

Extreme Drill Rate Performance

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*“Running over the same old ground
What have we found, the same old fears”*

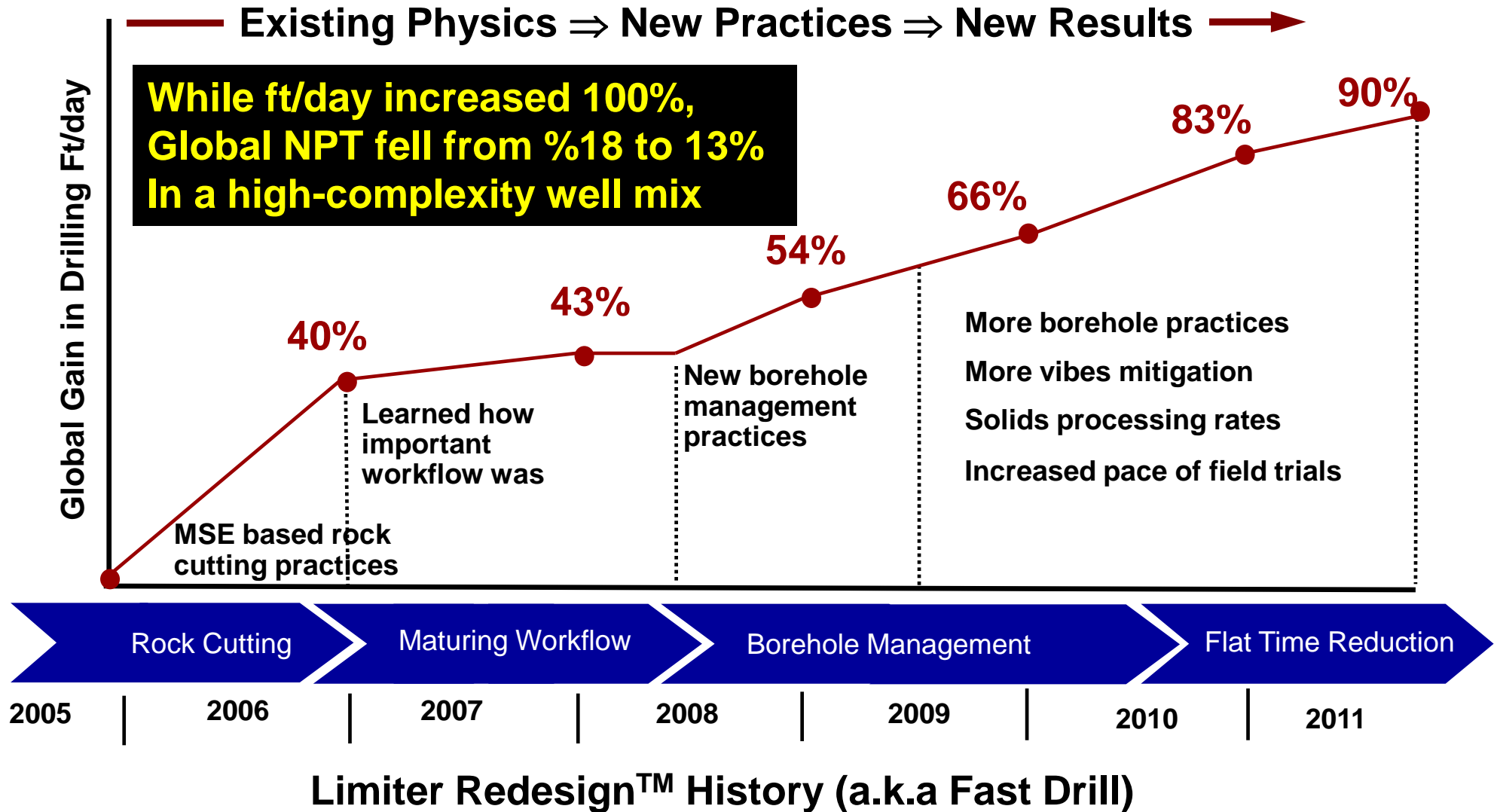
**Pink Floyd
Wish You Where Here, 1975**

The secret to extreme performance is to start with where you are, then change whatever is limiting you from going faster. Then do it again.

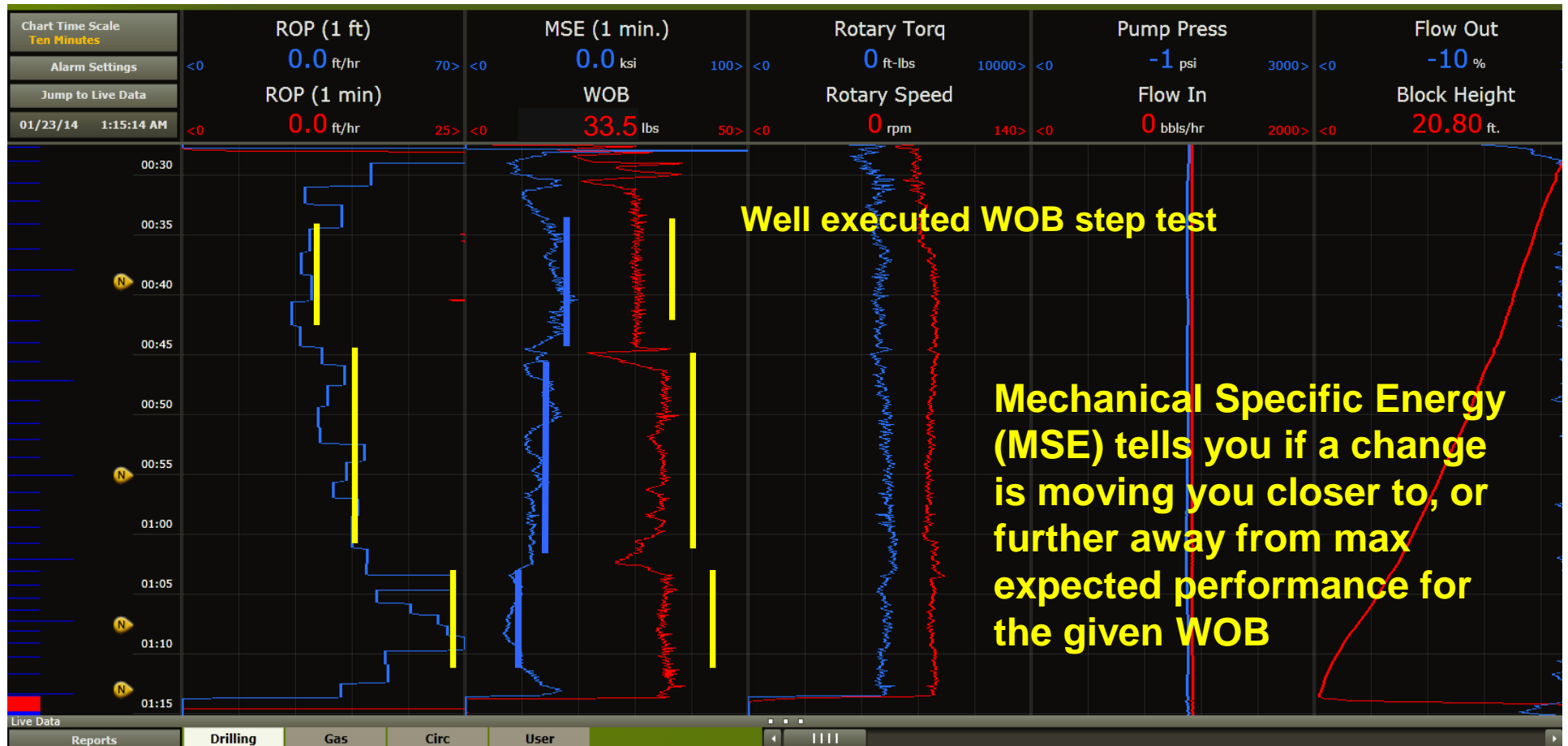
Eventually, your performance will become extreme

Sounds pretty basic, but is this actually what your company does?

Gain in Performance w/No New Emphasis on Trouble



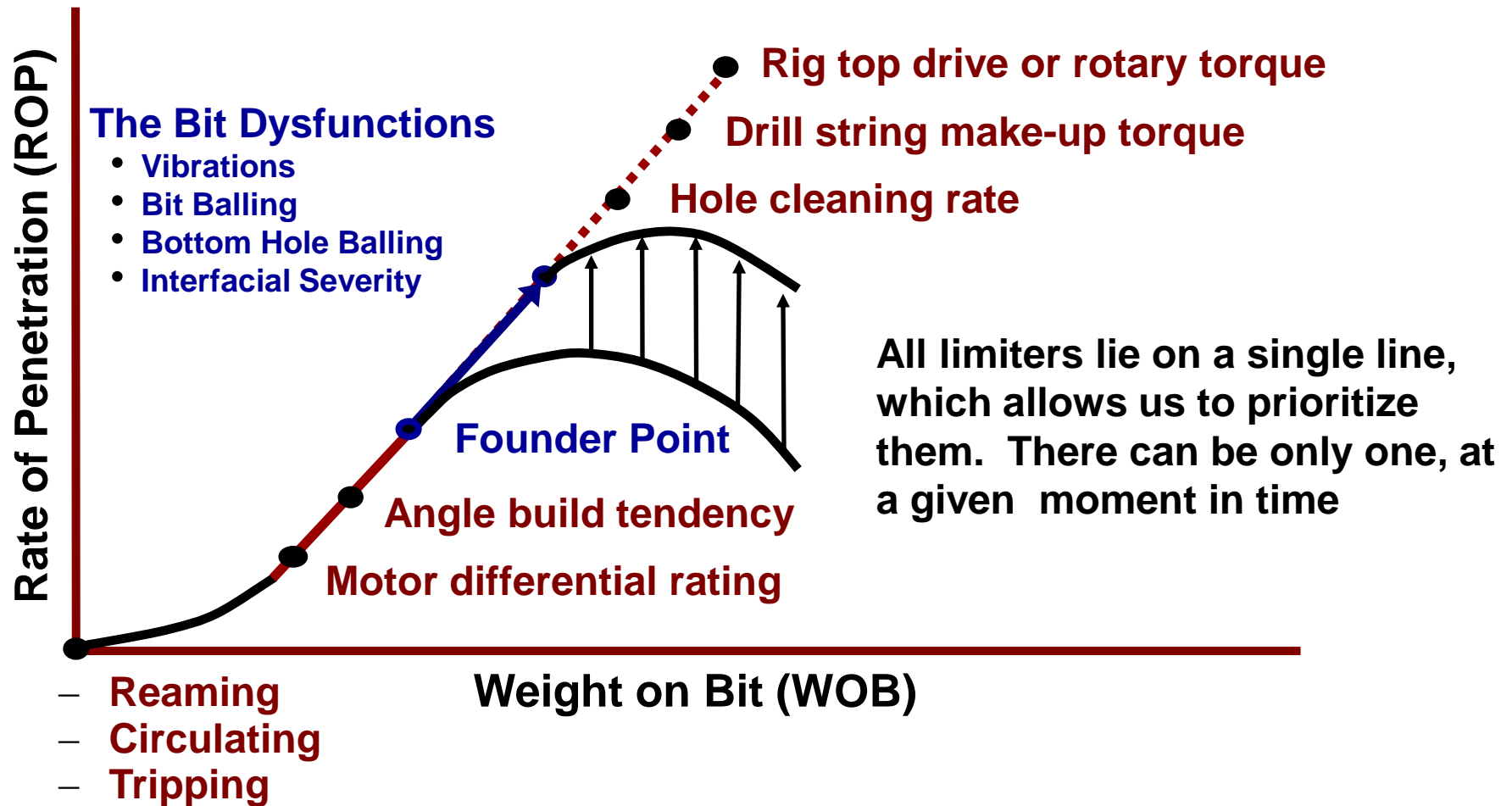
The 2003 Epiphany: MSE Can Illuminate Dysfunction



Mechanical Specific Energy (MSE)

The 2004 Epiphany: Limiter Redesign, Forever

Identify what limits you from raising WOB. Redesign or change practices to extend the limitation. Repeat, forever.....or to the economic limit of redesign

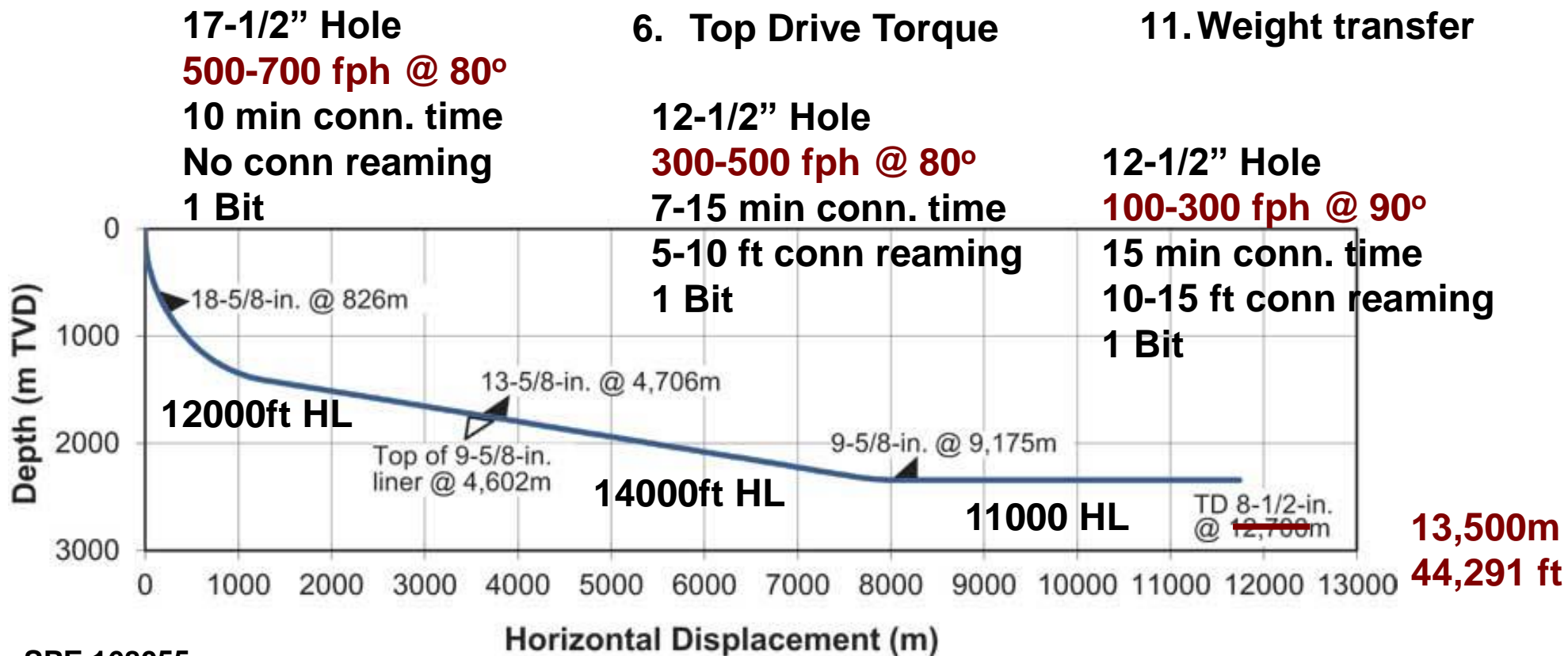


Sakhalin

Progressive limiter redesign (a.k.a. Fast Drill)

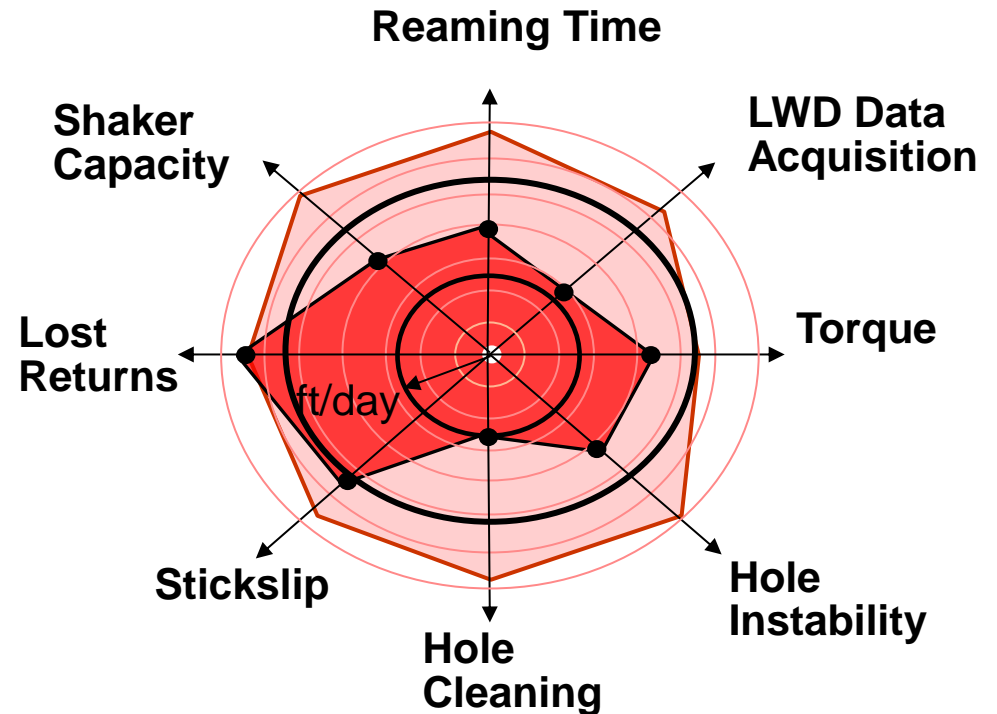
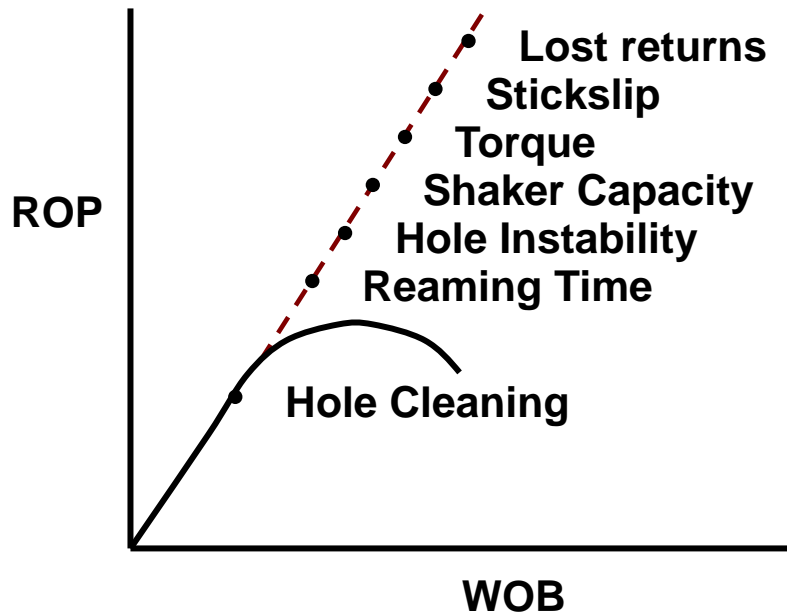
Limiters in the approximate order encountered:

1. Whirl
2. Instability
3. Shaker Capacity
4. Micro-doglegs
5. Weight transfer
6. Top Drive Torque
6. Whirl
7. Weight transfer
8. Stickslip
9. Weight transfer
10. Hydraulic lift
11. Weight transfer



SPE 168055

2010 Epiphany: If you redesign limiters, you redesign risk



1. Our drillers are smart and they've already "optimized" performance vs risk. If you drill faster by simply applying more WOB, NPT will go up, just like everyone expects
2. If you redesign your root limiter first, you expand the "safe operating space". Your NPT will go down because virtually all root limiters are actually risks

If what you are calling your limiter does not feel like a risk, it is not your real limiter. Keep looking

The Prima Fasciae limiter is easy to identify and everyone already knows what it is (i.e., we have hole enlargement and need to raise the MW).

The root limiter is always a collateral risk (i.e., if we raise the MW, we will get differentially stuck)

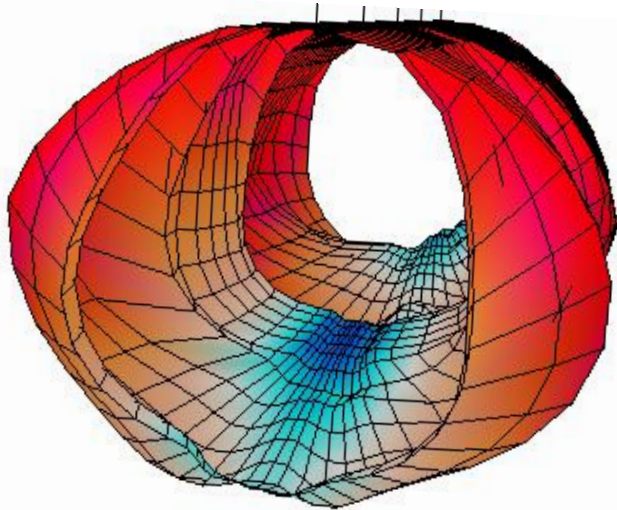
If you don't take responsibility for redesigning the collateral risk, the prima fasciae change will never happen – and usually shouldn't

The best way to know what the real limiter is, is to **ask the person doing the work what concerns they have with your proposed change in practices**

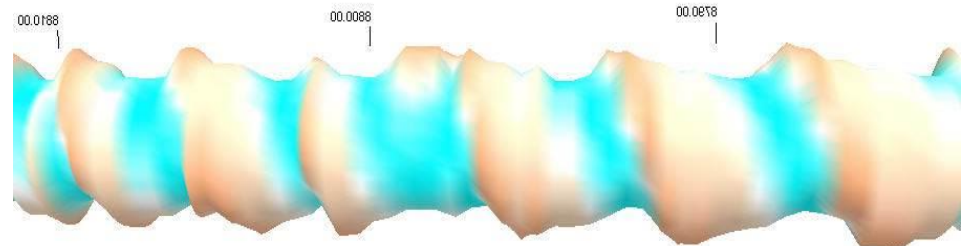
The 2008 Epiphany: Borehole Dysfunction Dominates ft/day

Particularly in extended reach or horizontal drilling, the instantaneous drill rate is limited by borehole quality

Instability



Whirl-Induced Spiral



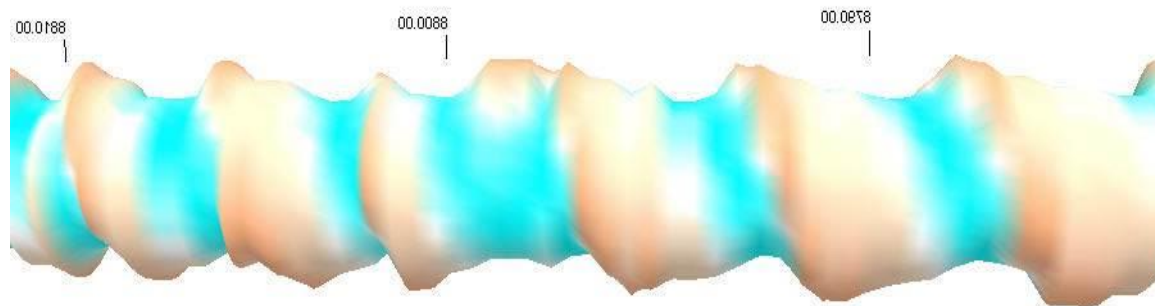
Aggie Analog Whirl Analyzer™



Example of Limiter Redesign: Borehole Patterns

Patterns limit performance:

- The primary cause of tight hole and reaming on connections
- Loss of weight transfer when rotating (reduced ROP)
- Stickslip due to torque in stabilizers (spiral of death)
- Inability to slide
- Inability to achieve objectives (high friction factor)
- Inability to get casing down
- Effect on cement quality when centralizers cannot be run
- Reduced ability to run low clearance casing

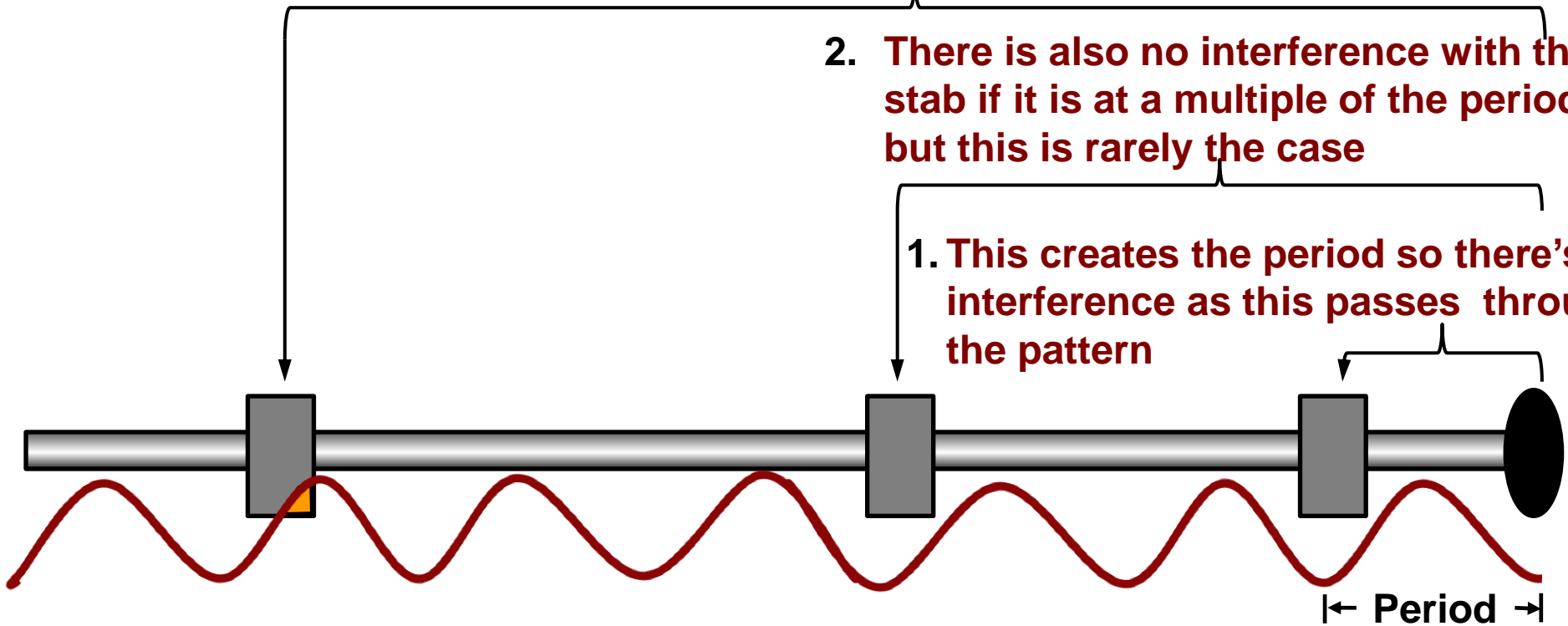


Diagnostic: Tight Hole (Interference in a Spiral)

3. Any stabilizer that is not at a distance that is not an exact multiple of the period must have an interference fit

2. There is also no interference with this stab if it is at a multiple of the period, but this is rarely the case

1. This creates the period so there's no interference as this passes through the pattern

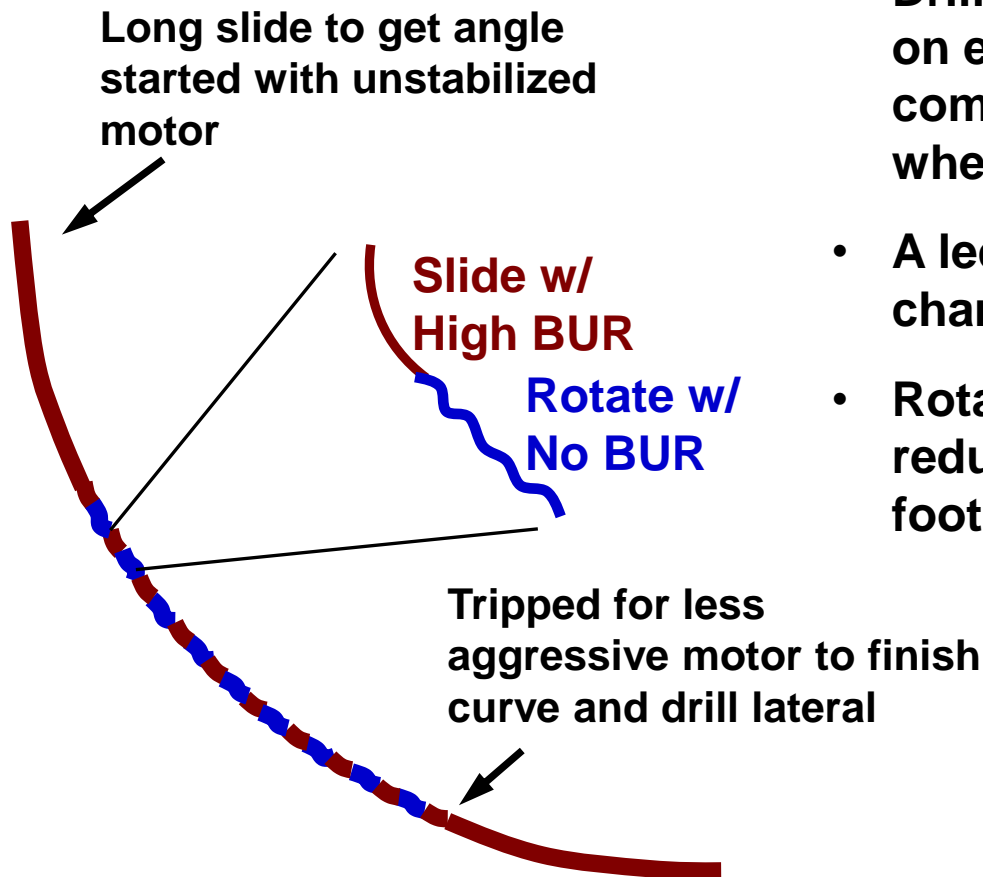


This is hard to imagine, but you have to think about this being a 3D spiral (rather than this 2D) and how the stabs would move through it. In this example, if the bit and near bit are traveling freely in the valley of the spiral, the top stab must be in a bind.

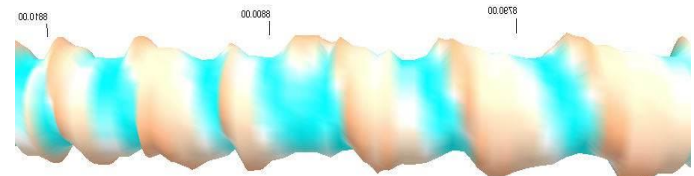
Bent Motors Desparately Want to Create Spiral Hole

1. Build up rate (BUR) with unstabilized motors is initially low, then increases with angle. BUR also depends on WOB as it changes the flex and curvature in the motor/DCs. BUR with stabilized motor is uniform and less sensitive to WOB.

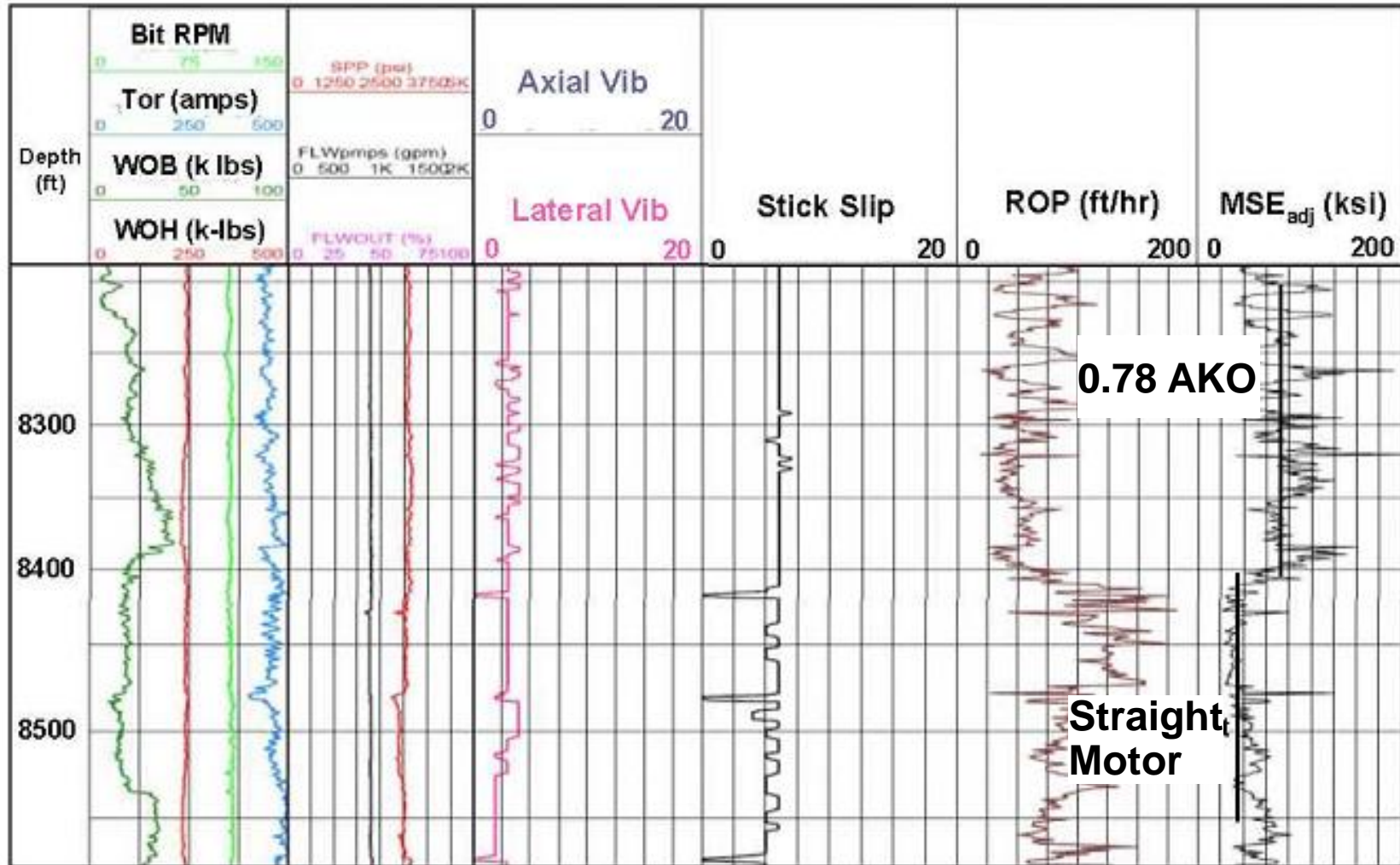
- Driller typically slides 30-50% of the time on each 30ft joint. The average build rate is combination of very high build (dogleg) when sliding and very little when rotating
- A ledge is created where the driller changes from sliding to rotating.
- Rotated footage may be spiral hole, which reduces weight transfer while sliding. Slide footage is smooth with stablizers



Spiral Hole with Bent Motor



Bent Motors: Major Cause of Whirl - Minimize AKO



Operational Practices or Redesign to Reduce Patterns

Patterns are largely due to the bit cutting sideways due to whirl. Mitigate whirl and you mitigate the patterns

- Run RPM step tests with MSE to determine non-resonant speeds
- Run WOB step tests with MSE and very high WOB to increase depth of cut
- Reduce the blade count to increase depth of cut
- Run 4-6" gauge length to limit rate of side cutting
- Run roller reamers to improve weight transfer in spiral to increase depth of cut (DOC)
- Use active torque control to mitigate stickslip to allow higher WOB
- Apply WOB quickly after connections (30-60 sec)
- Move stabilizer placement to reduce forward and resonant whirl
- Use packed assemblies to allow higher WOB without building angle in vertical wells
- Reduce the bend angle in bent motor assemblies to only what is needed

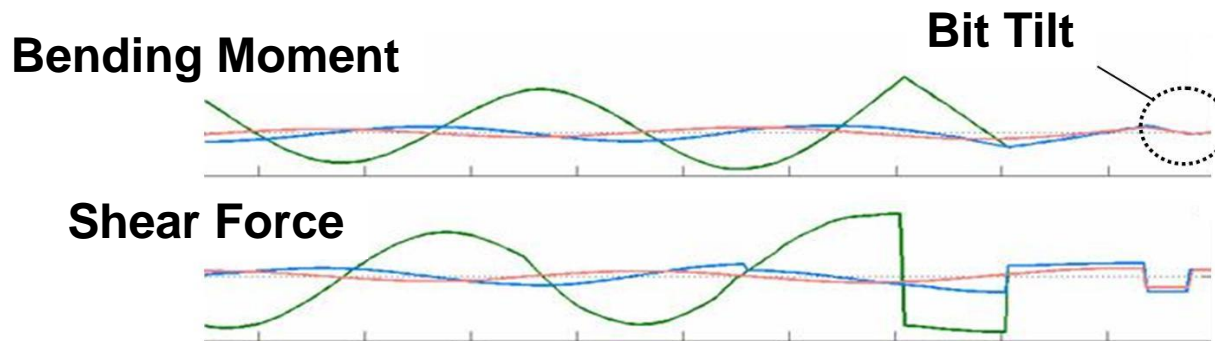
But Wait, There's More

- ❑ Use RSS to eliminate bent motors, particularly in hard rock. You may be able to get similar low bit whirl with a motor, but only if you commit to low AKO (0.5-0.78), very high DOC (WOB) and extended gauge bits**
- ❑ Consider designing build rates to allow continuous sliding to eliminate patterns in curve**
- ❑ Reduce gauge activity of bit (no side cutters on gauge pads)**
- ❑ Use DOCC to allow higher WOB when limited by stickslip**
- ❑ Use Depth of Cut Control to allow higher WOB when control drilling or to provide tool face control**
- ❑ Train all key personnel in vibration management, particularly directional driller (2-3 G's is not OK). Take responsibility for changing practices, and vibrations management**

Engineering Redesign: Extend the Gauge Length

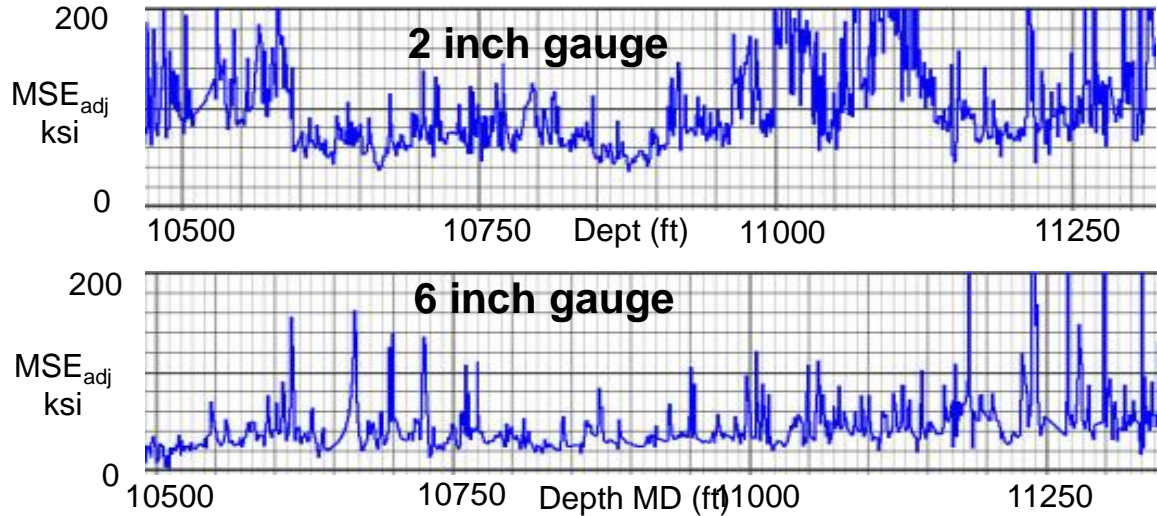


Even if the bit cutting structure is balanced, the vibrational sine wave arriving from the BHA will tilt the bit face and create side cutting. Gauge length does not prevent this, but it constrains the severity (gain) in the amplitude of the borehole pattern that can develop before the bit moves on to the next increment of hole. It prevents a small pattern from becoming a large one, and it encourages decay in the pattern, rather than gain



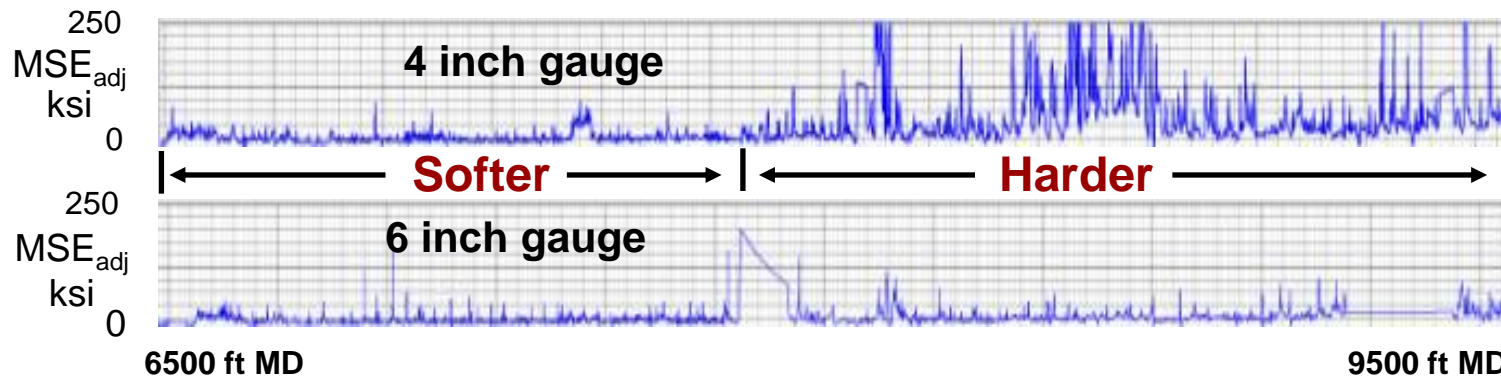
Engineering Redesign: MSE Declines with Gauge Length

MSE pattern is similar, but reduced



Comparison of well with different gauge lengths

Less effect in softer formations where amplitude is lower to start with

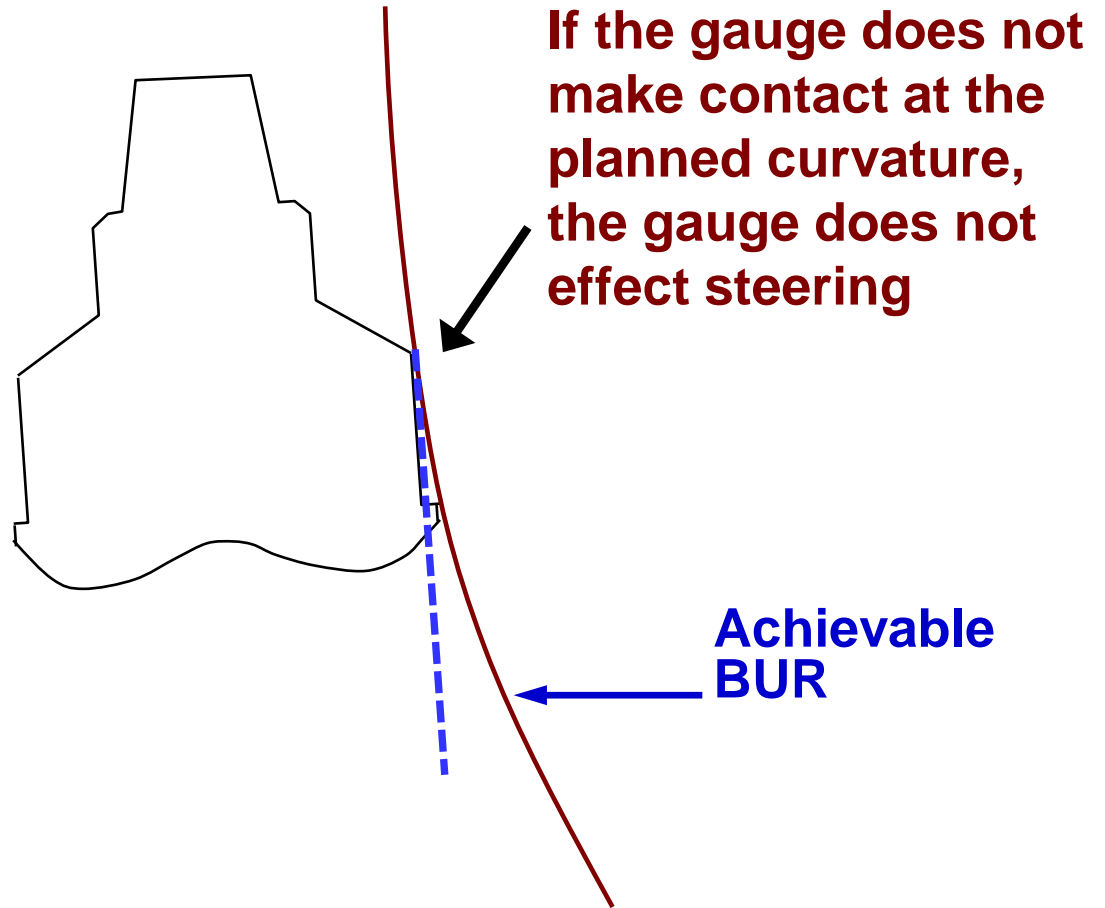


What will people fear? I won't be able to build

If the extended profile does not touch the wall at the planned borehole curvature, it will not prevent the planned curvature from being drilled

In general, a minimum of 4" gauge length should be used, whether the bit is on a motor or RSS. In most applications it is possible to go beyond this to 6-8".

Work with your vendor to determine the allowed gauge length for the given application



What will people fear?: High WOB will reduce bit life

1. If there is no dysfunction, higher WOB actually increases bit life
2. The DOC increases with WOB until the axial force per cutter contact area equals rock strength, so the force per contact area will always stay equal to rock strength, regardless of the total WOB (i.e., 5ksi in 5ksi strength rock)
3. Wear occurs on the tip, not the face, so it is controlled by sliding distance. Increasing WOB increases the depth of cut (DOC), which reduces the sliding distance required to drill a given distance

Example:

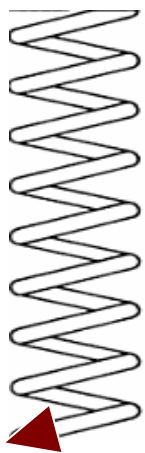
To drill a distance of 100 ft the outside cutter of an 8-1/2" bit slides:

@ 150 fph

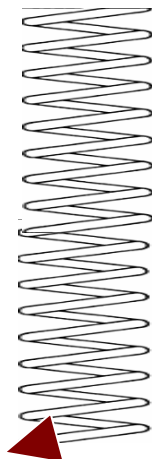
@ 50 fph

10,679 ft of sliding

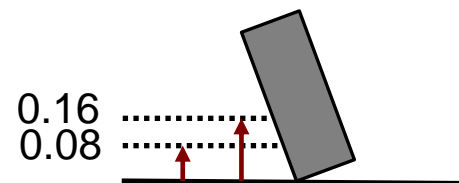
32,038 ft of sliding



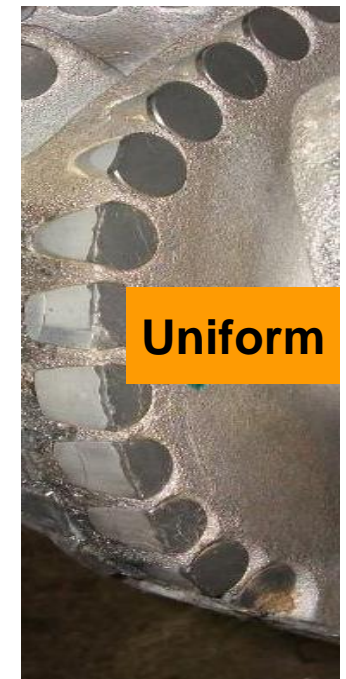
0.24 inch/rev



0.08 inch/rev



Axial force/area
equals rock strength,
no matter the DOC



Risk is Not the Only Thing That Limits People from Changing

Limiters Redesign Change Model

To change performance you absolutely must change how someone works. Technical and Operational leaders should develop the plan, not managers. It's technical and operational.

1. Identify the root limiter and what is preventing you from changing it
2. Develop a new physics-based practice to extend the limiter
3. Determine the risk that is actually preventing the person from changing and redesign it (just ask)
4. Achieve clear management support for the new way of working
5. Provide specific training and procedures for how to do the work differently
6. Create a metric that proves the desired change in practices is happening, and that the physics are correct - not just that performance has changed (i.e., MSE)

The scale of these activities depends on the type and magnitude of change

Key Take-Aways

- **Management of operational reliability differs from management of performance**
 - **If you're designing for reliability assume everyone is bad and demand conformance. Give them standard practices**
 - **If you are designing for new performance, assume everyone is good. Give them knowledge and get the heck out of the way**
- **Teach the employee how something really works (physics-based practices), and good people will just want to do it**
- **If they don't, ask yourself why. It will be because you haven't actually redesigned the collateral risk they see in the primary change you want**
- **Anytime you want change, ask the person doing the work what concerns them, and do something about it. That's your job**

Here's one place to get new physics-based practices

Download the new API Drilling Manual 12th Edition Drilling Practices (DP) Chapter

- a) Rock Cutting Mechanics
- b) Practices to Manage Bit Dysfunction
- c) Connection Practices
- d) Reaming Practices
- e) Tripping Practices
- f) Hole Cleaning
- g) Borehole Instability
- h) Lost Circulation

In each area, the physics are discussed (how things really work) at a level appropriate for field personnel. The format of each subject is 1) what are the physics that control performance, 2) what can the driller measure or observe in real time to diagnose the limiter, and 3) what can the driller do in real time to change the performance