EDR HL does not match up with rig AD or Historian
2. Rig AD HL sensor swaps between multiple sensors with offsets up to 30Klbs. Control loop cannot chase instantaneous changes so AD is not as efficient as it could be
3. Can’t look at historical data to determine if HL has been calibrated correctly
4. Operator data from EDR does not line up with Contractor data from rig in value or in time
5. 10 second or 1 second data from EDR misses fast changing data from sensor swapping, so it is mistakenly interpreted as ‘setpoint issue’ or a slow AD



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Ten Key Drilling Measures Needing Improvement

1. Rotary / top drive torque
2. Joint makeup/break torque
3. Hookload
4. Rotary / top drive rotational speed
5. Standpipe pressure
6. Drilling fluid pump rate
7. Drilling fluid tank/pit volume
8. Drilling fluid density
9. Drilling fluid viscosity
10. Block position

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Drilling Process Rely on Key Measurements and Instruments

Drilling Processes Examples	Key Measures/Instruments
Kick Detection	(6) Drilling fluid pump rate, (7) pit level sensors
Well Control	(5) Stand pipe pressure, (8) Drilling fluid density
Keeping within mud weight window (PP/FG)	(8) Drilling fluid density, (6) Drilling fluid pump rate
Managing Surge/Swap	(8) Drilling fluid density
Avoiding losses	(6) Drilling fluid pump rate
Avoiding drilling dysfunction, optimization of parameters (MSE)	(10) Block position, (1) Rotary/top drive torque, (3) Hookload, (4) Rotary/top drive rotational speed
Space out of tubulars	(10) Block height
Landing/setting weights	(10) Block height, (3) Hook load
Detecting drill string washout	(5) Stand pipe pressure, (6) Drilling fluid pump rate
Avoiding drill string connection damage	(2) Joint Makeup/Breakout Torque
Avoid damage to downhole tools, bit	(6) Drilling fluid pump rate, (5) Stand pipe pressure

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Example Tolerances for Key Drilling Sensor Data

	Measurement	Practical Field Tolerances
Hoisting System	Block Position	Better than +/- 1 ft.
	Hookload	Better than +/- 5,000 lbs
Rotating System	Rotary Table Torque	Better than +/- 5,000 ft lbs
	Top Drive Torque	Better than +/- 2,000 ft lbs
	Rotary Rotational Speed	Better than +/- 5 RPM
	Top Drive Rotational Speed	Better than +/- 5 RPM
	Joint Makeup/Breakout Tool Torque	Better than +/- 5,000 ft lbs
Circulating/ Fluid System	Pump Stroke Count / Stroke Rate	Better than +/- 2 SPM
	Pump Pressure / Stand Pipe Pressure	Better than +/- 10 PSI
	Drilling Fluid Flow In Rate (derived)	Stroke counter * Constant entered by Driller, +/- 10 gpm
	Drilling Fluid Flow Out %	+/- 5% (relative)
	Drilling Fluid Flow In/Out Rate	Better than +/- 10 gal/min Coriolis meter
	Drilling Fluid Tank Volume (total)	Better than +/- 10 bbl
	Drilling Fluid Density	+/- 0.05 ppg
	Drilling Fluid Viscosity	+/- 5 cp

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Current State Data – Hookload Example

Operation: Hoisting and lowering for hole cleaning operation with Top Drive RPM and mud circulation rates are constant
Sensor variation: 20,000 DaN (45,000 lbf) hookload

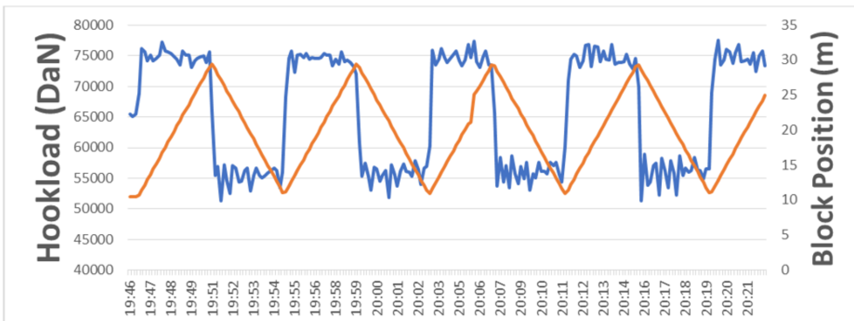

Fig.-1: Hookload and Block Position Variances (hookload is in blue, and block position is in orange)

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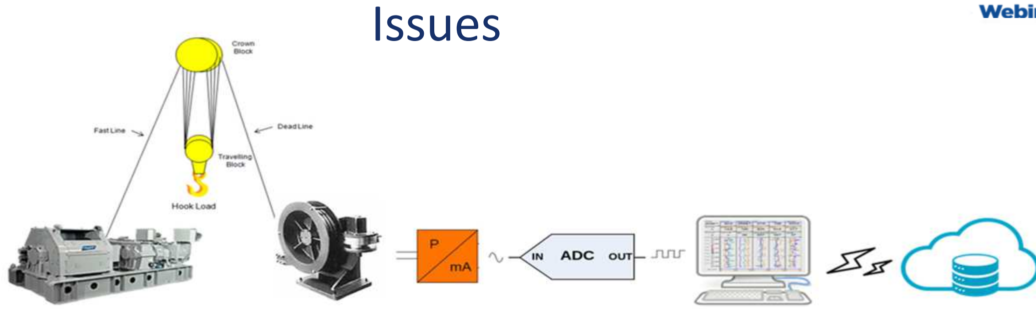
Example - Stack up of Hookload Data Quality Issues



SYSTEMATIC
Friction, both static and dynamic, in the sheaves resulting in -0.5%

MEASUREMENT
Air in oil, 1% entrained air results in -3% measurement error (ASTM D6793)

CONVERSION
Excitation error from power supply resulting in +/- 0.3%

CALCULATION
Offset error from incorrect calibration/ zeroing

PROPOGATION
Rig data captured at high sampling rates is converted to 5 second data for WITS, 99% loss of data

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API Spec Q2

API SUBCOMMITTEE 18 TG5 – QUALITY
With Rig Contractor Collaboration

Elements Requiring Procedures

- **Personnel Competency / Training**
- Document Control
- **Control of Records**
- Risk Assessment
- Service Design
- Contingency Planning
- Purchasing
- Verification of Purchased Services & Service Related Product
- Execution of Service
- **Service Quality Plan**
- Identification & Traceability
- Service Related Product Status
- **Customer Property**
- Preservation of Service Related Product
- **PMITP**
- **TMMDE**
- **Service Performance Validation**
- Nonconformities
- Management of Change
- Monitoring, Measuring & Improvement
- Internal Audit
- Analysis of Data
- Improvement
- Corrective Action
- Preventative Action

Source • S. Hagen ExxonMobil

Data Quality

- API Spec Q2 sets expectations for the establishment of controls (procedures) for Records, Customer Property, TMMDE, and Service Performance Validation
- It is not prescriptive on how to create, collect, store, maintain, transfer, process and present information and data to determine its quality
- It is incumbent upon the User to define other methods that must be must be incorporated into and/or supplements the quality management system
- ISO 8000-8:2015 – Data Quality - Information and Data Quality: Concepts and Measuring
- ISO 8000-61:2016 – Data Quality – Information & Data Quality Management Process Reference Model - DRAFT

Source • S. Hagen ExxonMobil

Preventative Maintenance, Inspection & Test Plan: PMITP

- The organization shall maintain a documented procedure for the establishment of a PMITP.
- As a minimum, the PMITP shall include:
  - Actions which address preventive maintenance;
  - Reports that document use history, repairs or redress, modifications, remanufacturing, inspection, and test activities that allow direct verification for reuse of product;
  - List of critical spare part requirements by the customer and/or technical requirements including those recommended by the OEM; and
  - Controls that ensure equipment integrity to original performance requirements and design acceptance criteria are maintained.
- Original performance requirements that cannot be met shall
- Undergo the MOC process.

Source • S. Hagen ExxonMobil

Control of Testing, Measuring, Monitoring, and Detection Devices

- The organization shall determine the required testing, measurement, monitoring, and detection equipment (TMMDE) to be controlled and necessary to provide evidence that service or service-related product meets specified requirements
- The organization shall maintain a documented procedure to ensure that TMMDE is calibrated and maintained for the execution of the service or in the provision of the service-related product.
- The procedure shall address:
  - Equipment traceability;
  - Frequency of calibration;
  - Calibration Method;
  - Acceptance criteria;
  - Suitable environmental conditions; and
  - Required assessments
  - Records

Source • S. Hagen ExxonMobil

Part 2 - Summary

1. Multiple efforts are now underway trying to address the data quality issue
2. As mentioned in Part 1 - Increase understanding and transparency are important
3. Need to convince the industry and demonstrate that better data will be a *positive impact, not a cost impact*.
4. Multiple benefits will be seen in safety, efficiency and effectiveness
5. For Rig Automation this will be an absolute requirement

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PART 3

CREATING OPEN SOURCE MODELS, TEST CASES AND DATA

Based on SPE 194082 • Creating Open Source Models, Test Cases, and Data for Oilfield Drilling Challenges

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Part 3 – Creating open source test cases and data

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- It is not enough to react to issues once drilling has started, but to design, model, and verify that a drilling system will achieve the desired objectives before drilling starts
- The goal of modeling is to help drill a round, ledge free hole, without patterns, with minimum vibration, minimum unplanned dog legs, minimum breakout, that reaches all geological targets, in one run per section, in the least time possible.
- This requires robust verifiable models.
- There have been three key impediments to building on prior models;

Availability and reusability of existing models

Open source data sets to compare models to actual drilling data

Benchmarks to compare new code to existing models

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Creating open source test cases and data

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- A coalition has been formed to help the industry create open source, sharable, expandable models of drilling systems to facilitate the objectives above.
- This coalition has started to share best in class models and data. These initial efforts will lead to even better examples and encourage others to share and contribute to their improvements.
- The authors also plan to set up and qualify benchmark cases for use by the community to rate the value of existing and incoming models.
- Removing past barriers, this open source initiative will speed the adoption of ever improving models of drilling systems, improving performance and removing risks.

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There will be multiple models for different problems.

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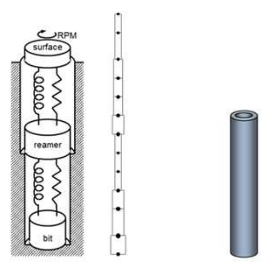
Drill String Dynamics Example

A majority of technical models can be interpreted as networks of single degree of freedom oscillators (SDOFs).



Point Mass — Rigid Body — Discrete Methods — DOF → Continuum

Point Mass	Rigid Body	Discrete Methods	Continuum
on a line: 1 *in a plane: 2* *in space: 3*	*in a plane: 3* *in space: 6*	*Multi Body Models: few* *Finite Element Model: many*	*infinite*

MODELS	**Lumped Parameter Model** *Rigid masses separated by kinematic pairs of springs, dashpots. Function only of time.*	**Distributed Parameter Model** *Distribution of parameters in time-space, wave propagation taken into account*
MODELS	**Soft-String Model** *The drillstring has no bending stiffness, and has continuous contact with the wellbore*	**Stiff-String Model** *The drillstring has bending stiffness, and has point contact with the wellbore*
MODELS	**Static / Steady-State Model** System in equilibrium, disturbances not considered	**Transient / Dynamic Model** Time varying system, disturbances (e.g., start-up) considered
MODELS	**Linear Model** Model in which the system of equations can be linearized	**Non-Linear Model** Everything else
MODELS	**Discrete Model** Model of a single component, such as a drill bit	**Coupled Model** Systems model of consisting of joined models of discrete components
SOLUTIONS	**Analytic Model** Exact mathematical solution with closed form equations	**Numerical Model** Approximate solution, for example using the finite element method, transfer matrix method, Monte Carlo simulation, etc.
SOLUTIONS	**Frequency Domain Model** Model solved in the frequency domain, typically faster but with reduced capability	**Time Domain Model** Model solved in the time domain, typically slower but with improved capability

→ Increasing complexity or requirements →

Courtesy Hanno Reckmann, Theory of Dynamics, a University Course

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Model Requirements

- Models must be open source, well documented with the objective and expected outcomes, include commented code, and shared in a publicly available repository.
- They must include a User's Guide explaining how to run the core software and how to extend software capabilities.
- The fundamental principles, base equations, assumptions, and any known limitations must be included in a Theory Manual.
- Each company and researcher may publish only what they want to share.
- However, access to open source elements will allow end users to compare the results to show the potential benefit of Proprietary and Open Models.

Open Source Data Requirements (example)

Data

- EDR surface data –typically 34 channels of measured and calculated data
- Rig control system data
- Directional surveys
- Downhole burst data – vibration, WOB, Torque, RPM
- Bit and BHA forensic reports

Meta Data

- Data set description and well summary
- Rig Information
- Drilling time log
- BHA design details, run reports
- Mud Properties and hydraulics

Open Source Benchmark Requirements

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Problem Scenarios

- Standard drilling operations – drilling ahead with changes in parameters or boundaries
- Faults and events – kicks/losses, washouts, stick slip, whirl
- Industry Challenges – difficult to model and not fully understood, e.g. Effect of hole angle and curvature on vibration, Optimal control of directional assemblies

Provide Quantitative Model Metrics

- Accuracy - either absolute or relative error, or a combination
- Execution time and computing resources - processors, memory, storage, etc.
- Robustness - ability of model to complete simulations for a variety of inputs and the ability to return useful errors in case of failure
- Qualitative interpretation tools - graphical output, summary statistics

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Part 3- Summary

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1. An open source repository for drilling will speed up the rate of learning throughout the well execution workflow, including planning, BHA design, real-time operations, and post well analysis
2. Open source data sets to compare models to actual drilling data, and benchmarks to compare new code to exiting models build confidence in the output and expected results.
3. This open source initiative will speed the adoption of ever improving models of drilling systems, improving performance and removing drilling risks.

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Acknowledgements / Thank you / Questions

ExxonMobil, Apache, Schlumberger and Baker Hughes
for permission to publish reference materials

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SPE 189626 • Operator's Group, Rig Contractors, and OEM/Service Company Work to Solve Rig data Quality Issues

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