AADE
AMERICAN ASSOCIATION of DRILLING ENGINEERS

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A Business Unit of Turbo Drill Industries, Inc.

Steve Jones – President & CEO, Sanvean Technologies

Turning High-Frequency Bit and BHA Drilling Dynamics Measurements into Actionable Results to Improve Drilling Performance and Bit Life –

A Study of Embedded Drilling Dynamics Specific to Delaware and Midland Basins

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02/08/2022 Bush Convention Center, Midland TX

Agenda

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- The basic principles behind downhole measurements.
- Explanation of the factors that drive dynamics.
- Examples of common dynamics experienced in Midland and Delaware Basins.
- Open floor for discussion/questions.

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Introduction

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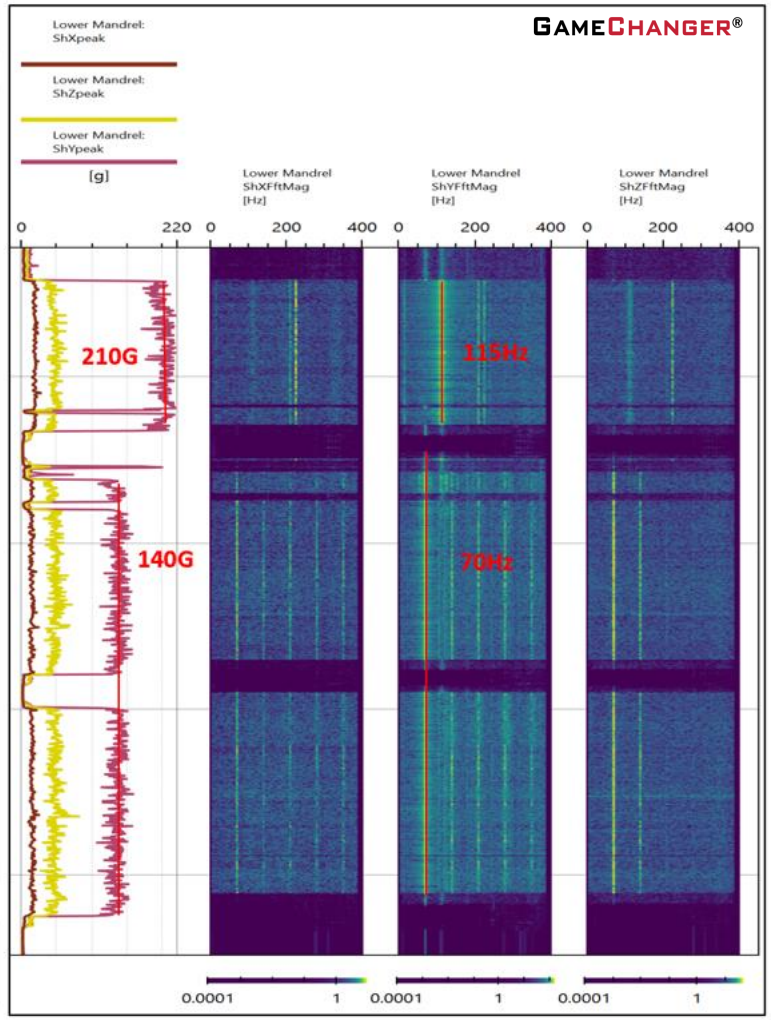
- **Why is it important to measure and understand drilling dynamics?**
  - Time savings
  - Cost savings
- **What is the industry standard for measuring drilling dynamics?**
  - MWD
- **Is MWD the "best" place to measure and understand system drilling dynamics?**
  - No
- **Why?**
  - Placement
  - Mounting
  - Transmissibility
- **What should be used to measure and understand drilling dynamics?**
  - High-frequency embedded sensors at the "points of interest" in the BHA.
- **Why?**
  - I am going to show you today.



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Dynamics & Strain-Based Measurements

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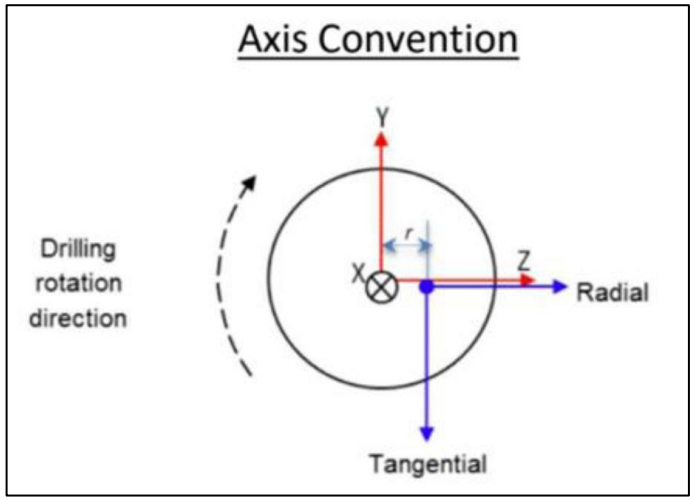
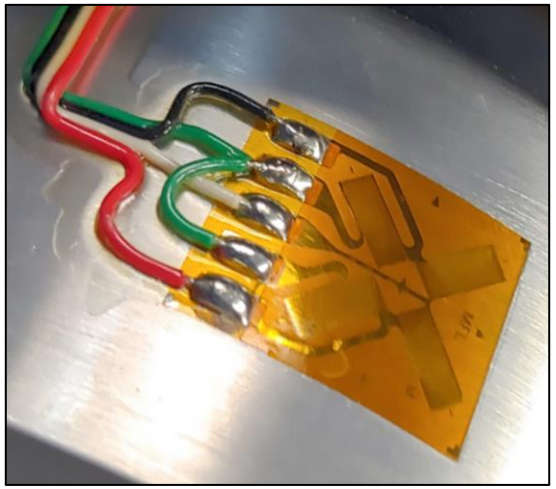
- **Dynamics Based Measurement**
  - Acceleration Components (3-axis) - Accelerometers
  - Torsional Components - Gyro
  - Temperature
  - Pressure
- **Strain Based Measurements**
  - Weight
  - Torque
  - Bending
  - Pressure
- **Science or Actionable Results?**
- **Cost?**





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Sanvean Technologies specializes in dynamics-based measurements.

Dynamics Measurement Placement/Sampling

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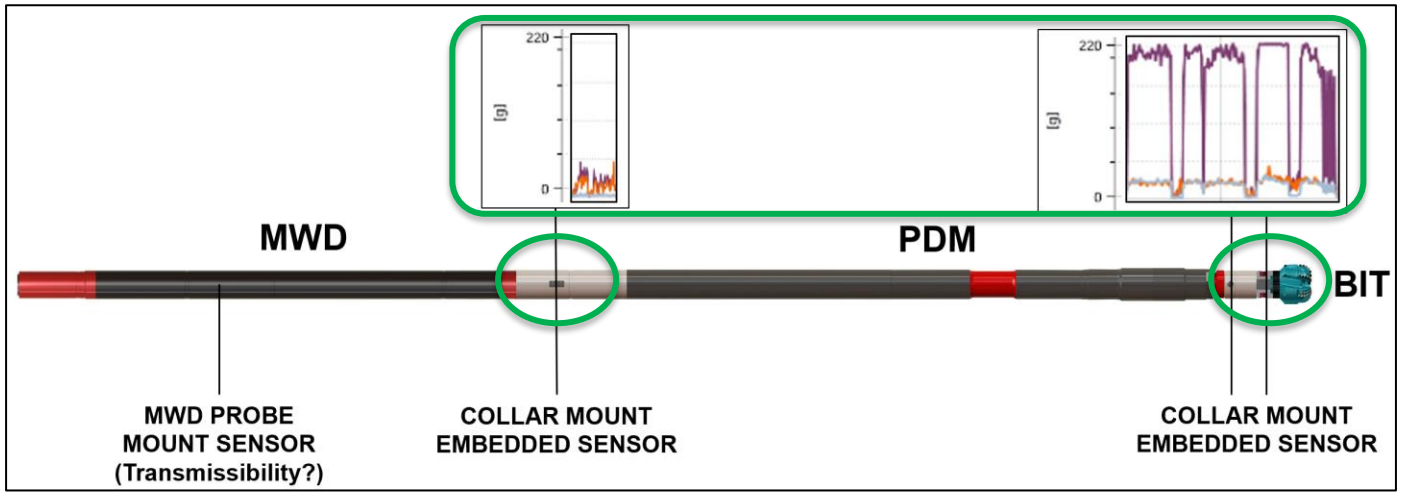
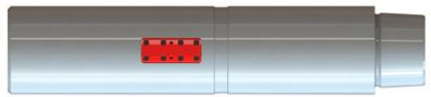
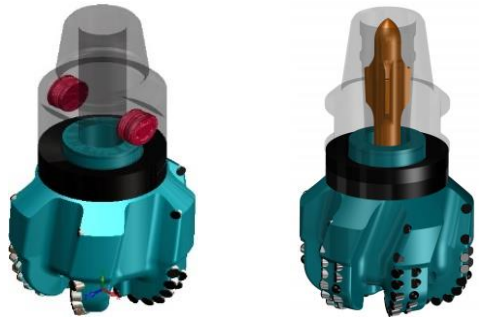
- **Placement**
  - At bit
  - Above power section
  - OD mount
  - Centerline mount
- **Measurements**
  - Acceleration (3-Axis Shock)
  - Angular Rotation (Torsional)
  - Continuous
- **Measurement Range**
  - Acceleration (+/- 200G)
  - Angular Rotation (+/- 330 to 1000 RPM)
- **Sampling Rates**
  - Acceleration (800-1600Hz)
  - Angular Rotation (100-1000Hz)







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When evaluating downhole data, all the above bullets are important to make the right interpretation of the data.

What Drives the Dynamics?

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- **Formation**
- **Drilling Parameters**
- **Rig**
  - Auto Driller/DAS
  - Torque Feedback Control Systems
- **BHA**
  - Conventional Steerable Motor
  - RSS
  - Bit
  - Power Section
  - Torsional Stiffness
  - Stabilization
- **Some or all of the above combined**

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Understanding the driving dynamic force and second/third order dynamics helps solve the problem.

Downhole Isolation Tools

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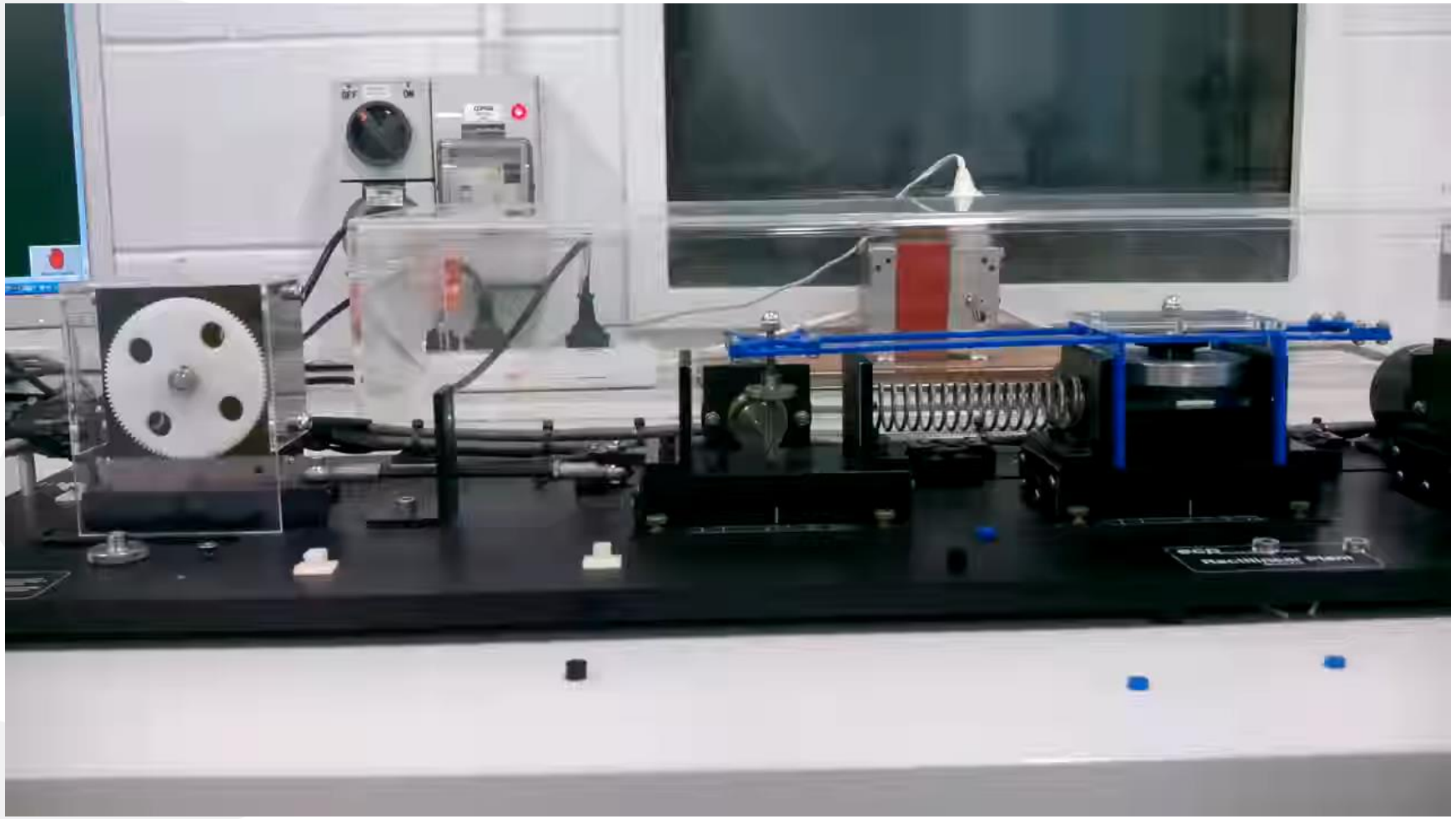

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Mechanical and Electro-Mechanical Downhole Isolation Tools will become key technologies to push drilling limits.

Real-time versus Memory?

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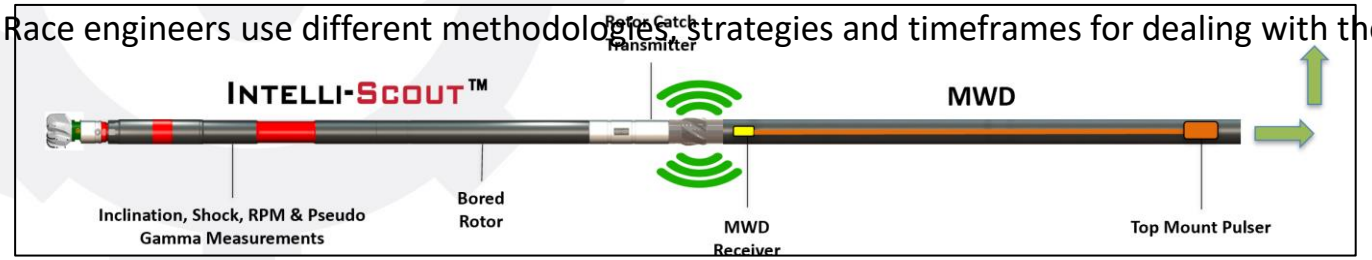
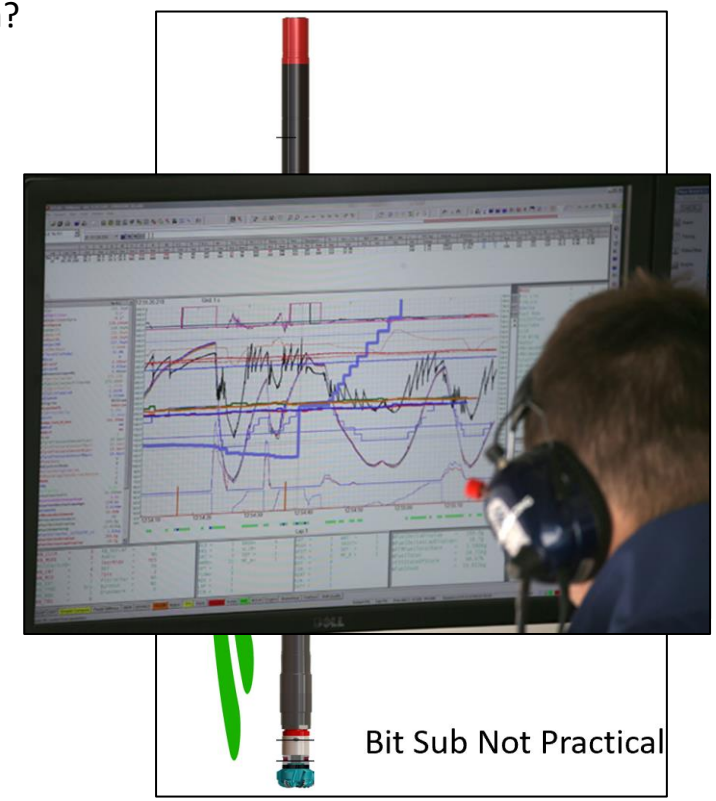
- **Sampling frequency and real-time transmission rates.**
  - If we down-sample or categorize high-frequency data, does it still contain the actionable information?
  - High frequency data would have to be processed downhole.
- **Sensor placement and engineering complexity/survivability (Cost!).**
  - Motor must be instrumented in a cost-effective fashion.
- **Multi-well pads provide an advantage for memory-based measurements.**
- **Method of real-time response is different from memory-based fingerprinting/road mapping.**
  - Real-time requires experienced personnel to interpret the data 24 hours/day (Cost!).
- **Compare F1/24 Le Mans Telemetered Data (High Tier/High Cost) to Club Racing Data Loggers (Low Tier/Low. Cost).**
  - Race engineers use different methodologies, strategies and timeframes for dealing with the data.





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At this point in time, at-bit high-frequency recorders and fingerprinting/road mapping is reliable and cost-effective.

Midland & Delaware Basin Formations – Torsional & Shock Profile Fingerprinting

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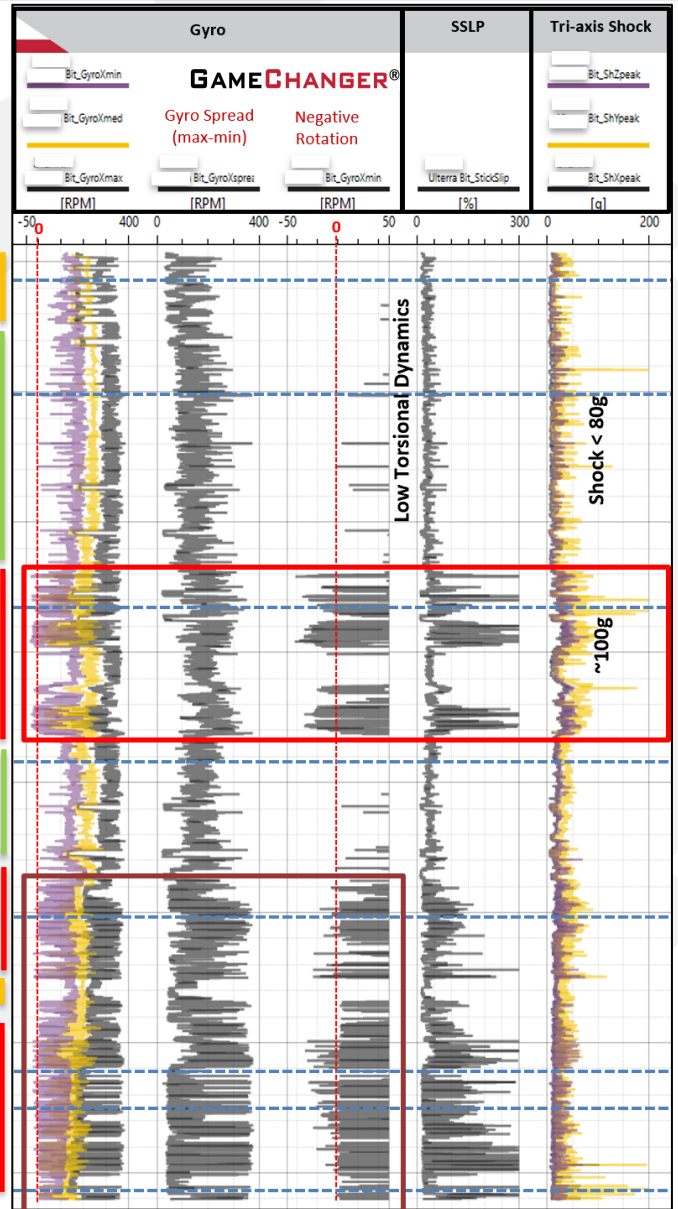

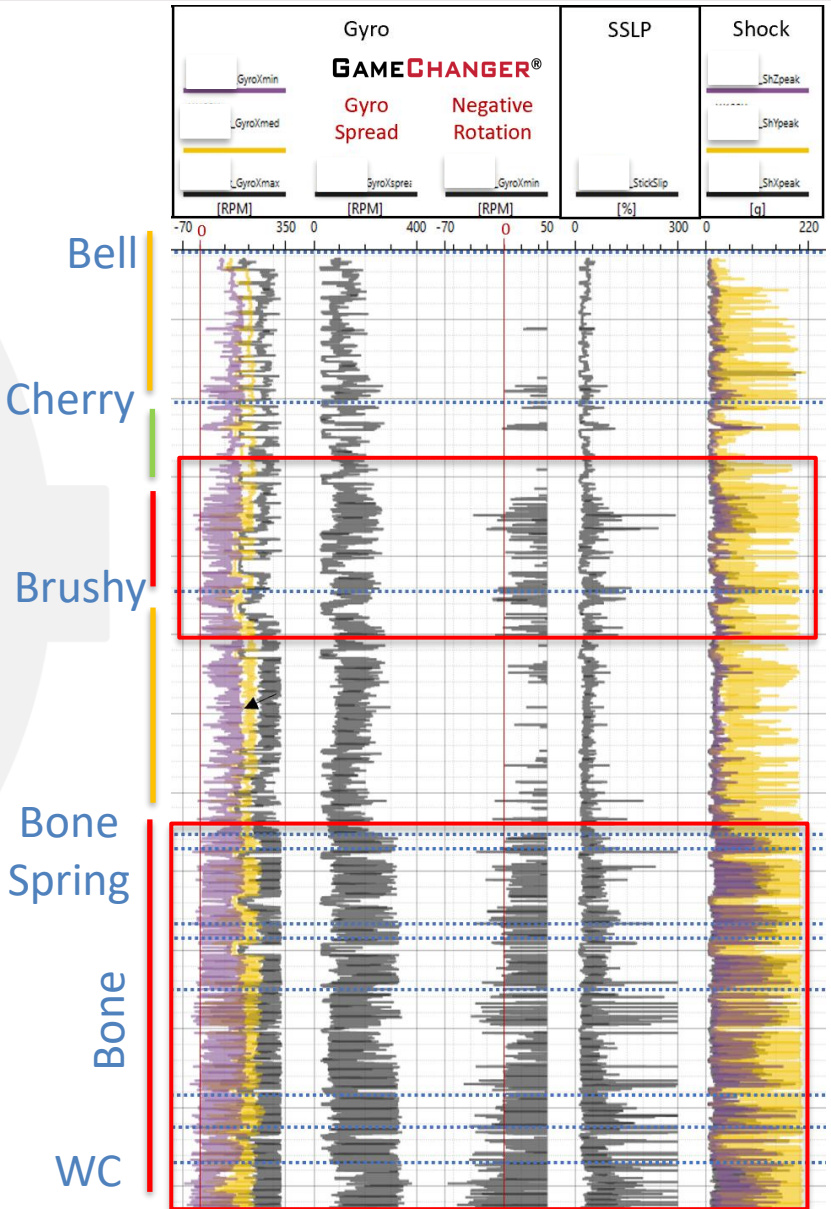

- The driving dynamic types are similar between Midland and Delaware Basins.
- The severity of the dynamic types are at a higher magnitude in the Delaware Basin.
- The formation driven dynamics can be fingerprinted utilizing high-frequency embedded sensors at the bit.
- Operators have invested in gathering the high frequency bit dynamics data for roadmap tuning and automation boundary conditions.

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Permian Bit Dull - Intermediates

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Midland Basin → → **Delaware Basin**

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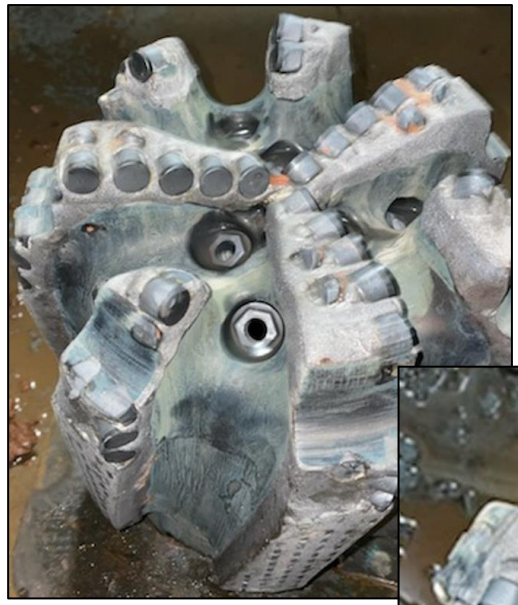
Bit dulls are highly variable based on intermediate hole-size.

Ring Out - Shoulder

PRIMARY OBSERVATIONS

- Torsional Dynamics
  - Stick-Slip
  - Torsional Oscillations
  - Motor back-drive/trapped torsional energy in string
- High sideloading on shoulder cutters
  - Steerable motor bend angle/stabilization
- Cutter wear/damage accelerated based on rock type



SECONDARY OBSERVATIONS

- Damage to back of depth-of-cut limiters
- Bit reverse rotation must be present
- What is driving the reverse rotation events?

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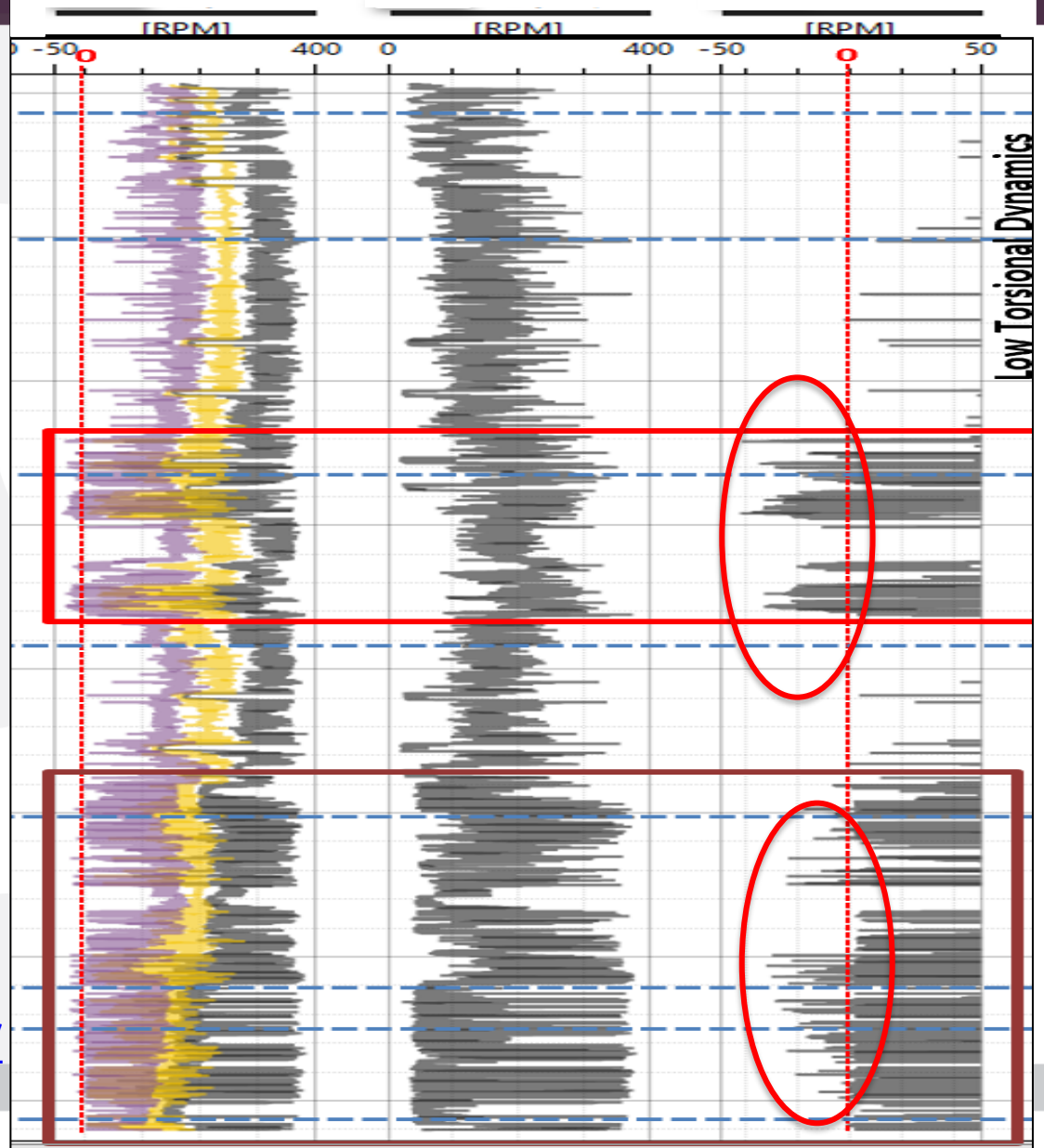
Close examination of bit dulls (before excessive DBR) can hold valuable clues to the driving dynamic.



High WOB to keep bit engaged in rock!!

BUT…..

Only to the point where secondary dynamics are not accelerating bit wear.

1. Eliminate bit reverse rotation events.
2. Reduce bit acceleration and deceleration magnitude.
3. Reduce back-drive and trapped torque in string.

THIS BALANCE CAN ONLY BE MAPPED WITH AT-BIT DYNAMICS TO UNDERSTAND EXACT FORMATIONS/DEPTHS THAT ARE DRIVING THE DYNAMIC.

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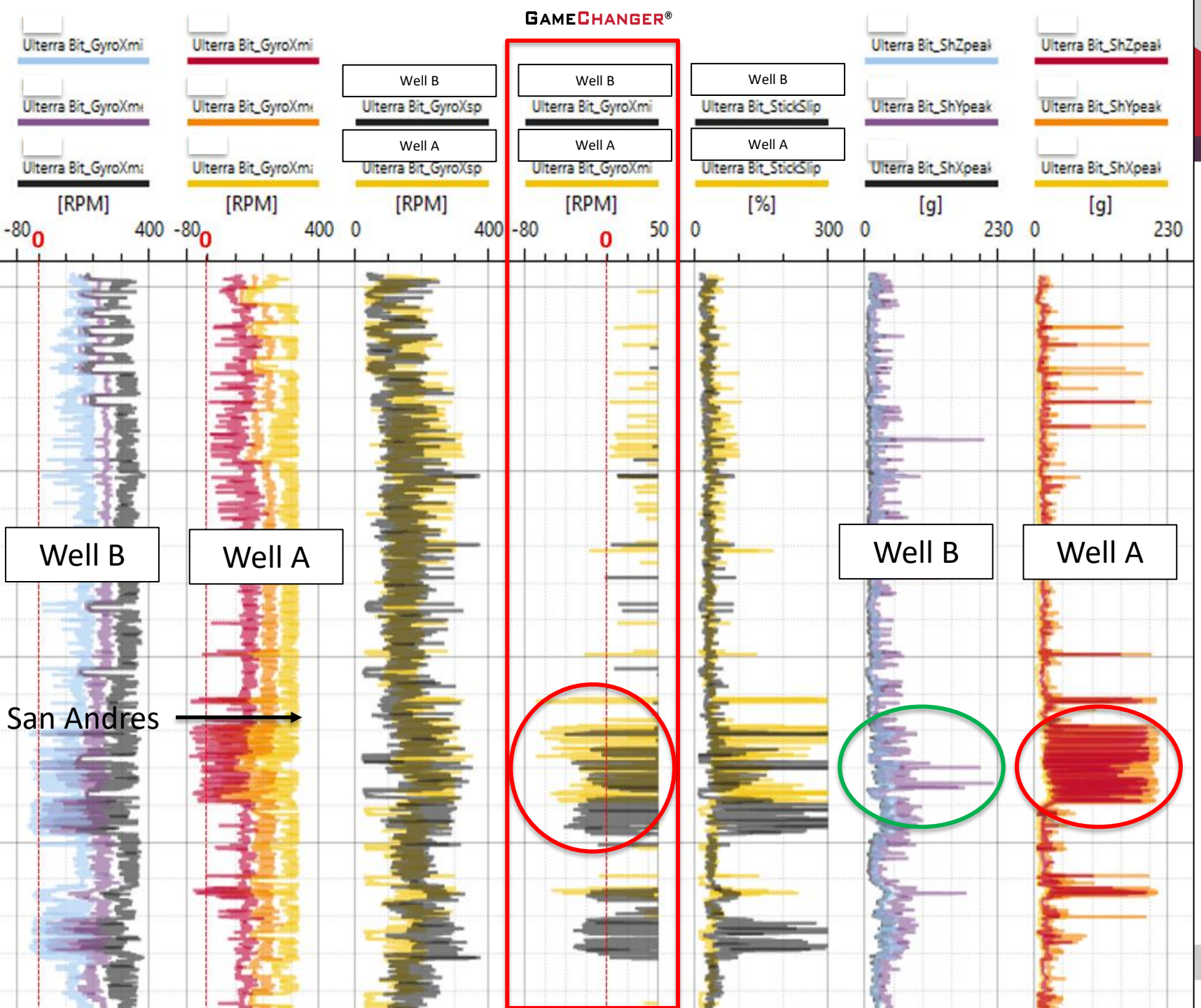

1. Bit Torsional Dynamics
2. Bit negative rotation
3. Is there a third dynamic component of interest? What is the primary driver?

HIGH SHOCK
MINIMAL SHOCK

Not all shocks are driven by the bit/rock interaction - Torsional dynamics at a certain level will start to create shock impact.

Torsional Driven Shock Events

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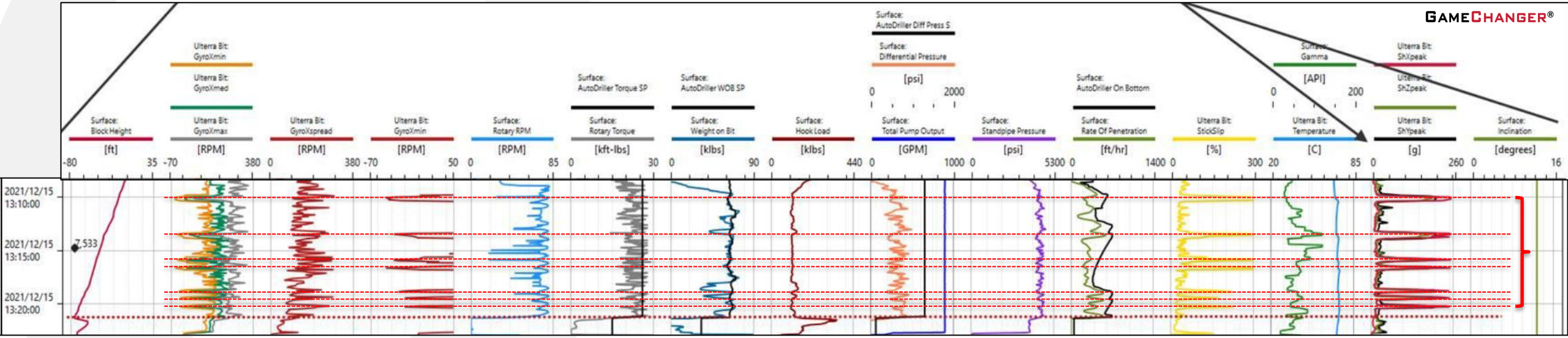

It’s not the rock – It’s driven by us!

Mud Motor Back-Drive – First Hidden Dynamic!

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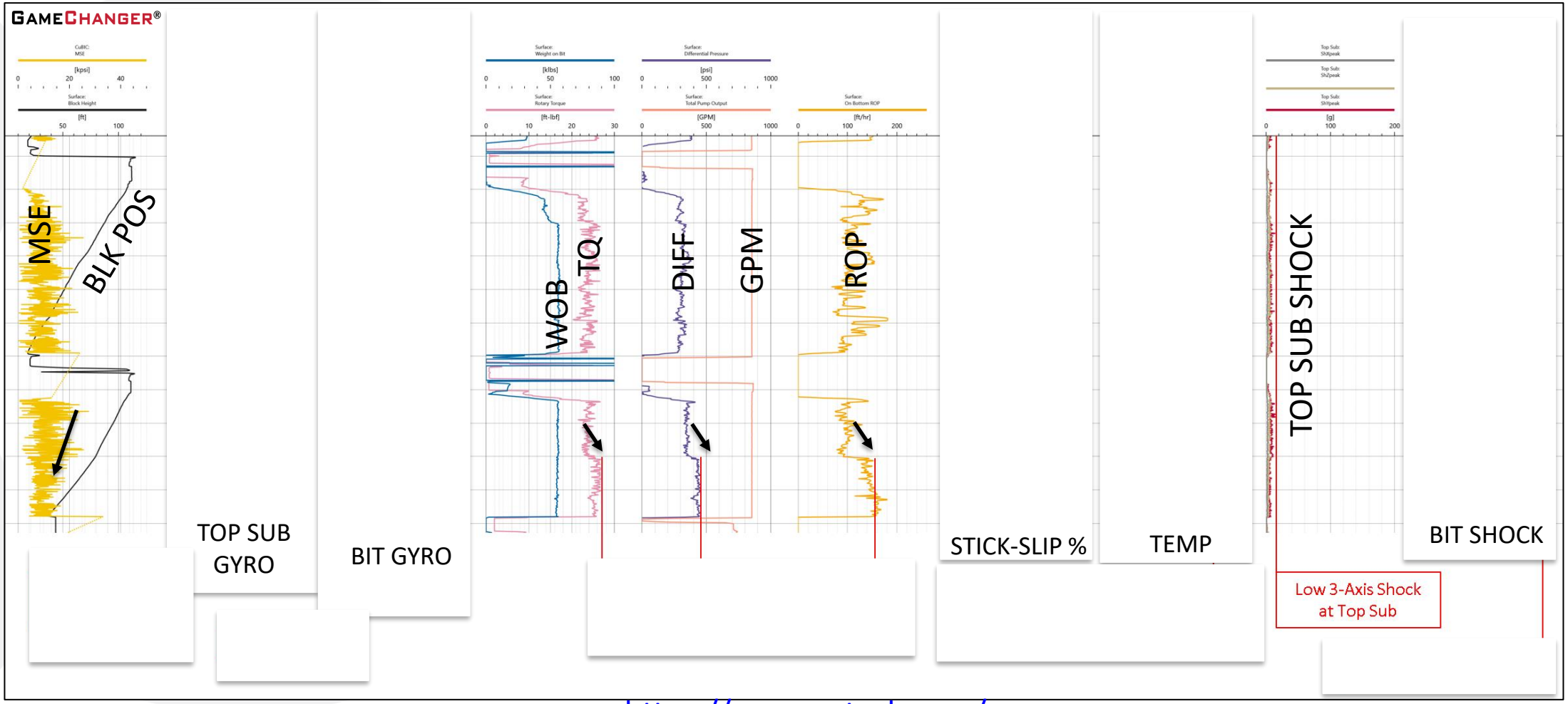

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This is an example of at least two components driving the dynamic – formation and motor back-drive!

MWD Pulse Dynamics – Second Hidden Dynamic!

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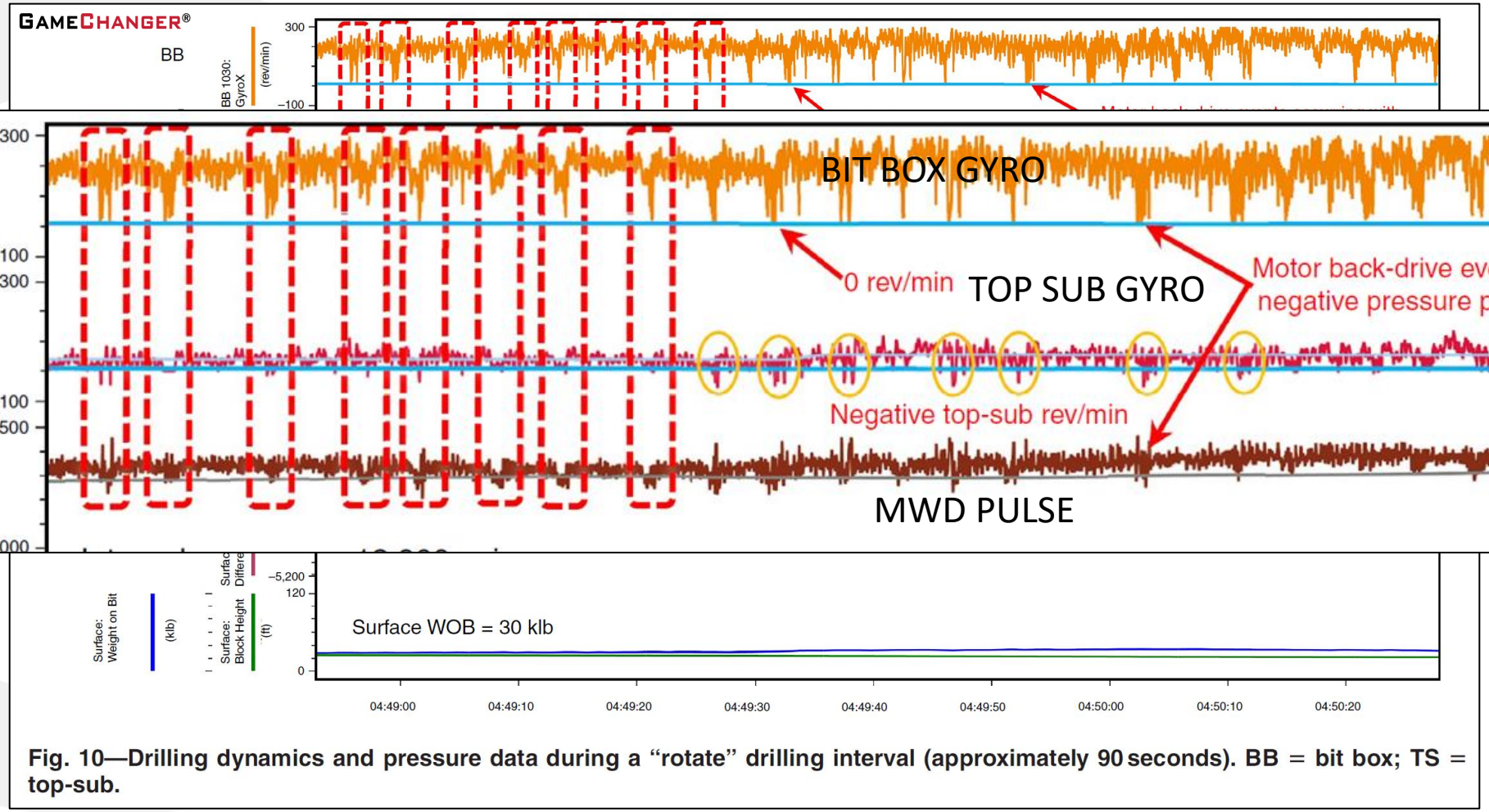

Fig. 10—Drilling dynamics and pressure data during a "rotate" drilling interval (approximately 90 seconds). BB = bit box; TS = top-sub.

Motor Back-Drive increased in magnitude with MWD pulse!

RSS Whirl – BHA & Bit

- Forward, backward or chaotic?
- Who cares?

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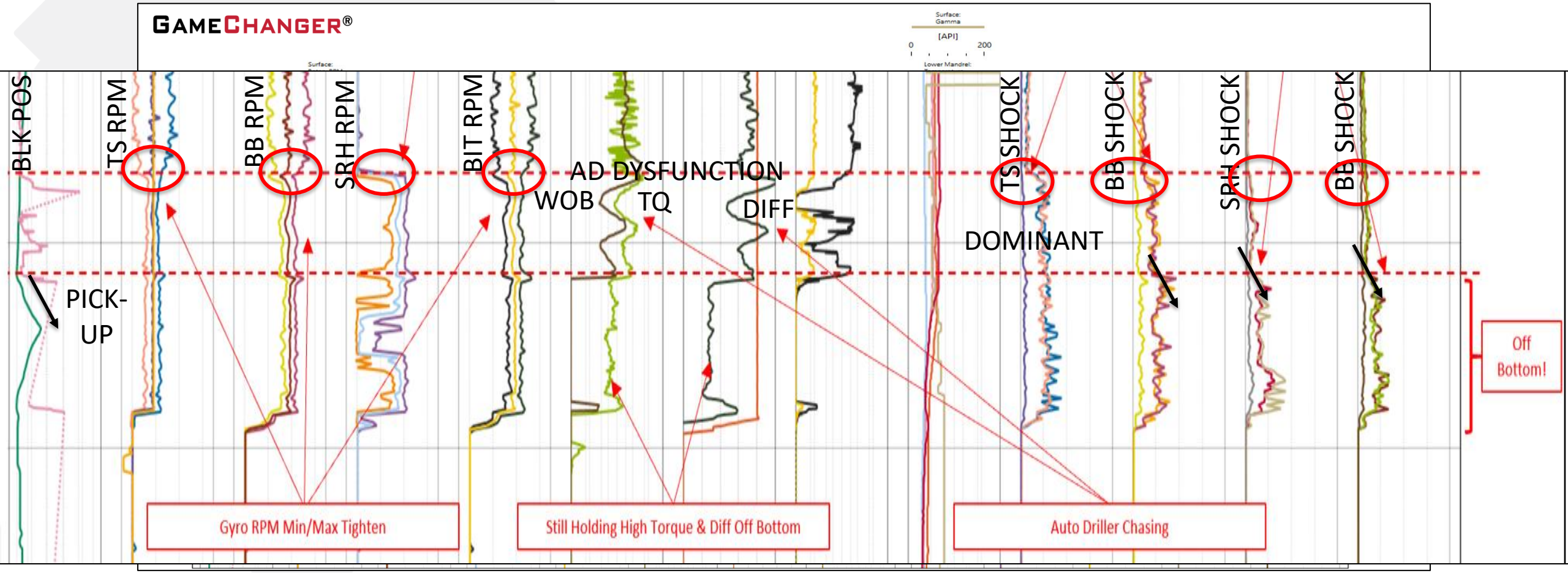

The only way to kill this whirl dynamic is to come off-bottom and shut down everything – then start-up again!

Mapping DAS Downhole Dynamic Response

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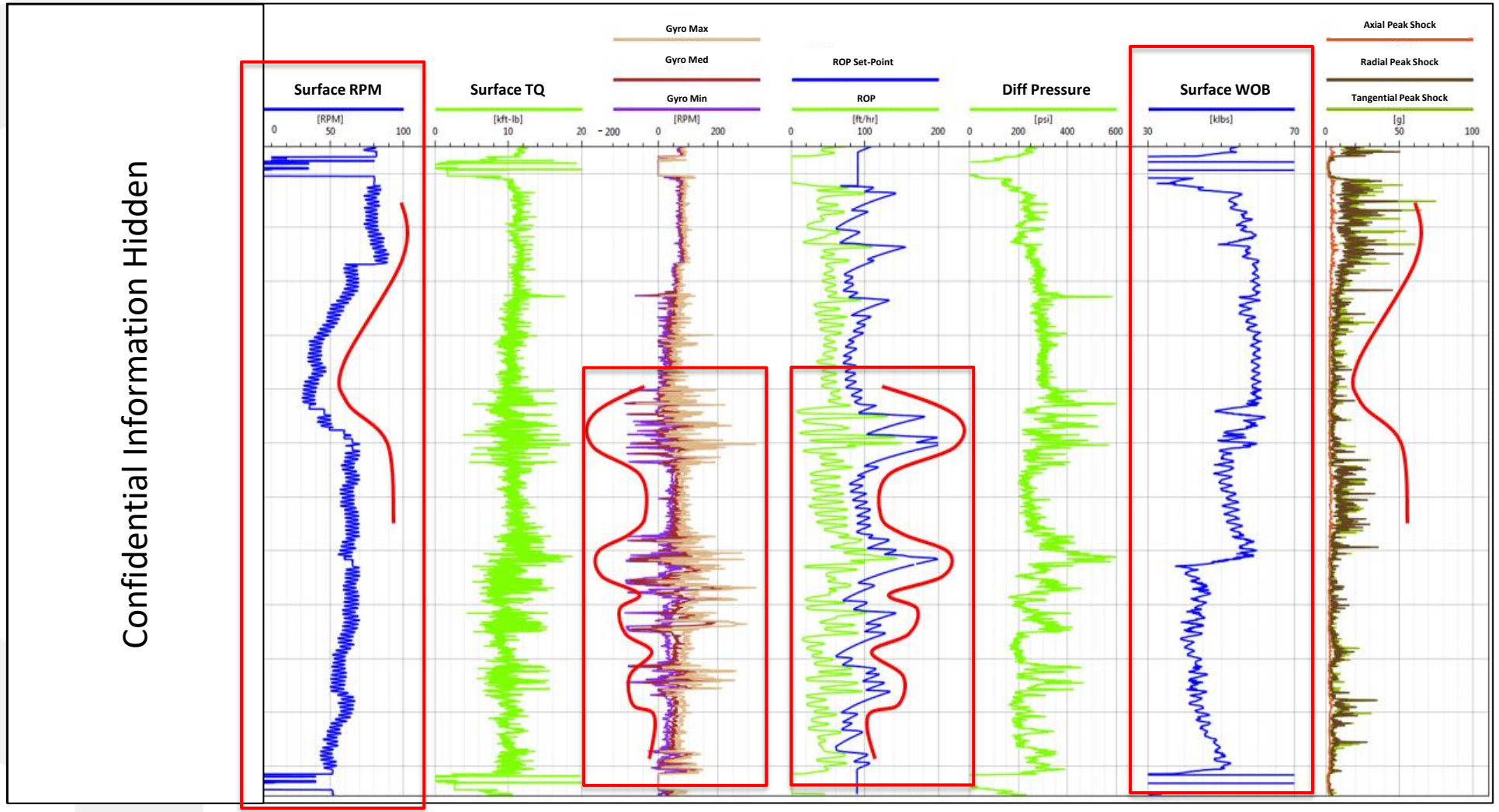

Dithering and Hunting RPM & WOB can cause dysfunction if boundary conditions are not controlled!

Understanding HFTO & Suppression

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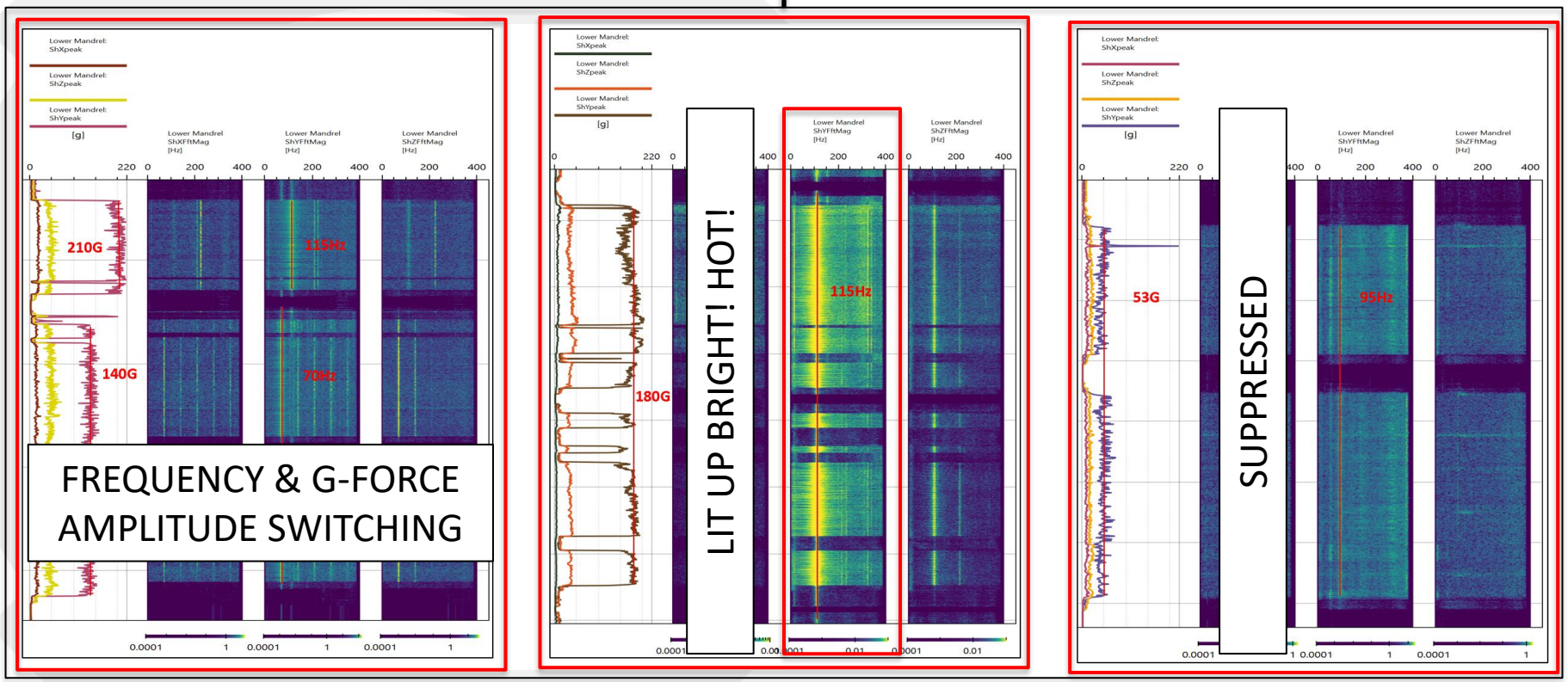
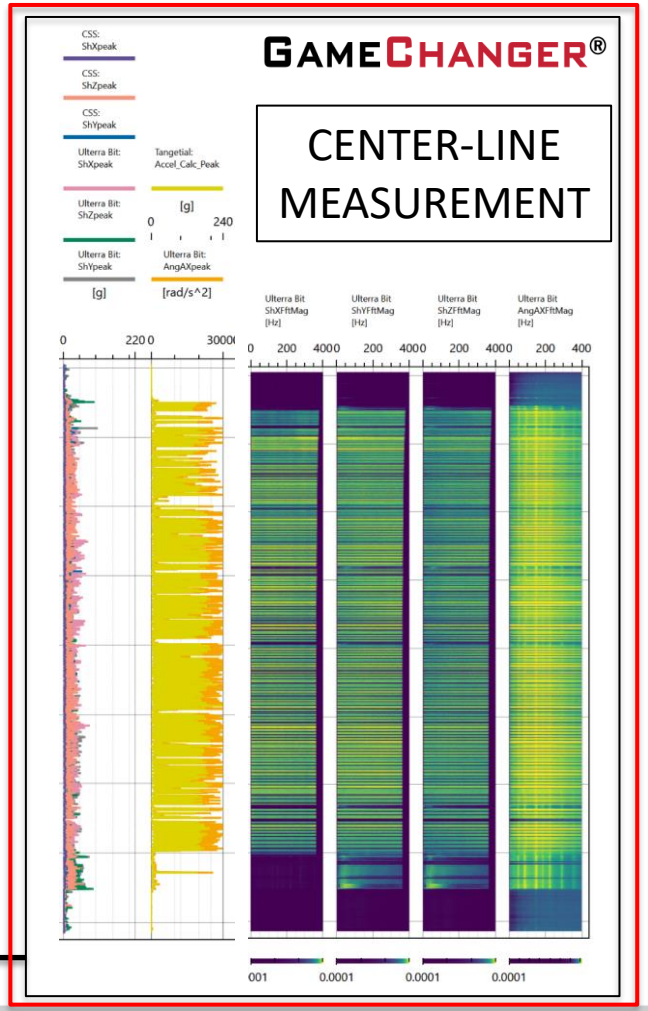
Tangential Acceleration with Sensor Offset from BHA Centerline





Angular Acceleration Translated to Tangential Acceleration

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Reducing HFTO damages does not mean isolation tools are required in every well! Know your bench…..

Fingerprinting & Road mapping

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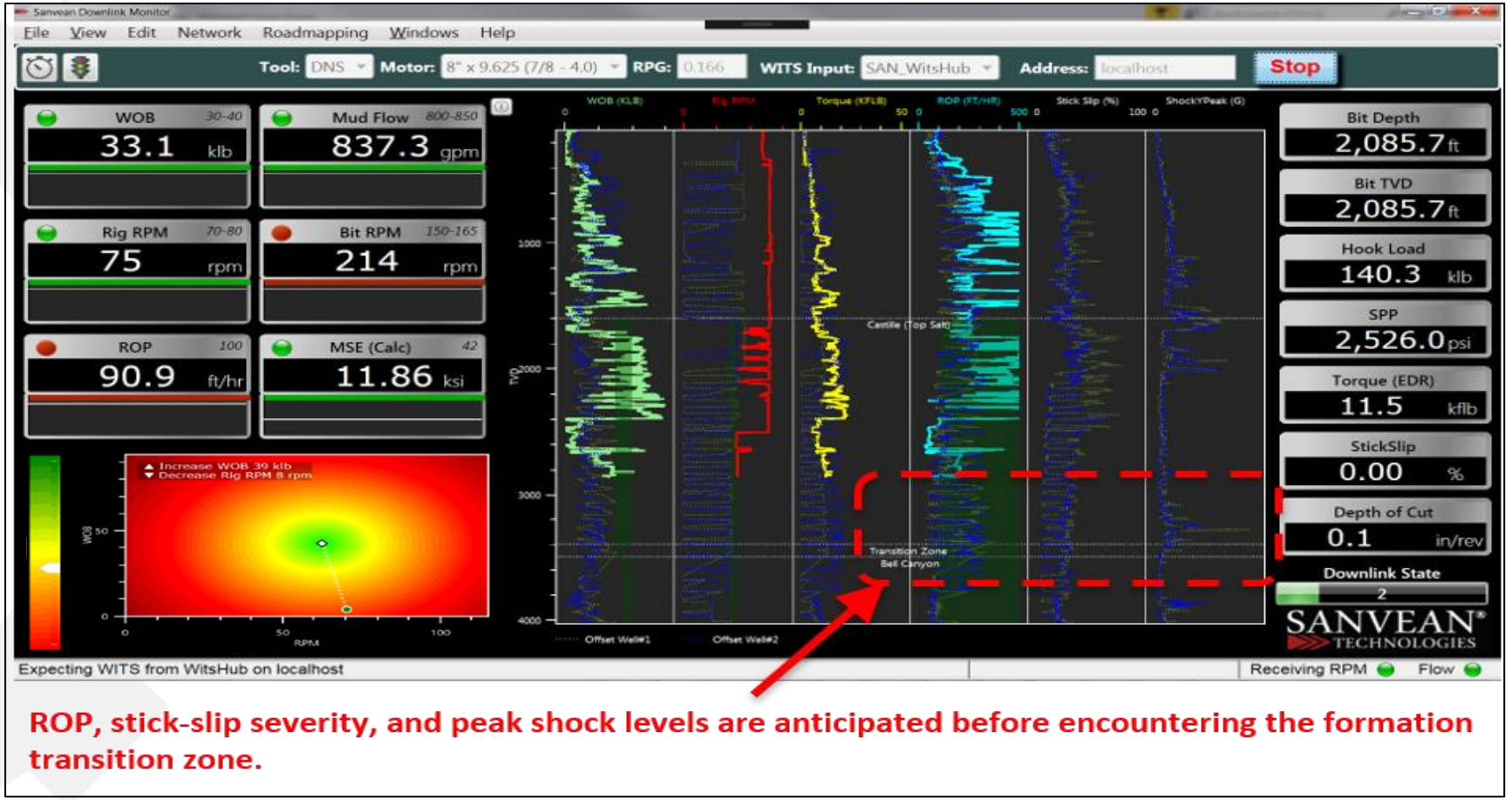
- Surface and high-frequency downhole data overlay.
- Correlate high-frequency downhole dynamics response with surface feedback.
- “Tune” performance well after well.
- “Look-ahead” feature from offsets of importance.



ROP, stick-slip severity, and peak shock levels are anticipated before encountering the formation transition zone.

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To delivery consistency, inputs need to be consistent from start to finish!

I appreciate your time today. Thank you!

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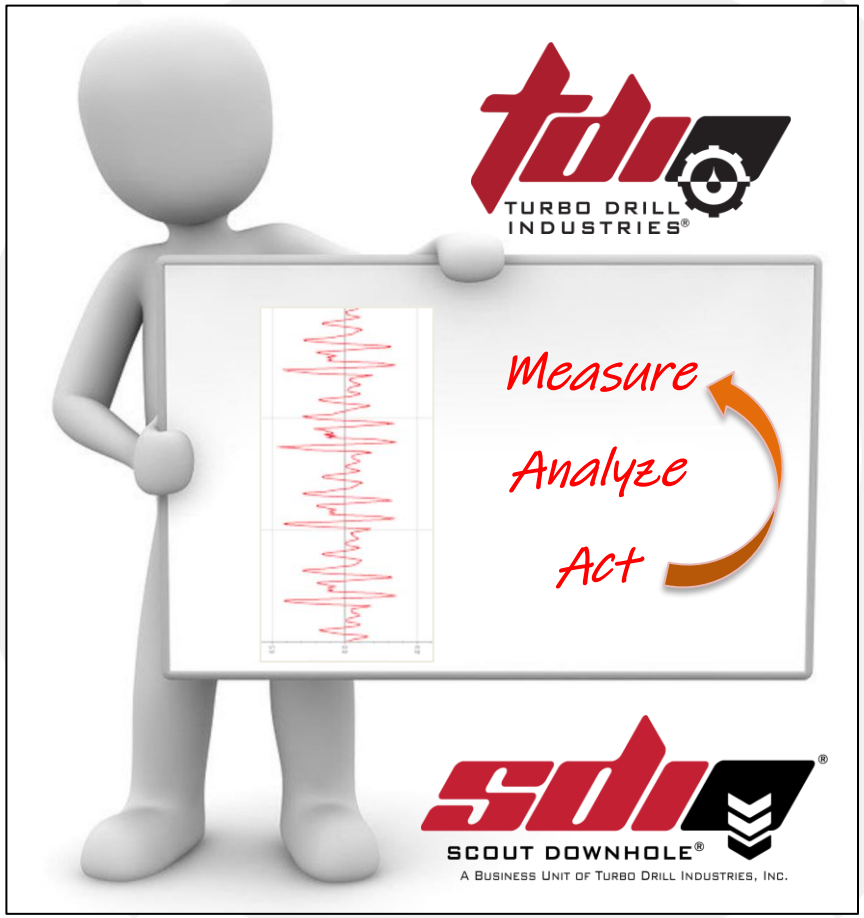

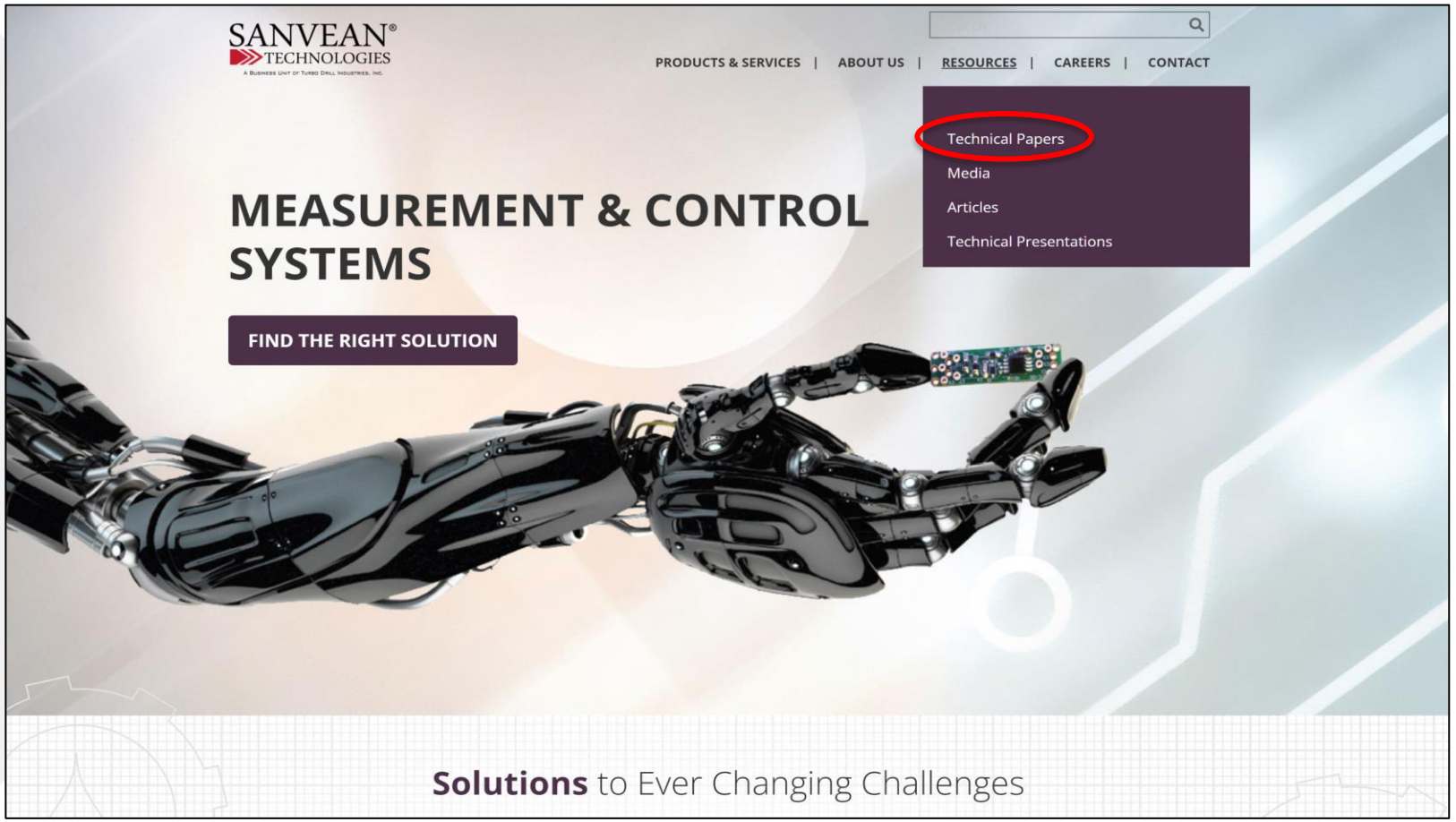

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