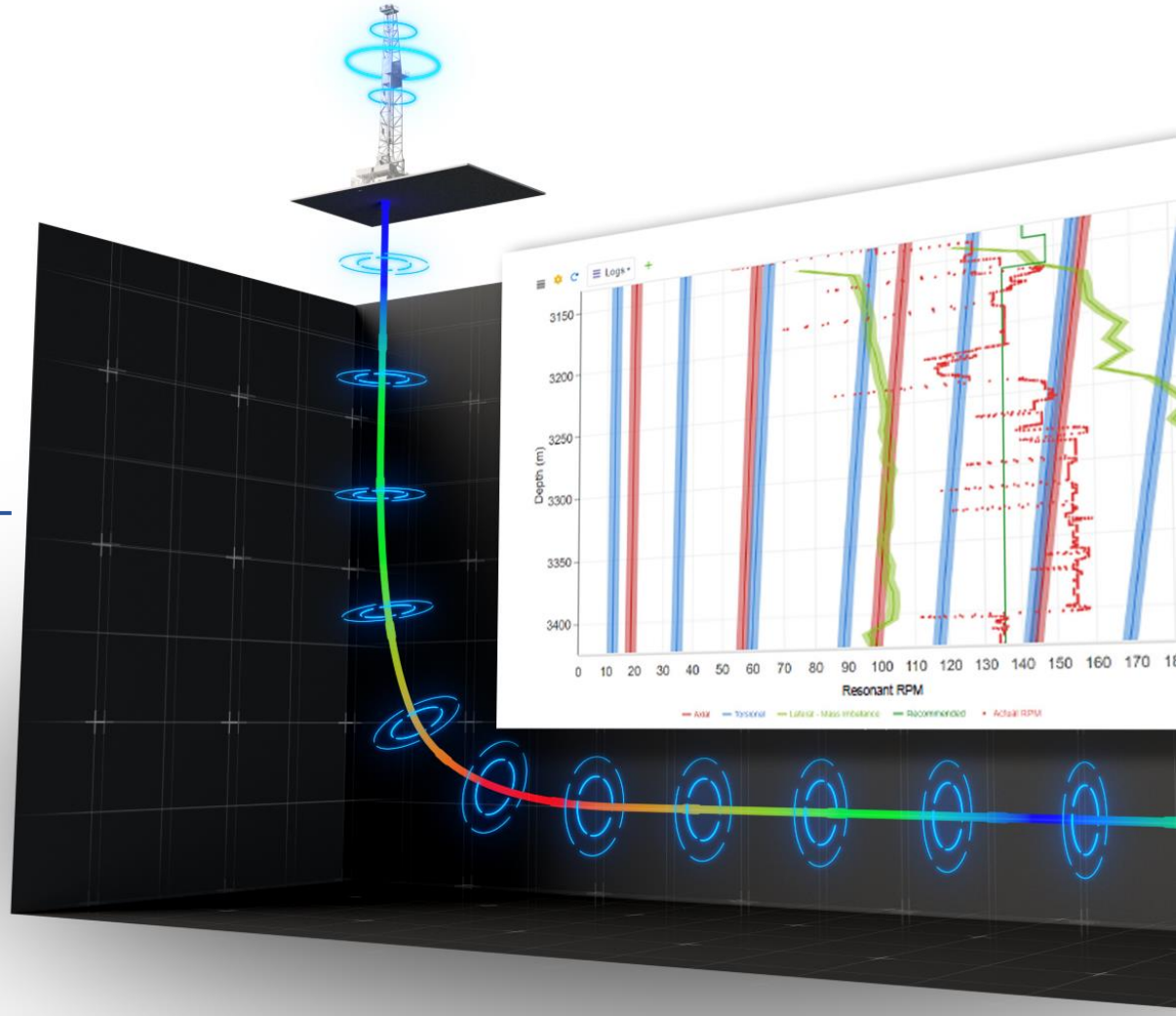
Predictive Vibration Mapping

Prevent Dysfunction and Tool Failures



De-Risk Your Drilling Program

Excessive vibrations in the BHA that are not managed with critical frequencies/RPMs put your well at risk.

- Bit bounce
- Stick-slip & whirl
- Reduced ROP
- Tool failure
  - Twist-off
  - Unplanned trips

Avoiding harmonic frequencies (critical RPMs) doesn't mean you avoid ALL lateral vibrations. Other causes may still force the string and/or BHA to vibrate.

However, these vibrations are less likely to start and continue when using the right speeds.

What Do You Know About Vibrations in Your Wellbore?

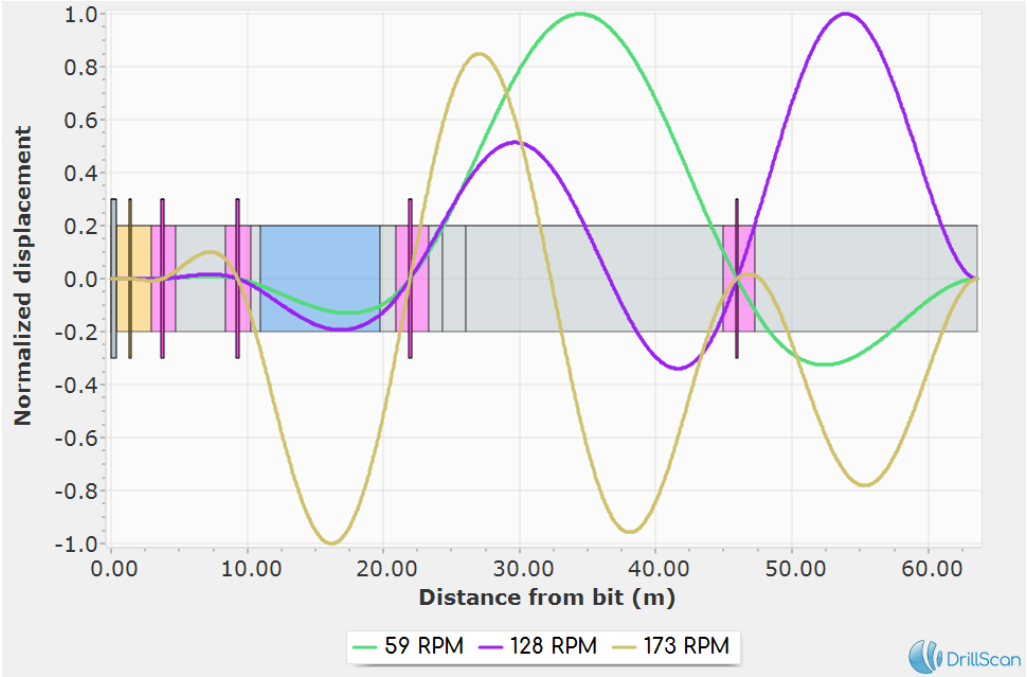
Drilling vibrations are complex but should NOT be ignored in the pre-planning stage

2 Sources of Excitations

- Your largest source of excitation is rotating the string in a resonant frequency
- Transient nature of external forces acting long drill string

Drilling with a mud motor?

- The center of mass of the rotor usually rotates backwards, creating an additional lateral mass imbalance
- We provide safe rotation speeds so your mud motor is not creating additional lateral mass imbalance.



In this example, H&P's software shows you max displacement or vibration around the collar when rotating the drillstring at these RPMs.

Reduce Downhole Vibrations & Drive Performance

Accurate Models Matter

H&P provides rapid and precise modeling results based on the latest physics-based modeling software to determine critical frequencies/RPMs so you can drill at safe rotation speeds.

- Identify axial & torsional vibrations through the entire drillstring length
- Visibility to lateral vibrations between the bit and first POC in the wellbore
- Significantly enhance set point management workflows

Predictive Vibration Mapping helps you know where to drill more efficiently with the least vibrations.

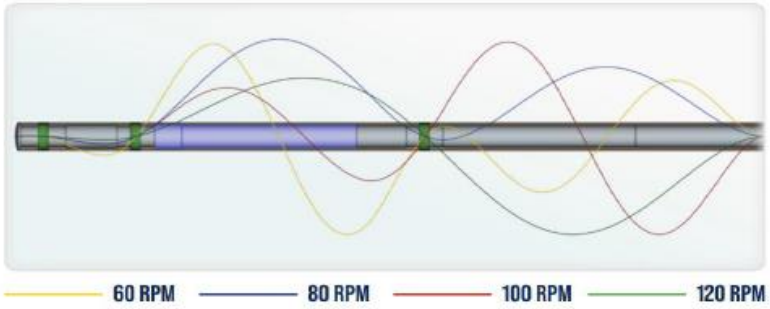
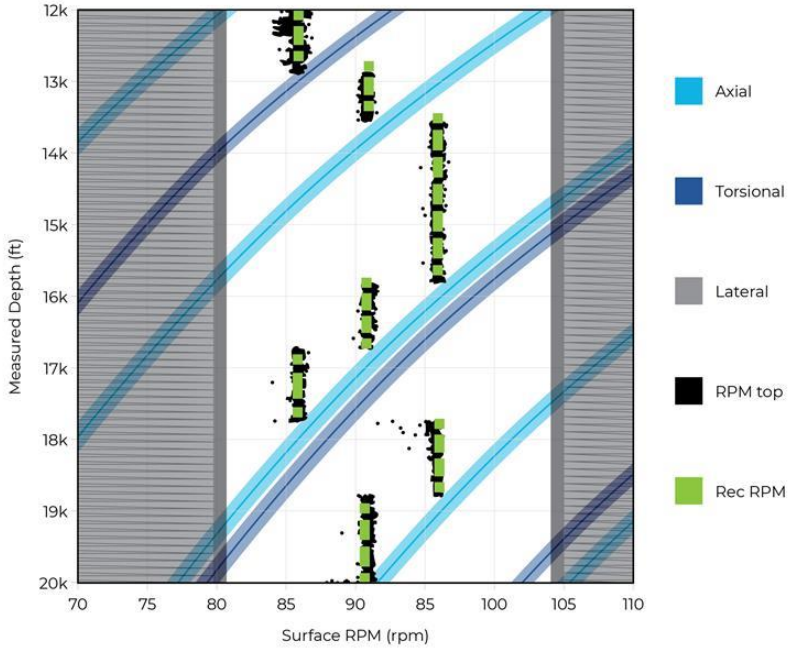
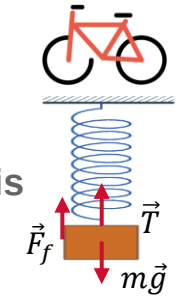
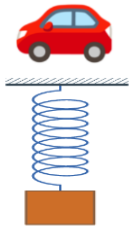
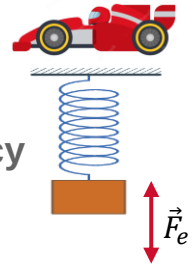
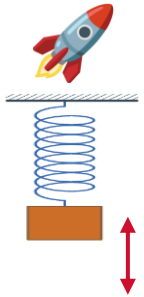


FIGURE 2: MIN/MAX DISPLACEMENT RELATIVE TO CRITICAL SPEED (AMPLITUDE OF VIBRATION)



Get the Goldilocks Model

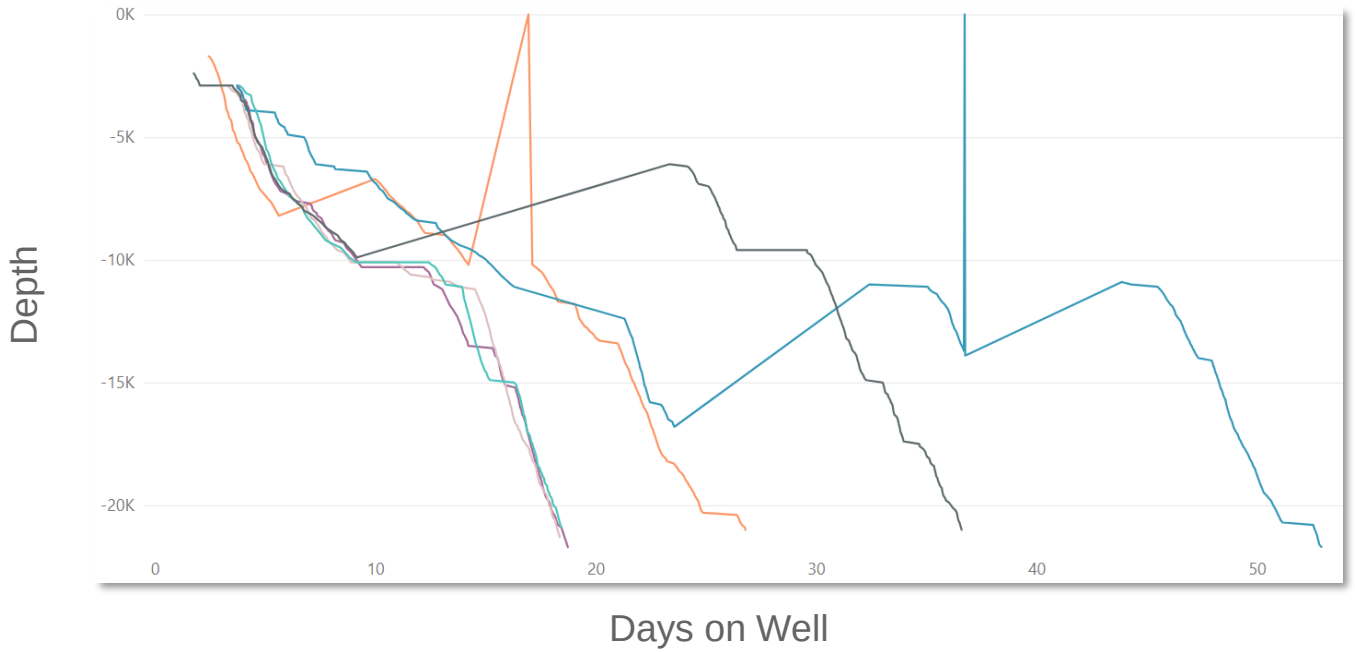
- Simple models that don't account for lateral vibrations and wellpath design miss the mark
- FEA calculations are too complex & take days to give a solution
- Predictive Vibration Mapping
  - Up-to-date science with a fast computation time
  - Calculates resonant frequencies for drillers to avoid, while recommending the optimal RPM

	Static Analysis 	**Predictive Vibration Mapping**  $\omega_0 = \sqrt{k/m}$	**Forced-frequency Analysis**  $\vec{F}_e \sin(\omega_e t)$	**Time-domain Analysis**  $\vec{F}_e(t)$
Hypothesis	Static contact forces	- No external forces - Fixed pivot contacts	- Linearized contact forces - Periodic external excitations	Non-linear dynamics (FEA)
Outputs	- Side forces - 3D deflection	- Resonance frequencies - Normalized modal shapes	- Vibrations amplitude - Strain energy	- Time-based - All profiles
Computation time	Very fast	Very fast	Fast	Long
Ease of use	Basic	Basic	Intermediate	Advanced

What's the Value of Consistency?

If you're trying to achieve factory drilling and you're using the same:

- ✓ **BHA**
- ✓ **Motor**
- ✓ **Parameters**
- ✓ **Formation**



- Do you know why your tripping?
- Why it's not consistent every time?
- Do you sometimes drill a section in 1 run and sometimes 3? How does that look on your AFE?

On an $100k spread rate
1 trip in the lateral takes on average 16 hours
2 trips are costing you $130,000

Predictive Vibration Model Reduces 0.37 Trips Per Lateral, Saving ~ $2k Per Day

AWE engineers provided drillers with recommendations for RPMs so they can **avoid critical frequencies**

10 Months of Data

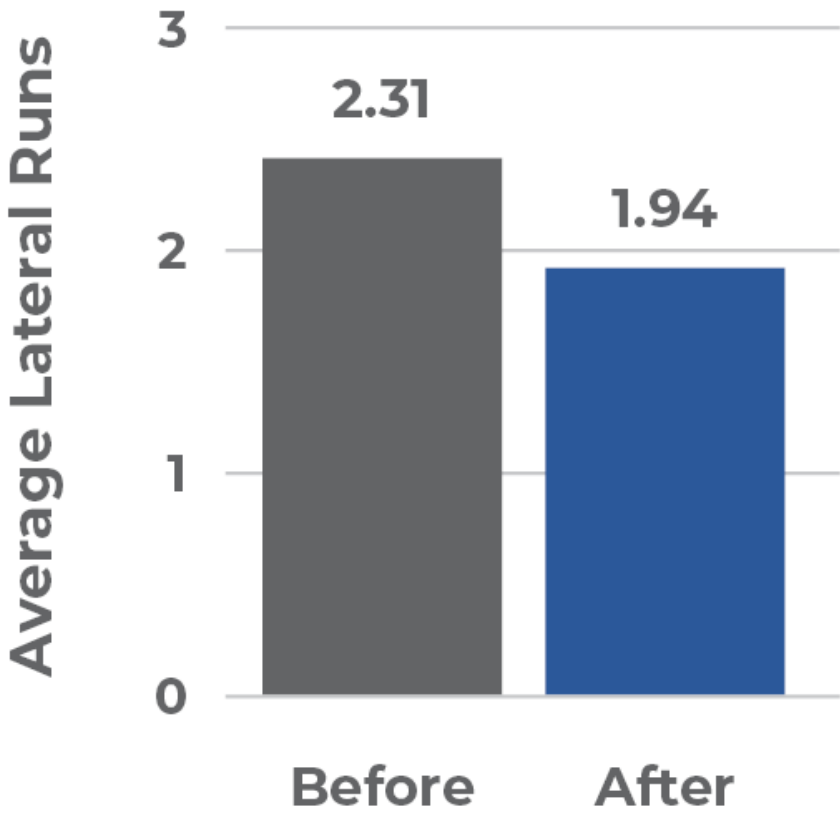
- 72 laterals across 6 rigs
- 36 laterals before the service started, 36 after

Outcome Achieved

- Overall reduction of 0.37 trips per lateral

Operator Impact

- ~ $2k in savings per day



Case Study: Operator Reduces Trips By Over 65% in both the Intermediate and the Lateral

Challenge

- Operator was averaging 2.8 trips in the intermediate & 3.25 in the lateral

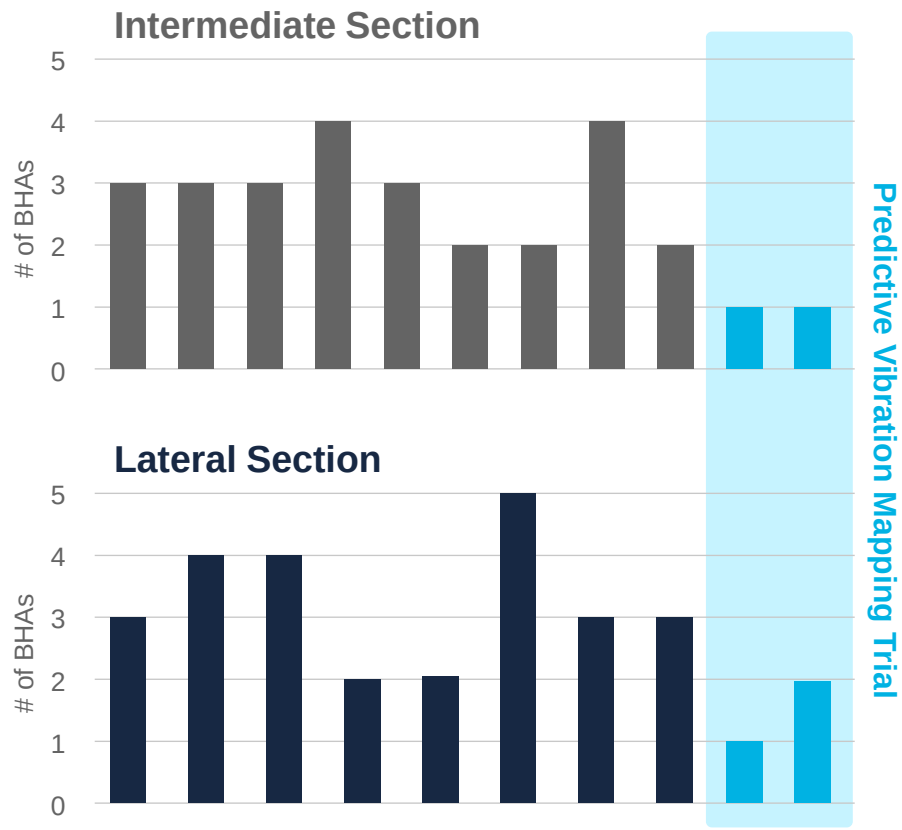
Solution

- H&P trialed Predictive Vibration Mapping

Result

- 65% reduction in trips in the intermediate
- 69% reduction in the lateral

WTX Delaware Basin Rig



Case Study: 50% Reduction in Downhole RPM Fluctuations & A Substantial Decrease of Up to 40% in Lateral Shock

Challenge

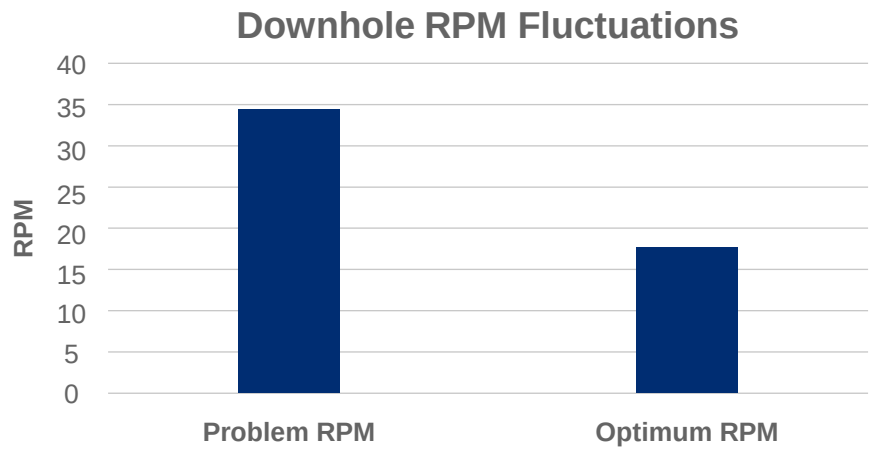
- Advancing performance by mitigating potential failures

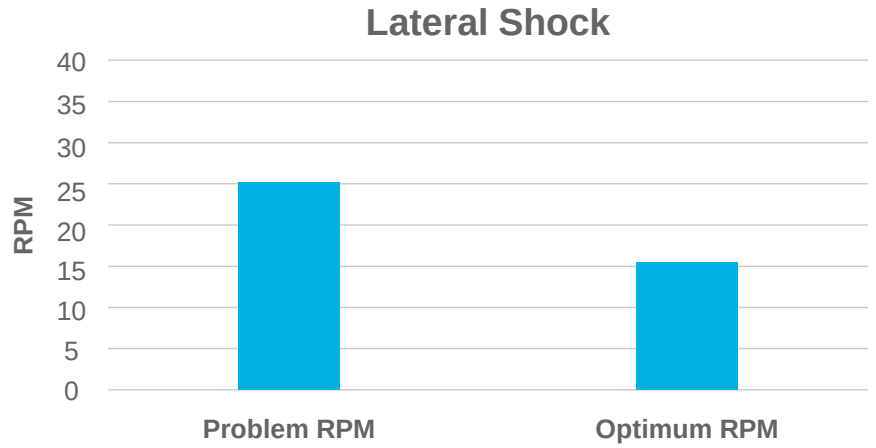
Solution

- Comprehensive post-analysis leveraging downhole data
- Predictive Vibration Mapping forecasted surface RPM levels that might trigger vibrations and inefficiencies
- Dynamic, real-time model that was accessible from both the Operator's monitoring center & rig site

Result

- Adhering models suggested RPM adjustments resulted in a 50% reduction in downhole RPM fluctuations and a substantial decrease of 40% in lateral shock





Identify Resonant RPM. Reduce Downhole Vibration. Drive Performance.

What We Provide

Powered by DrillScan® physics-based modeling software, we provide multi-step computations so you can enhance set point management workflows & mitigate excessive vibrations at resonant frequencies.

- Drilling roadmap of resonant RPMs
  - Seamless transfer of your recommendations into automated digital roadmap
  - Detailed on-boarding
  - Post performance review

What You Achieve

We approach customer challenges by thinking about the outcome they are trying to achieve. With Predictive Vibration Mapping, H&P can help:

- Reduced Drilling Dysfunction
  - Mitigated Shock & Vibration
- Reduced Tool Failures
  - Less Trips
- Provide Consistency

DELIVERING BETTER OUTCOMES.