Use of Mechanical Specific Energy Calculation in Real-Time to Better Detect Vibrations and Bit Wear While Drilling

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Outline

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  - Drilling Strength (DS)
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- Conclusions

Mechanical Specific Energy

- Commonly defined as the amount of energy required to destroy a unit volume of rock
- Pioneered by Teale in 1964 –but mostly used by bit vendors
- Popularized as an efficiency index in 2005
- Efficient drilling: MSE ≅ 3-4x CCS or UCS
- Changes in MSE can be due to:
  - Change in formation
  - Downhole Vibration
  - Bit Wear
  - Bit Balling

$$MSE = \frac{WOB}{A_B} + \frac{120\pi * RPM * TOB}{A_B * ROP}$$

Mechanical Specific Energy

$$MSE = \frac{WOB}{A_B} + \frac{120\pi * RPM * TOB}{A_B * ROP}$$

Teale's Equation

Can be neglected

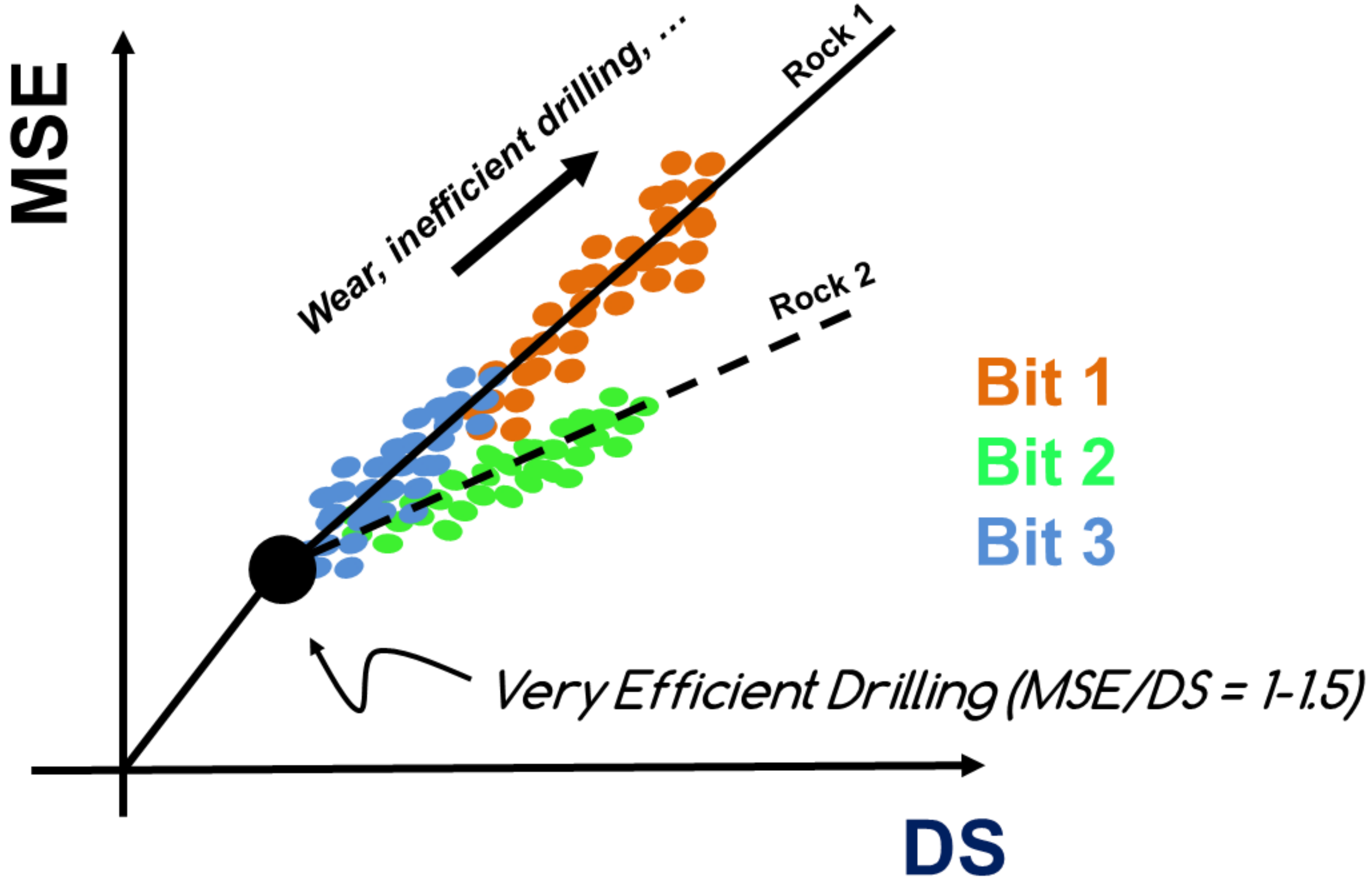
$$MSE = \frac{2 * TOB}{R^2 * DOC}$$

Detournay's Equation

WOB= Weight On Bit
A_B = Bit Area
RPM = Rotation Speed
TOB = Torque On Bit

ROP = Rate of Penetration
DOC = Depth of Cut
R = Bit Radius

Drilling Strength



Drilling Strength

Detournay's Equation

$$DS = \frac{WOB}{R * DOC}$$

US005216917A

United States Patent [19] **Detournay**

[11] **Patent Number: 5,216,917**

[45] **Date of Patent: Jun. 8, 1993**

[54] METHOD OF DETERMINING THE DRILLING CONDITIONS ASSOCIATED WITH THE DRILLING OF A FORMATION WITH A DRAG BIT

[75] Inventor: **Emmanuel Detournay**, Cambridge, England

2188354A 9/1987 United Kingdom .

Primary Examiner—Hezron E. Williams
Assistant Examiner—Michael Brock
Attorney, Agent, or Firm—John J. Ryberg; Wayne I. Kanak

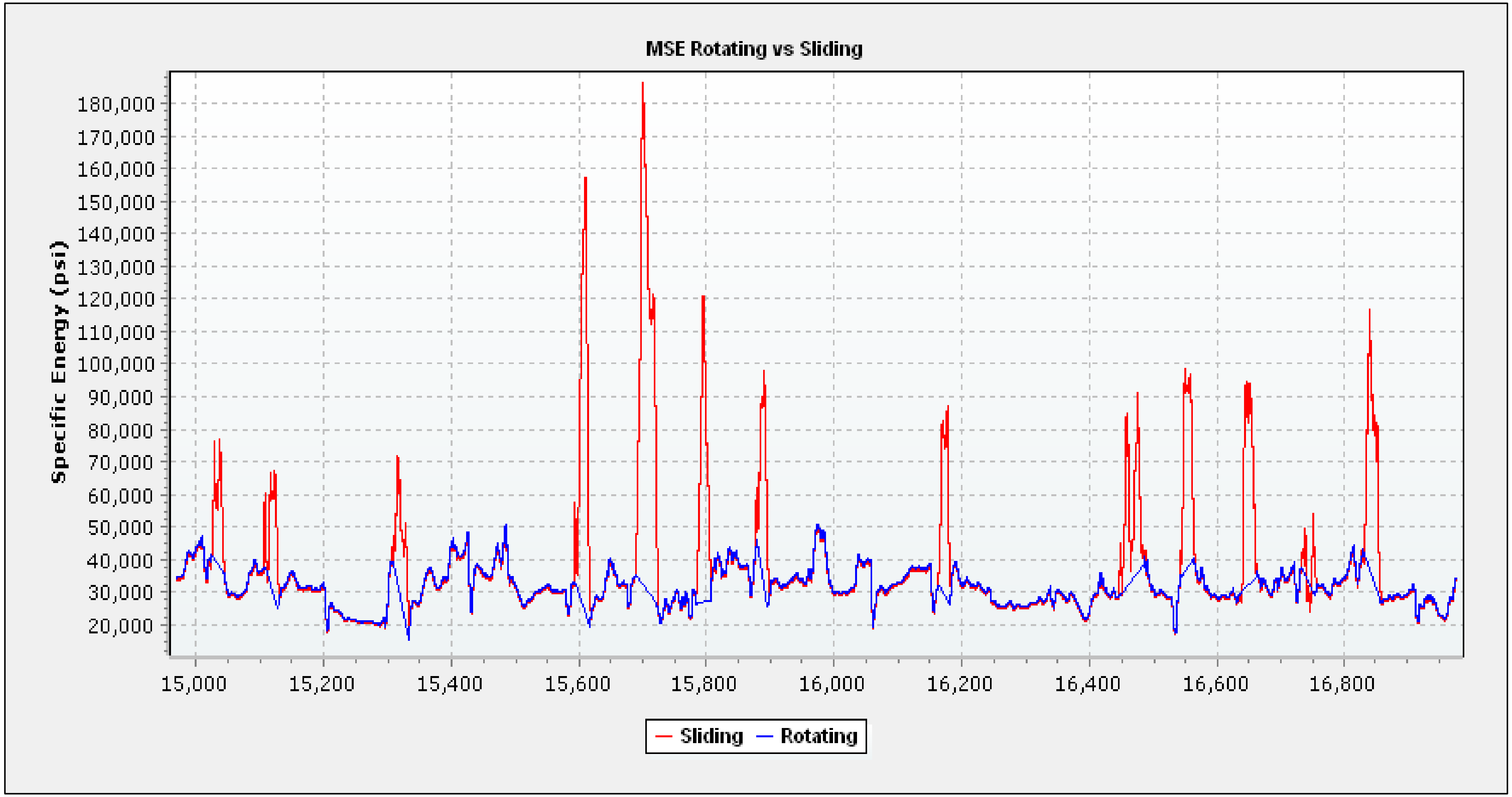
[57] ABSTRACT

MSE/DS Ratio

- Combining MSE and DS gives a new index to analyze drilling dysfunction
- MSE – Analysis of torque contribution to efficiency
- DS – Analysis of weight contribution to efficiency
- Patent **Method for detecting a drilling malfunction** WO 2015086777 A1
- Using MSE/DS ratio provides additional information
- Makes it possible to determine the type of dysfunction occurring

MSE	DS	MSE/DS	Dysfunction	
↗	↗	↘	UCS	↗
→	→	→		→
↘	↘	↗		↘
↗	↗	↘	Bit Balling	↗
↗	↗	↗	Vibration	↗
↗	↗	↘	Wear	↗

Data Collection and Processing

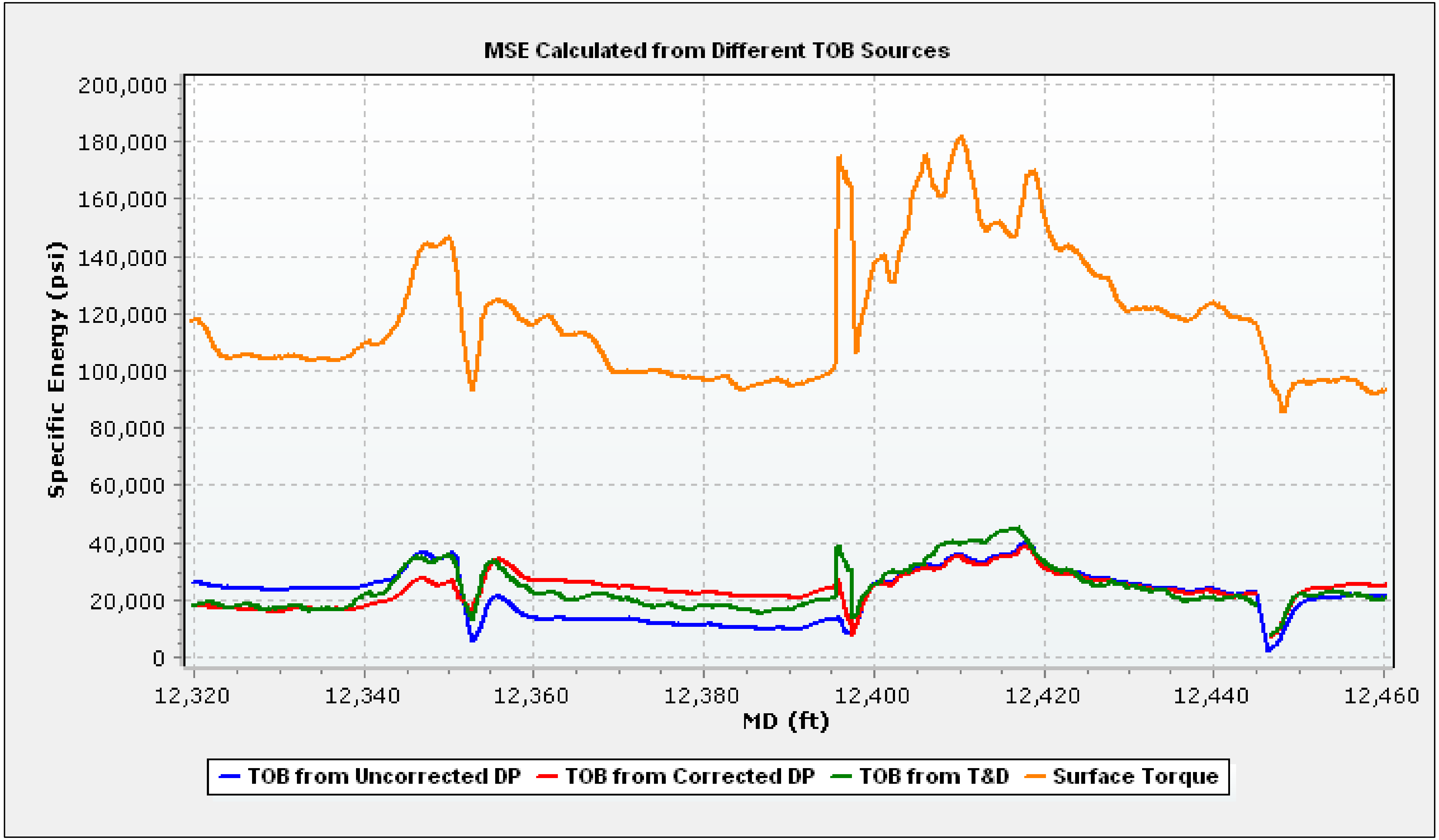


- Sliding and rotating data separated out
- Only rotating data used

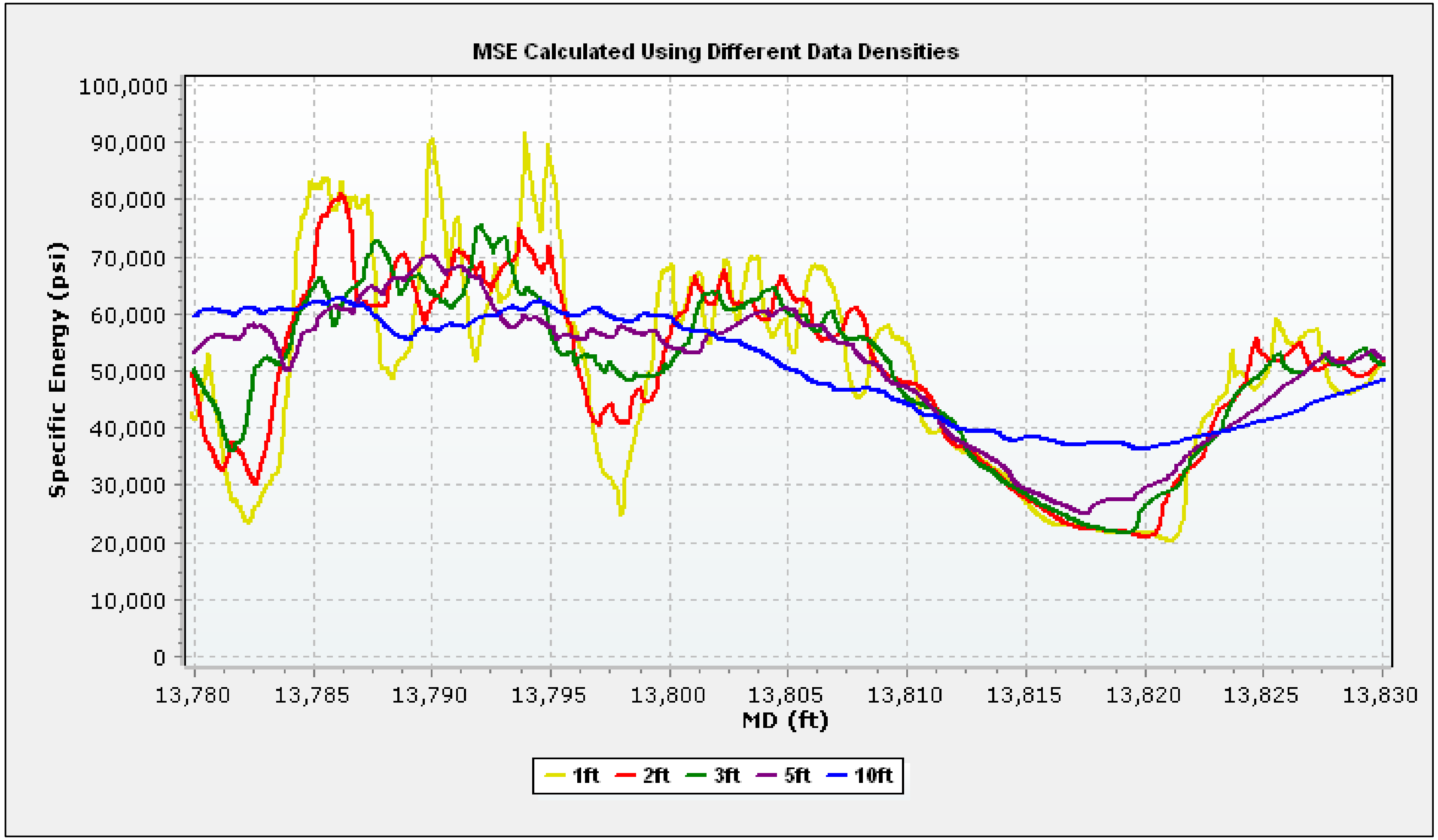
Notes on Torque

- Measured (sensor) TOB most accurate for MSE
- Downhole TOB can also be derived via:
  - **Differential pressure from mud motor**
    - Diff pressure is directly related to the torque output by the motor and a good indicator of DH TOB
  - **Torque and drag analysis**
    - Analysis of torque and drag can provide the torque contribution from the string
    - Removing the string torque from the surface torque leaves us with only DH TOB

Torque source comparison



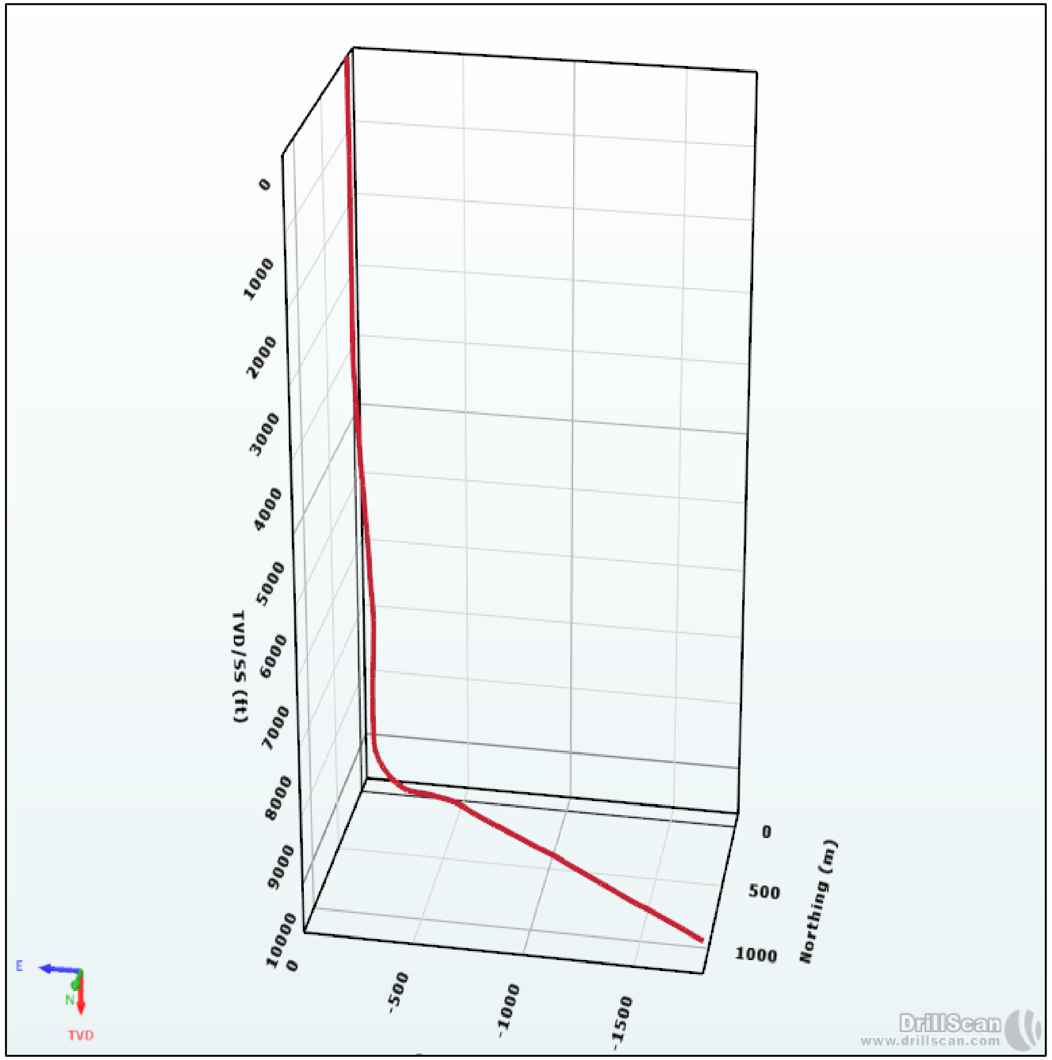
Data Density



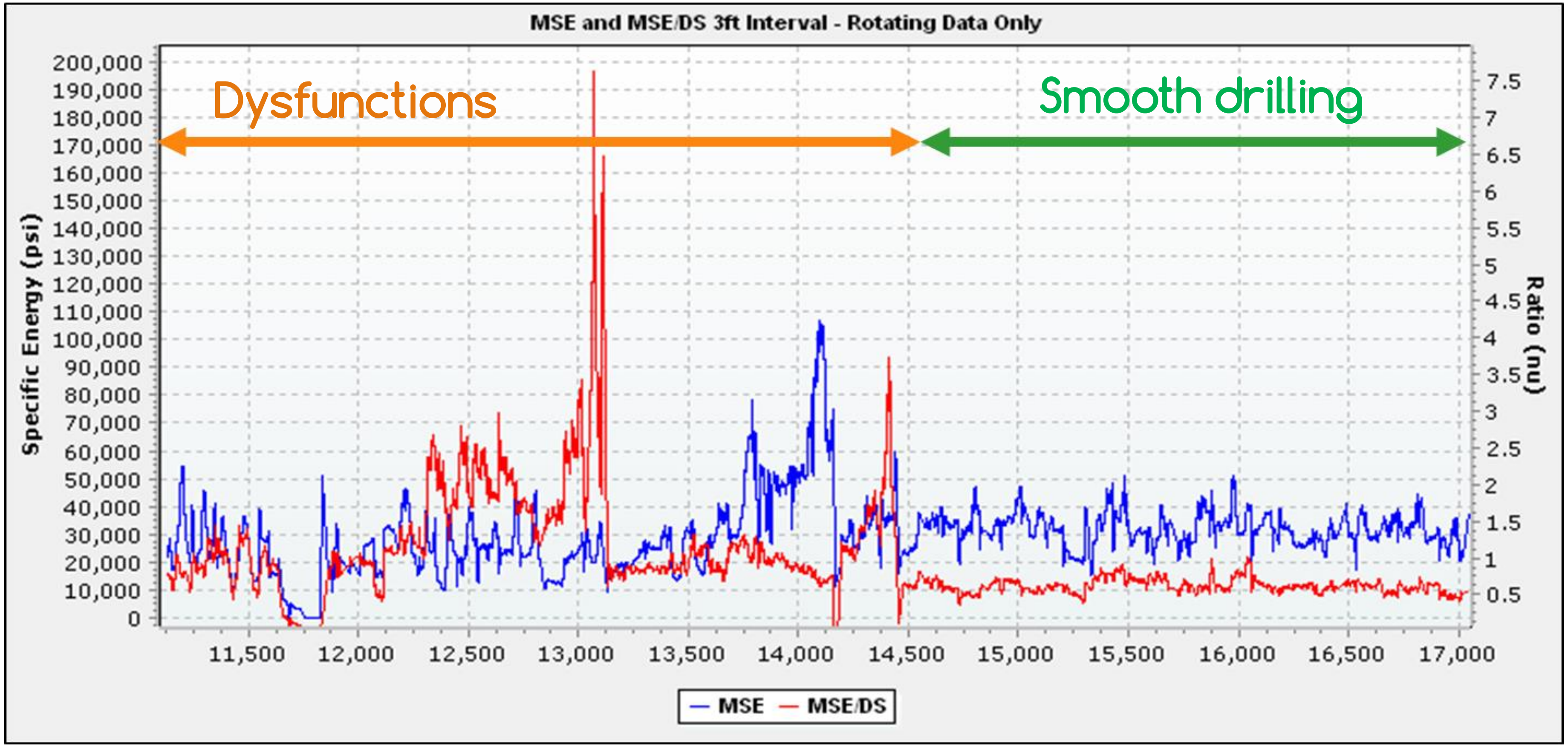
- Data density changes how MSE is viewed and perceived
- A minimum of one point per 2-3ft is recommended for a thorough analysis

Case Study

- Typical Eagle Ford well
- 9 5/8” casing shoe at ~9,000ft
- 8 ¾” 6,000ft lateral section
- 6 ¾” mud motor w/ 2° bend
- Curve and lateral drilled in two runs
- Lateral geosteered using gamma ray logs
- Formation considered homogenous
- PDC Bit: 5 blades, 13mm cutters



Results



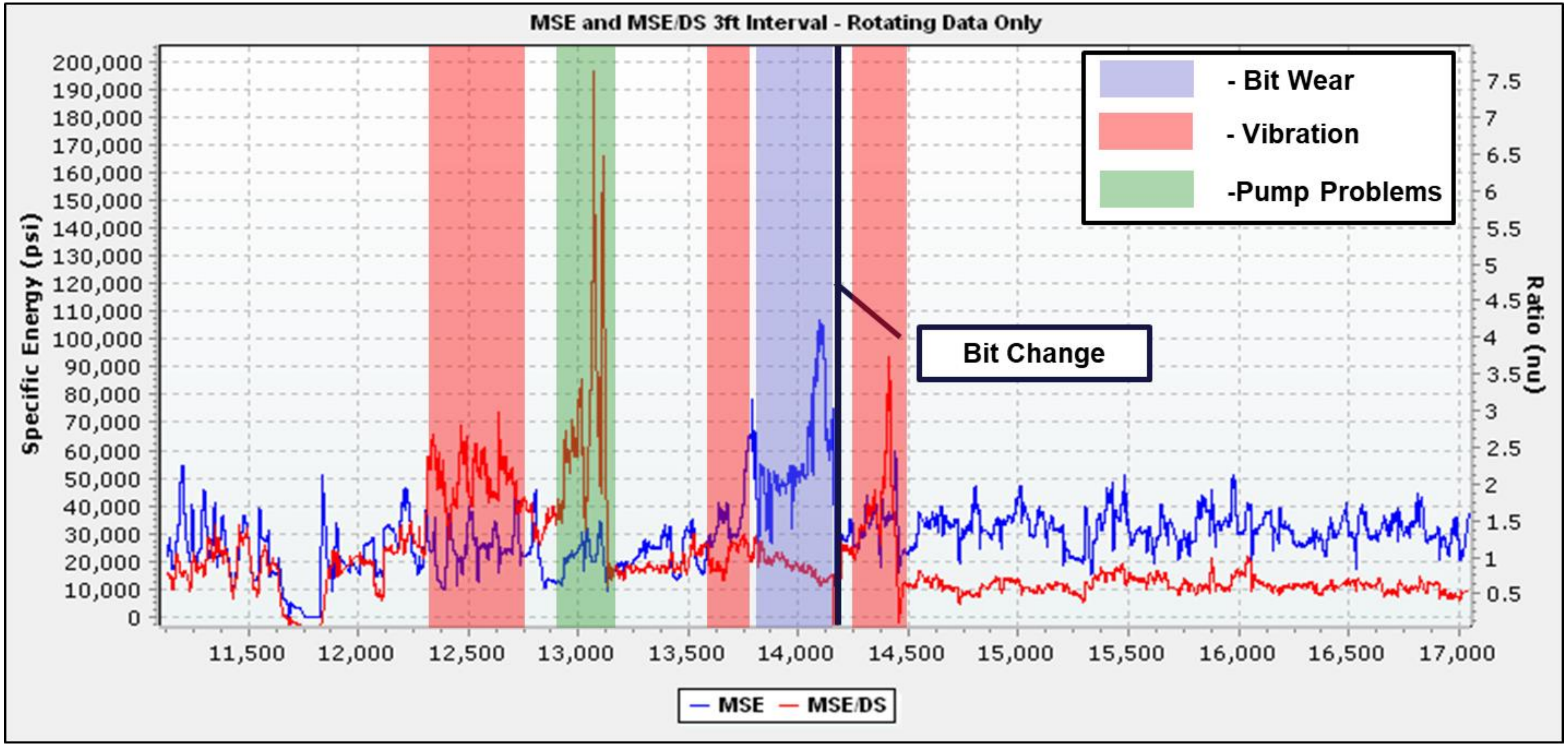
Significant dysfunction in a few places, MSE spikes and frequently changing ratio.
Efficient, steady state drilling with low to no dysfunction.
Ratio constant around 0.5

Results

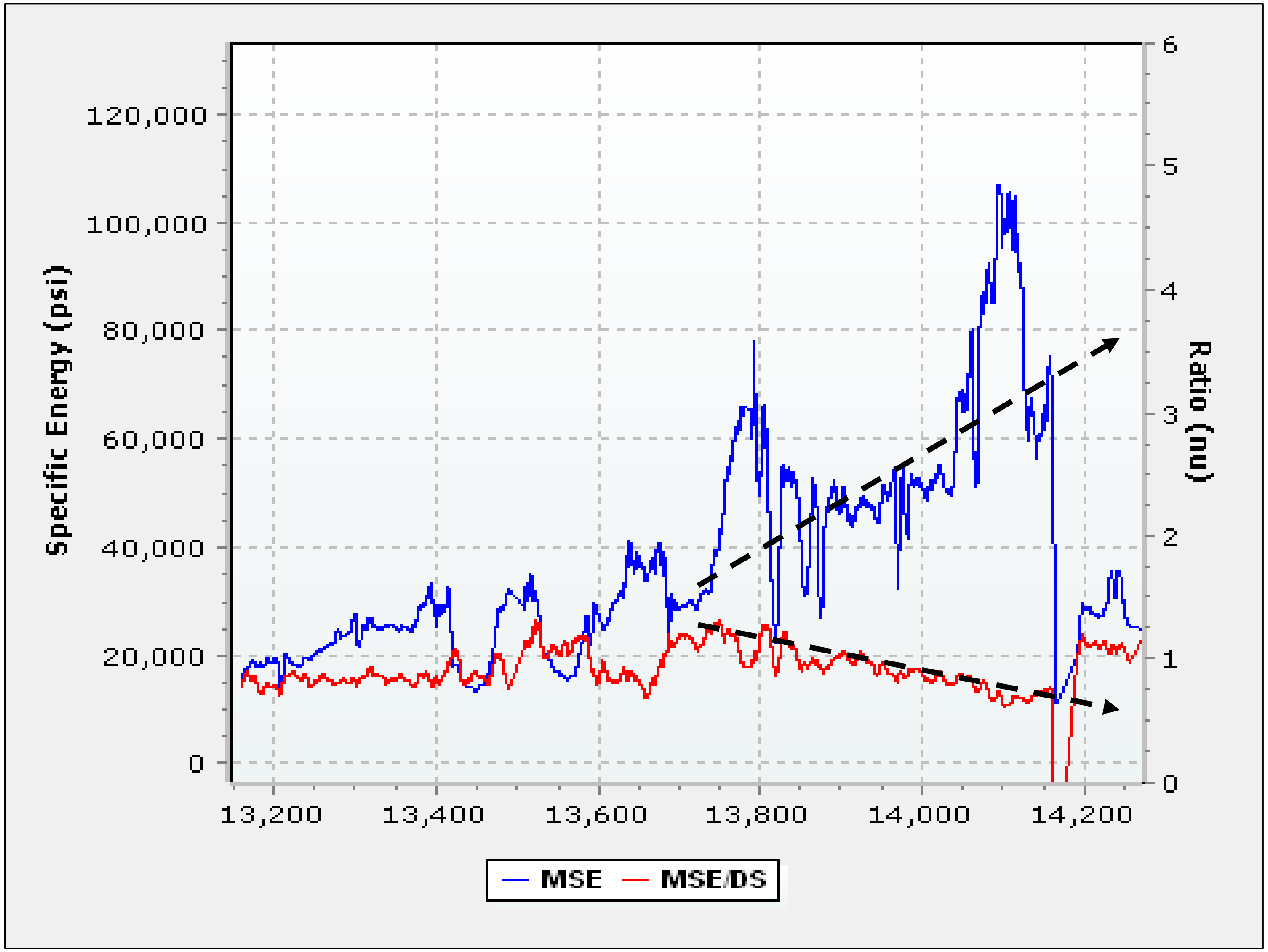
Three main observations:

- Pump Problems
- Bit Wear
- Vibration

MSE	DS	MSE/ DS	Dysfunction
↗	↗	↗	Vibration
↗	↗	↘	Wear



Bit Wear

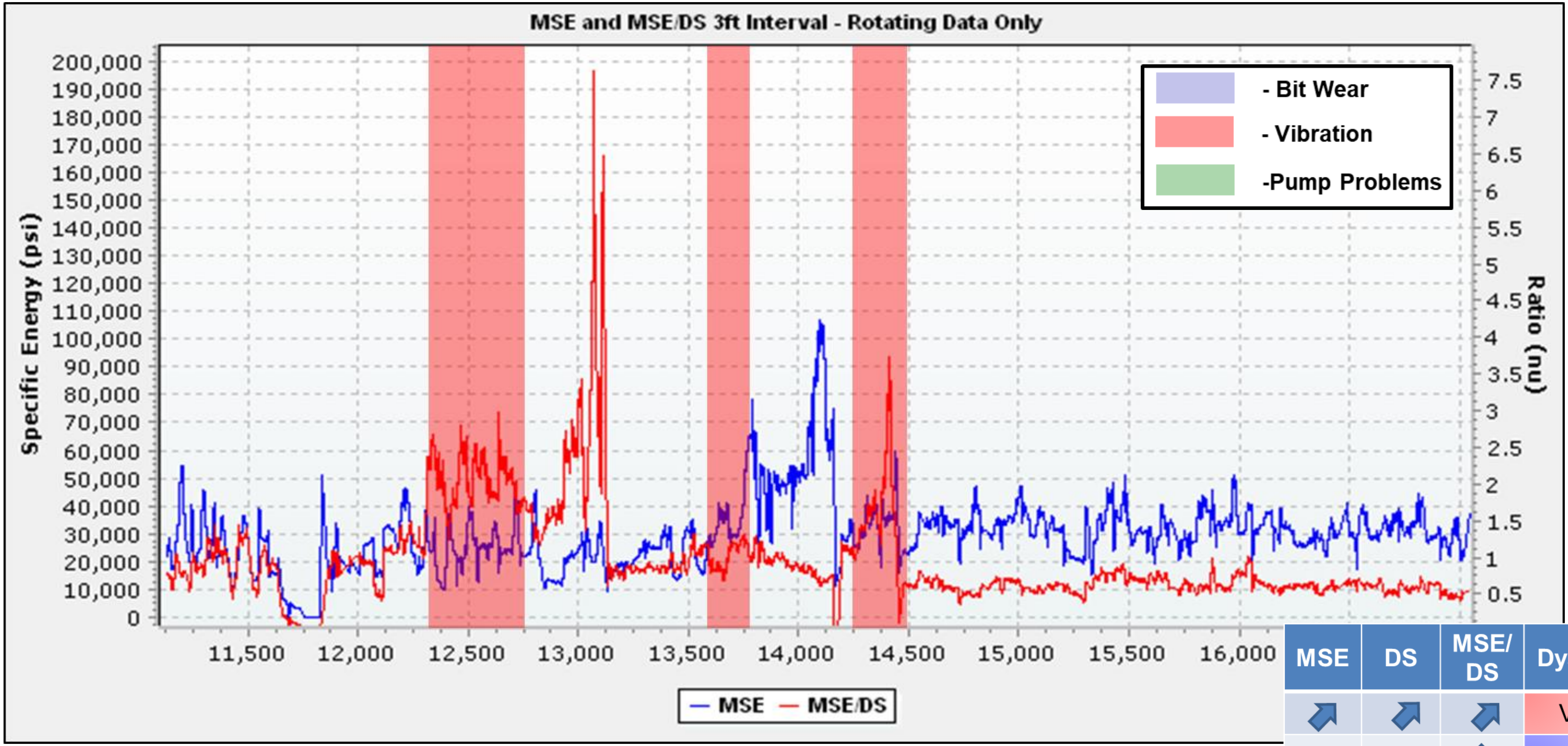


MSE	DS	MSE/ DS	Dysfunction
↗	↗	↗	Vibration
↗	↗	↘	Wear

- MSE increasing
- Ratio decreasing
- Indicates bit wear
- BHA was pulled for a bit change

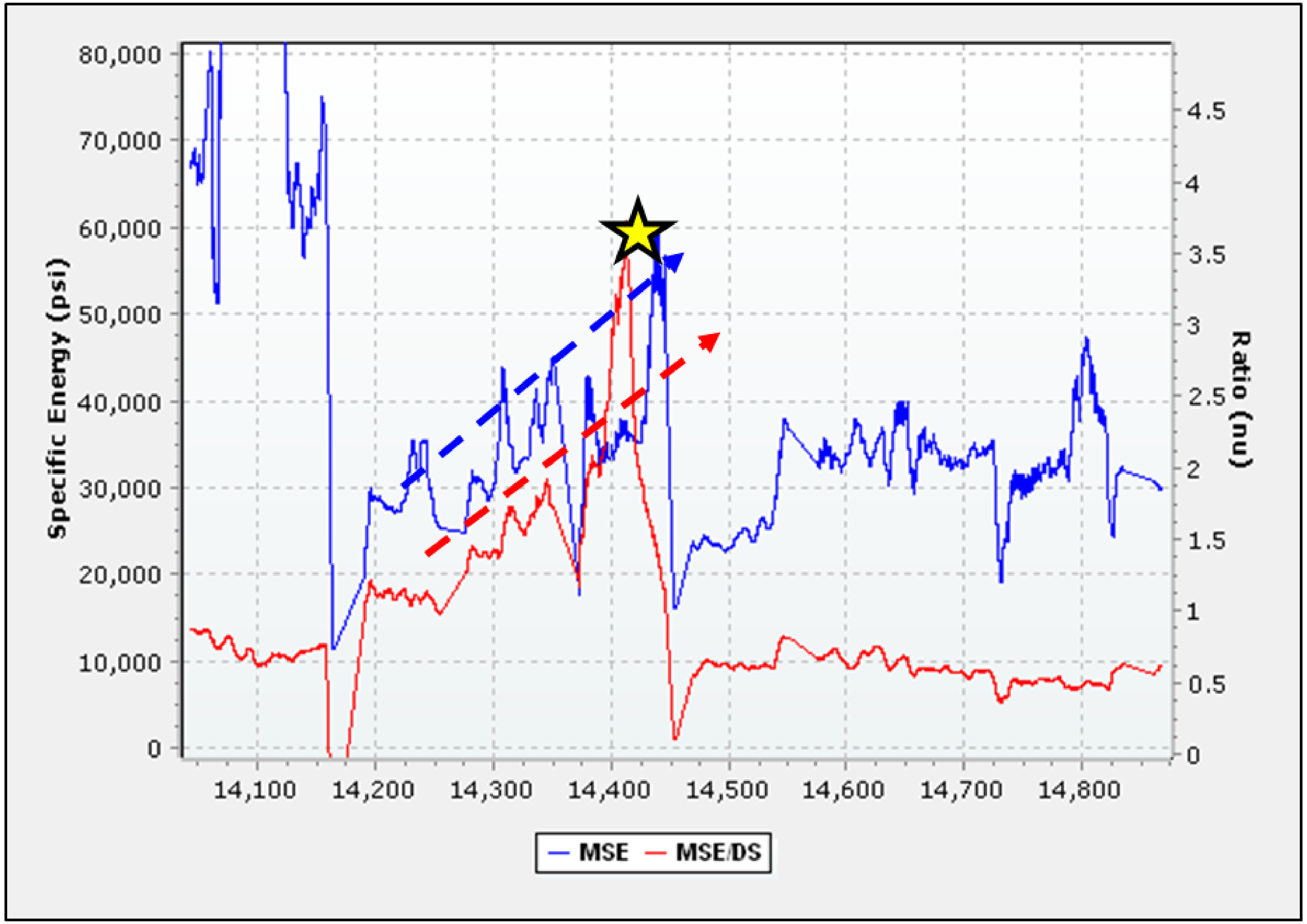
Results

Vibration detected at 12,500ft, 14,000ft and 14,200ft.



MSE	DS	MSE/DS	Dysfunction
↗	↗	↗	Vibration
↗	↗	↘	Wear

Vibrations

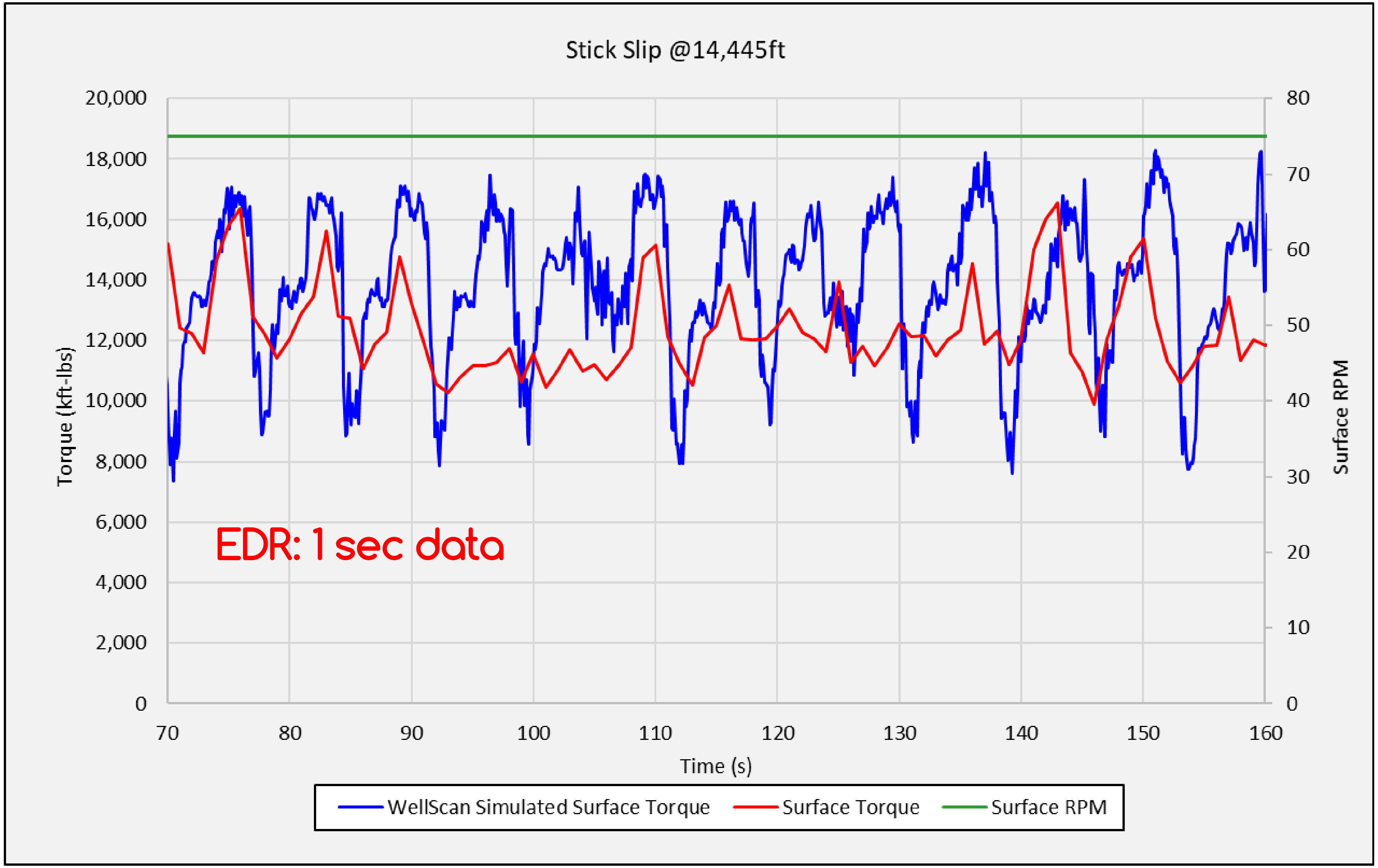


Root cause analysis showed stick-slip presence

Modeled and confirmed using software

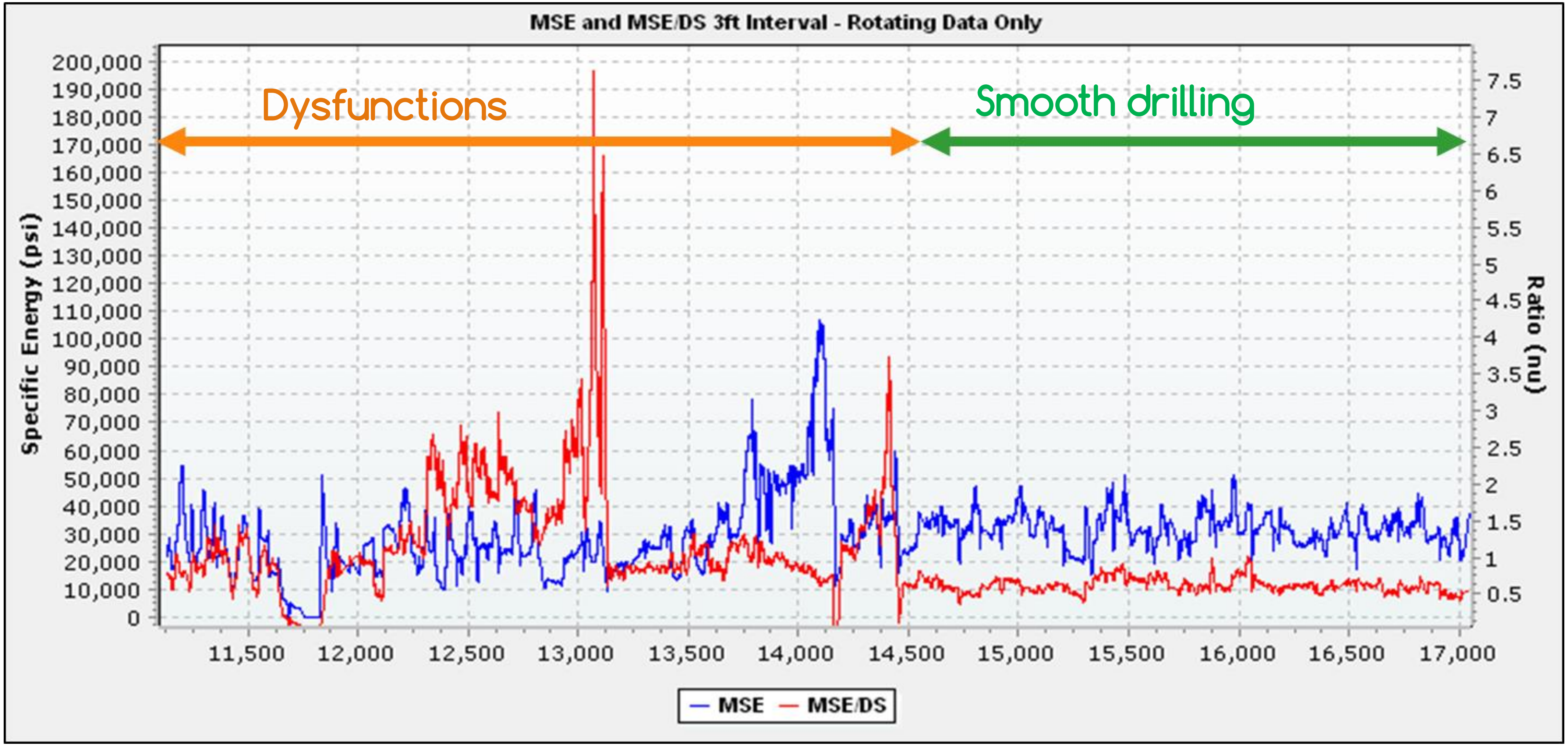
MSE	DS	MSE/ DS	Dysfunction
↗	↗	↗	Vibration
↗	↗	↘	Wear

Vibrations – Stick Slip



Results

Lateral continues to be drilled efficiently until the end



Conclusion

- MSE analysis: well known drilling efficiency indicator
- MSE combined with Drilling Strength: detection of dysfunction possible (new method):
  - Bit Wear
  - Vibration
- Data Quality & Processing is key
- Estimation of TOB necessary
- Case Study has shown that dysfunctions can be avoided with proper MSE monitoring while drilling

Thank you

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