



Drilling Optimization (Holistic Solutions)

**Efficiency, ROP Maximization Vs. Cycle Time Improvement
Implications, Challenges, and Opportunities**

#VDOORLOCKSMITH

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Overview

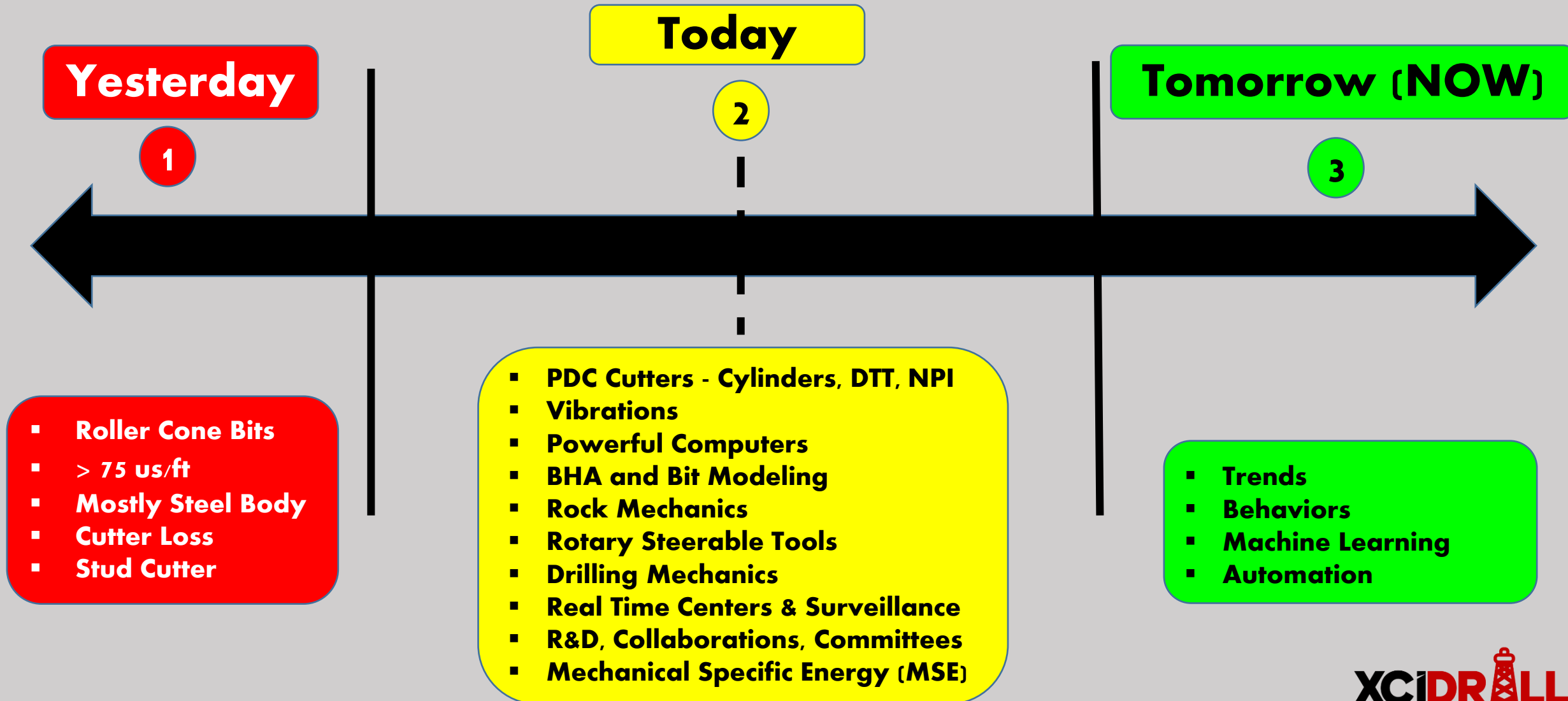
- **Performance Drilling**
 - **Definition**
 - **Yesterday, Today, and Tomorrow ... the Journey**
- **Drilling Efficiency Vs. Benchmarking**
- **Current Status**
 - **Challenges**
- **ROP Maximization Vs Cycle Time Improvement**
 - **Implications and Opportunities**
- **From Physics to Efficiency**
 - **Critical Conversations ... Part-A**
- **Next Steps**
 - **Drive to Automation**
 - **Critical Conversations**
- **Conclusions**

Performance Drilling

- **Definition:**
 - **Process to Achieve Cycle Time Improvement (Reduction and Consistency), through efficiency and reliability enhancements ... supported by comprehensive applications assessment, holistic drilling system evaluations, and detailed analysis of relevant data.**
- **Key Terms**
 - Cycle Time**
 - Efficiency and Reliability**
 - Applications Assessment**
 - Holistic Evaluations**
 - Relevant Data Analysis**

Performance Drilling

Yesterday, Today, and Tomorrow



Performance Drilling

Today's Engine – GMW's Hall of Fame

- **Sandia National Laboratories**
 - David Glowka
- **Shell Research Rijswijk**
 - Djurre Zigsling
- **Amoco Research Tulsa/Catoosa**
 - Tommy Warren, Allen Sinor, Sue Behr, Ford Brett
- **BP Colombia**
 - Martyn Fear, Alvaro Botero, Fernando Rueda
- **Hycalog and Anadarko (East Texas – Travis Peak)**
 - Bob Fabian (Hycalog), Fred McDougal & Eddie Schell (Anadarko)
- **BP Alaska**
 - Larry Wolfson
- **Allen Sinor et. Al. - [SPE/IADC 39306](#)**

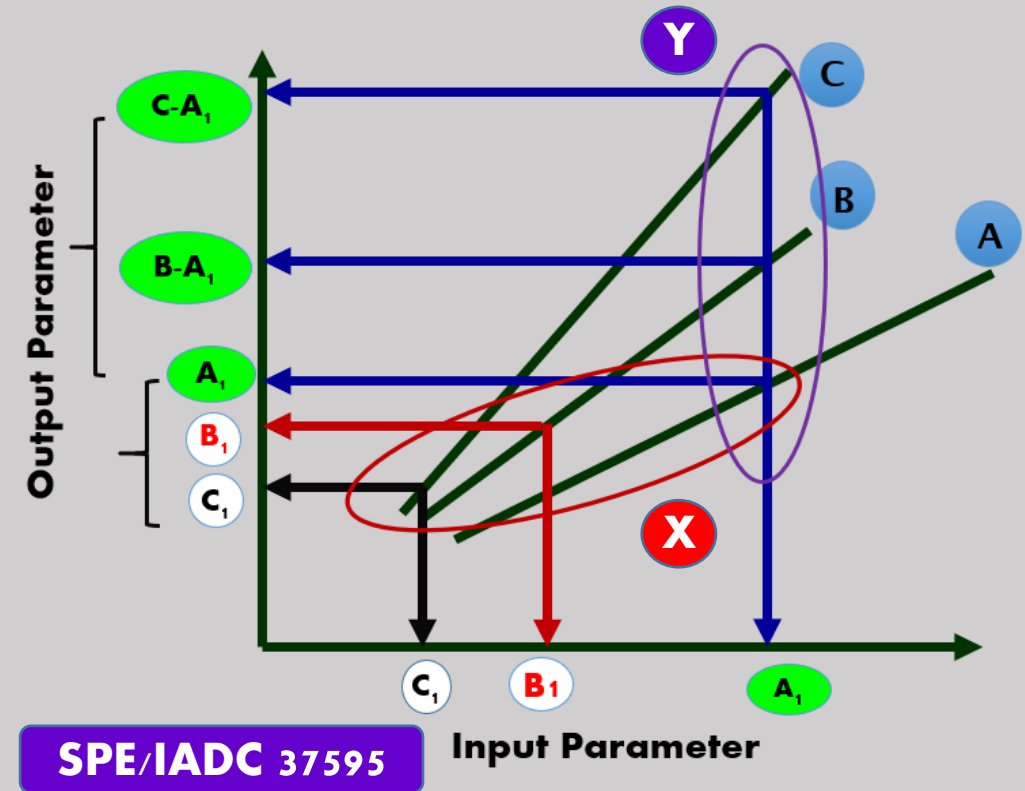
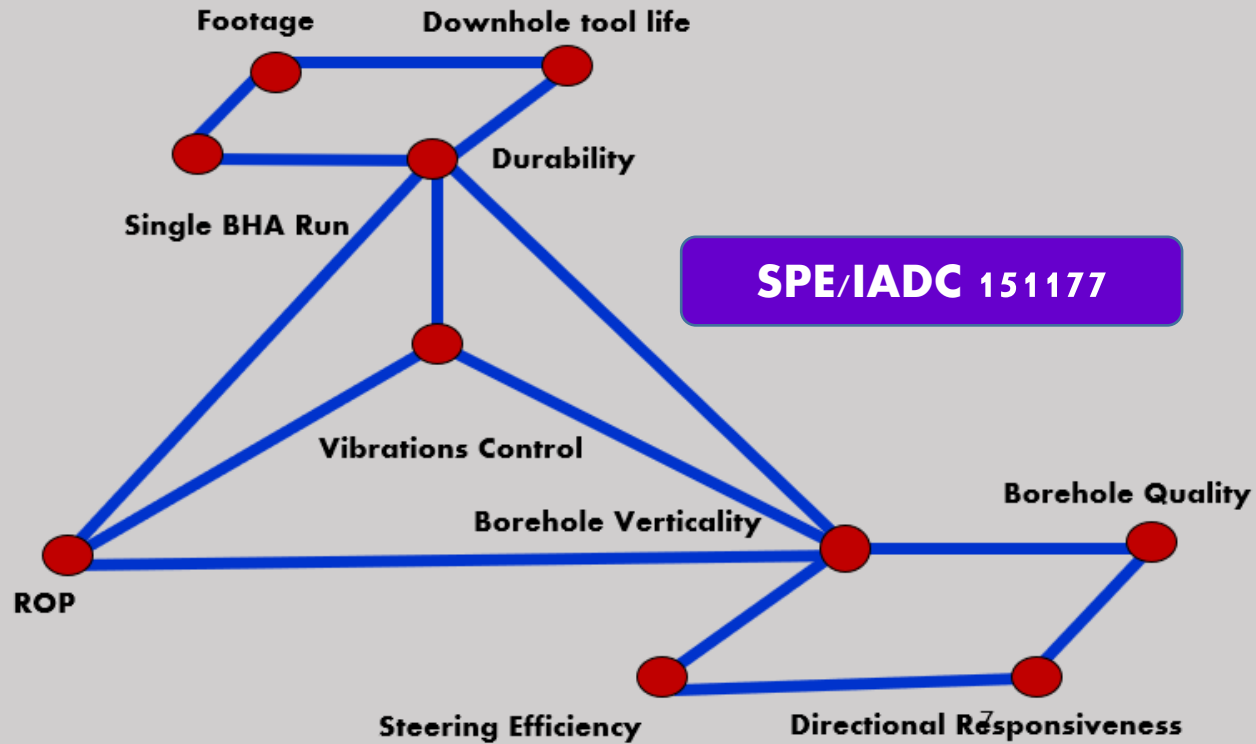
Drilling Efficiency and Benchmarking

Usama Sabir's Questions

- **Drilling Efficiency** **[SPE/IADC 128288 and SPE/IADC 119826]**
 - The Safe Construction, Placement, and Timely Delivery of a Useable, Value Based Wellbore, While Achieving Performance Requirements Needed to Establish the Lowest Cost Imprint.
- **Benchmark Vs. Pacesetter** **[SPE/IADC 151177]**
 - Basic @ What Questions ... If It Ain't Broke, Don't Fix It
 - Relational @ Why and How Questions ... If it Ain't Broke, Make It Better
- **Benchmarking Process**
 - Outputs and Inputs
 - $y_i = f(x_i)$
- **Benchmarking Definitions**
 - Procedure to Compare Output Parameters at Normalized Input Parameters, based on Ranking of Specific Operational Factors, Referred to as Cycle Time Factors (CTFs)
 - Normalized Input Parameters
 - Ranking of Cycle Time Factors (CTFs)

Benchmarking

Cycle Time Factors (CTFs) & Normalization Process (Inputs)

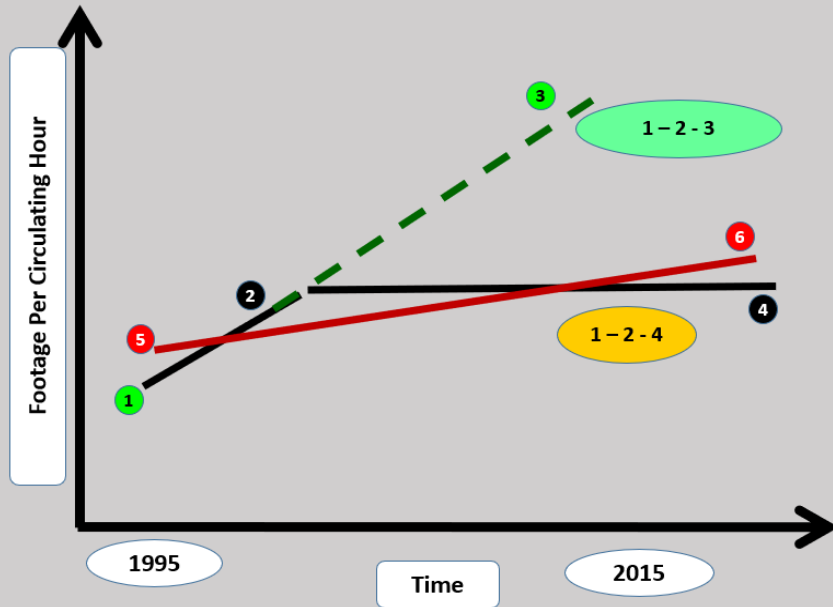


Usama Sabir's Benchmarking Questions

Questions: Benchmark? Efficiency? Are they the Same? Why Differences (Risk or Uncertainty)
To be Continued

Performance Trends

Time-line & Positions



The Relentless flow of new tools and techniques to improve drilling efficiency is NOT having the desired effect, according to one operator.

Don Francis: Editor Hart's E&P Magazine - February 2008

- i. **Extremely Risk Averse**
- ii. **Data Collection Vs. Data Analysis**
 - Where is the Actionable Information
- iii. **Over Dependence on Models**
 - Calibration and Predictive Challenges
- iv. **Who is Responsible (DD Vs. PDE)**
 - Torque – Friend or Foe
- v. **Drill Bit Commoditization**
 - Features Vs. Technologies
- vi. **Significance of MSE**
 - Value Vs. Trends
 - ROP and Implications
- vii. **Drive Systems Vs. Applications**
- viii. **Every Vibrations is Stick-Slip**
- ix. **BHA Designs**
 - What is the Objective
- x. **Rock Mechanics**
 - Hardness Vs. Drillability

Dave Holloway ... "Reality is ALWAYS an option"

Performance Drilling

Operations Concerns and Reaction

- **Associates Performance Drilling With ROP Maximization**
 - Is this True or False?
 - Answer Depends on What We Tell Them and Do
- **ROP Maximization Concerns**
 - Soft Rock at Higher Cuttings Volume
 - Hard Rock at Higher WOB
- **Hole Loading, ECD, Differential Sticking, Fractures and Mud Losses**
- **Wellbore Cycling & Instability (P_{off} and P_{on})**
- **Transition Zones and Sticking**
- **Tripping Challenges and Sticking**
- **Vibrations, Twist-Off, Over-Torque, Tool Reliability, Directional Issues, Bit Failures**
- **More Concerns than ROP**
- **Safe Operations & Efficiency**
 - Don't Want to get **STUCK**
 - Don't Want **Twist-Offs**
 - No **Over-Torque**

Steve Tkach

Experienced Drilling Engineer (also MPD)

Available for Consultation (+1 504 427 5426)

Getting Stuck

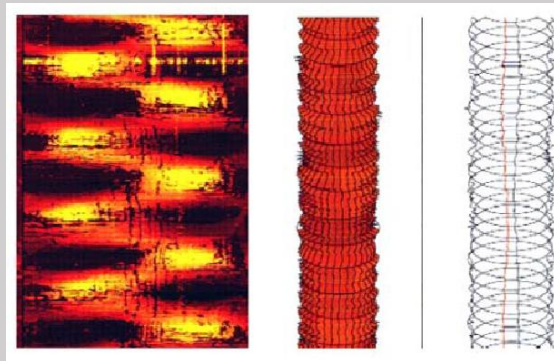
Borehole Quality/Condition

- **Cuttings Volume (Instantaneous ROP)**
- **ECD and PP (Differential)**
- **BHA Behavior**
- **Slide & Rotate Drilling Modes**
- **Bit Selection**
- **Downhole Tool Geometries**
- **Wellbore Tortuosity**
- **Drive System Functionality**
 - RSS and PDM
- **Vibrations**
- **Etc.**



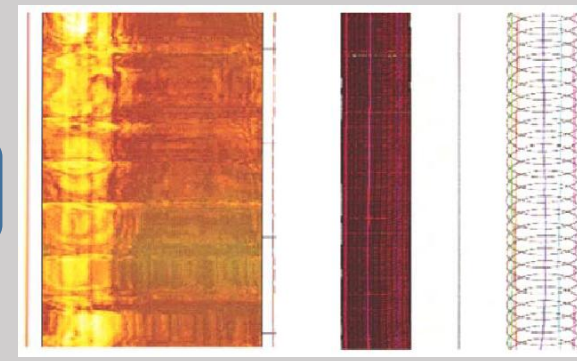
Images & Caliper
SPE/IADC 151248

John Clegg
SPE DL Presentation
Well Placement ...



Before Optimization

SPE/IADC 98931



After Optimization

Same: Formation, Hole Size, Section Profile, RSS, Rig, Crew

Performance Drilling

ROP Maximization & Implications

- **Goal: Operational Cost Reductions**
- **ROP Maximization**
 - **Cost Per Foot**
- **Efficiency Discussion**
 - **Type @ Mechanical**
- **MSE Vs. CCS**
 - **100% Efficiency (Several Other Claims)**
 - **If Achievable... (to be discussed)**
- **Implications from Drilling Mechanics**
 - **Parameter Requirements for Achievement**
 - **Possible Operational Consequences**
 - **Other Operational Considerations, Based on if ... Scenario**
- **Feeds into Operational Concerns**
- **Other Issues Exist (To be Discussed)**
- **No Cost Reduction Guarantees**

Performance Drilling Cycle Time Definition

- **XCIDRILL Definition**
 - Established for Sections
 - Considerations for Stakeholder Review
- **Times Associated With:**
 - BHA Pick-Up
 - Drill-Out
 - Drill Ahead
 - Trip-Out
 - Run Casing
 - Round Trips for BHA changes
- **Definition:** Cycle Time is total cumulative time associated with the following activities in a section: BHA Pick-Up, Drill-Out, Drill Ahead, Trip-Out, Casing Run, and Round Trips for BHA change.



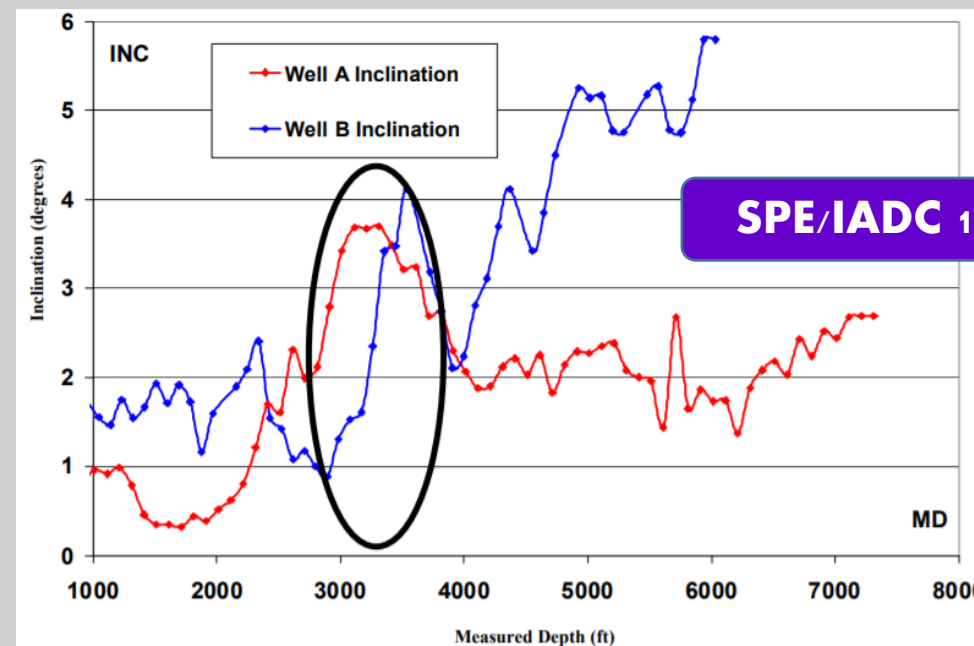
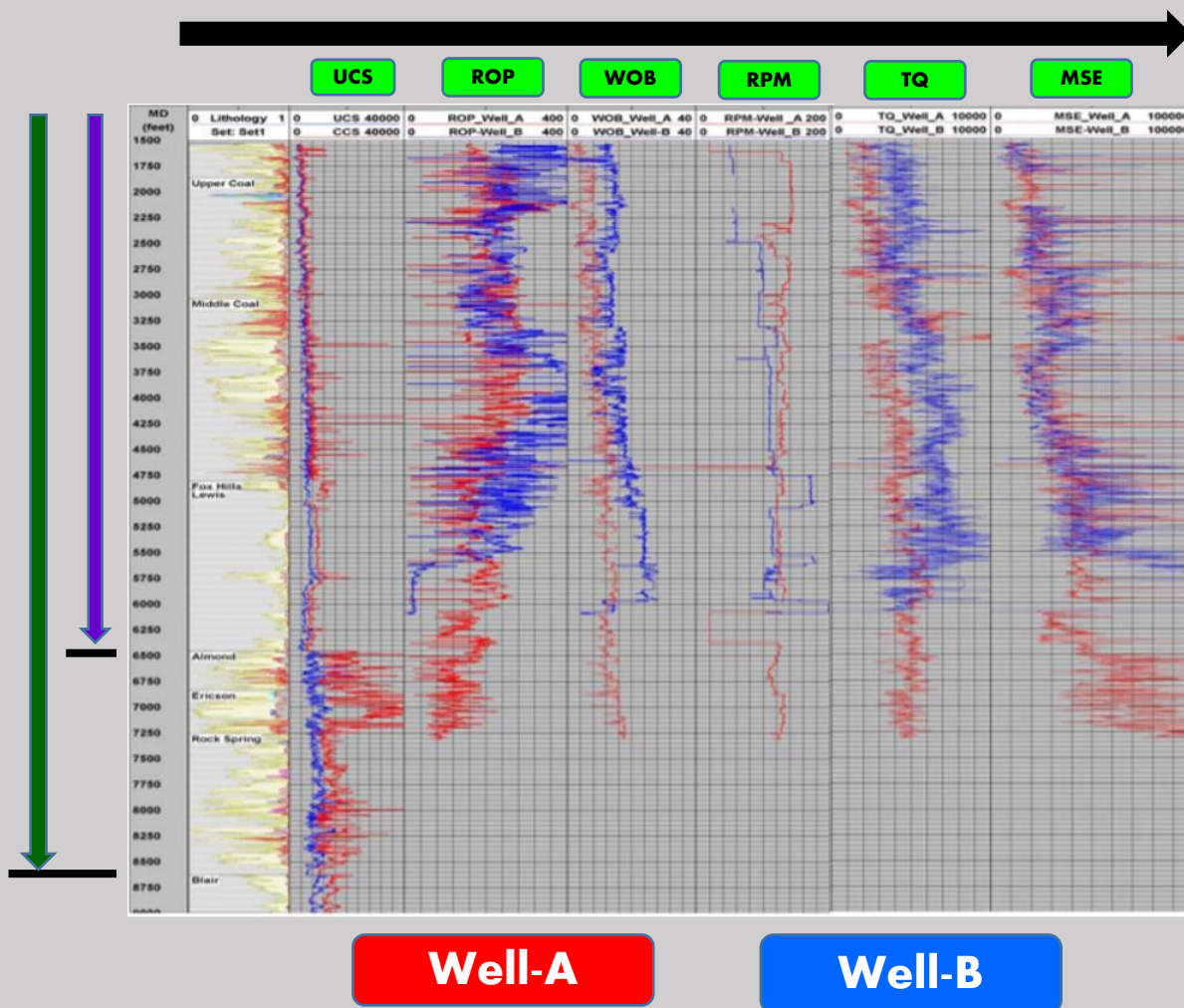
Performance Drilling Cycle Time Improvement & Implications

- **Goal: Operational Cost Reductions**
- **Considerations @ Cycle Time Factors (CTFs)**
 - Ranking for Project
 - Operational Cost Per Section
- **Efficiency Discussion**
 - Type @ Operational
- **CTF Ranking During Project Planning**
 - **Formation Drillability Vs. CCS**
- **Implications from Drilling Mechanics**
 - ROP is a CTF (Lots of Other CTFs)
 - Parameter Requirements for CTF Ranking
- **Addresses Operational Concerns**
- **Identifies and Addresses Project Risks**
- **Drives Cost Reductions**

SPE/IADC 57558

Field Case Discussion

ROP Maximization Vs. Cycle Time Improvement



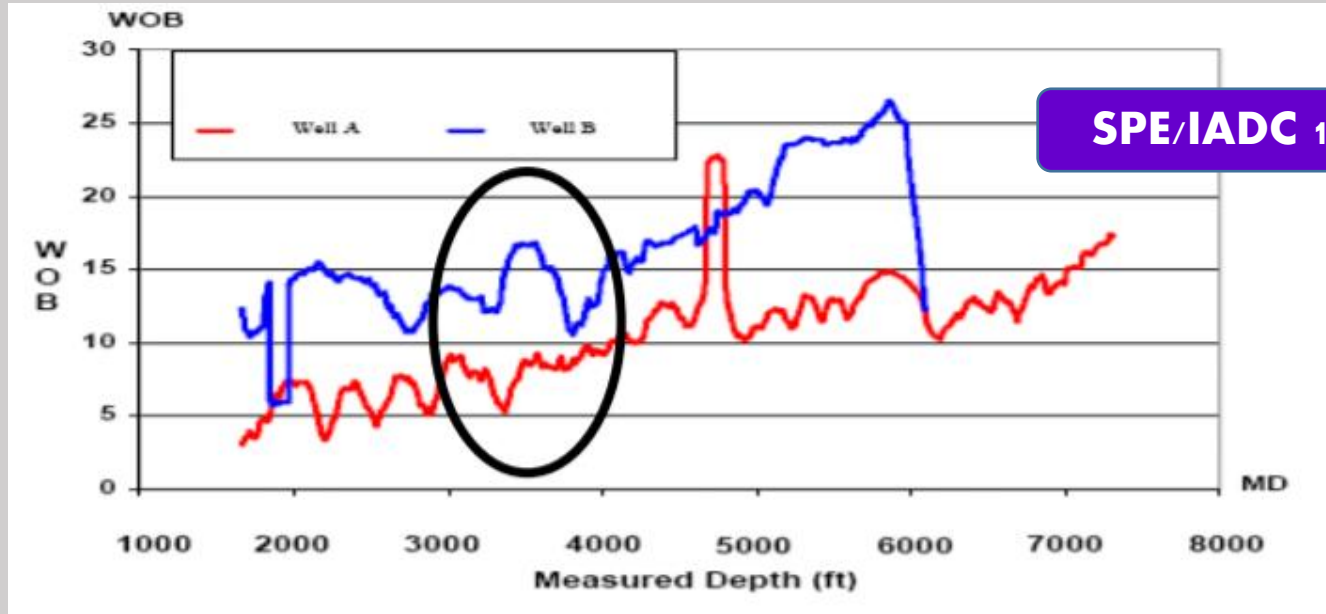
Well-A



Well-B

Field Case @ Performance Summary

ROP Maximization Vs. Cycle Time Improvement



SPE/IADC 119826

Well-A

Well-B



Well Name	Well Type	BHA Number	Depth In (ft)	Depth Out (ft)	Footage (ft)	ROP (ft/hr)	Trip (hrs)
Well A	Almond	1	680	7311	6681	98	N/A
Well B	Almond	1	624	6076	5452	89.4	N/A
		2	6076	6555	479	14.5	22
Well C	Blair	1	1545	8090	6545	74.3	NA
Well D	Blair	1	1257	8633	7376	77	N/A
Well E	Almond	1	673	7206	6533	80	N/A
Well F	Almond	1	589	7225	6636	83	N/A

Physics To Efficiency

Some Critical Conversations

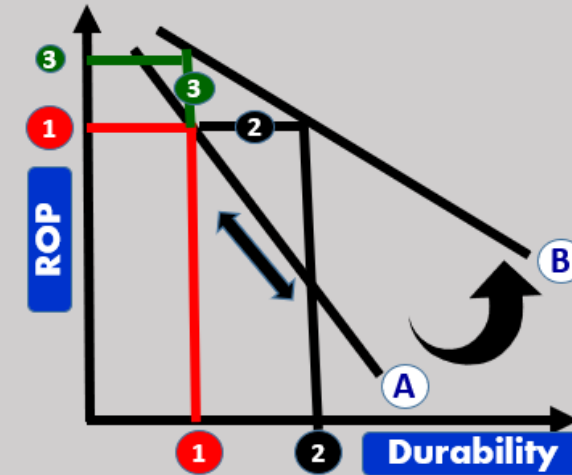
- **Evaluation of Cycle Time Factors (CTFs)**
 - Today, Focus on ROP and Durability
- **ROP Vs. Durability**
- **Failure Modes**
 - Static Vs Dynamic
 - Durability Considerations
- **Depth of Cut (DOC)**
- **ROP Vs. DOC**
- **Rock Failure Mechanism**
- **MSE Vs. 100% Efficiency**
- **Directional @ PDM**
 - PDM & Bend Size
- **Directional @ RSS**

ROP Vs. Durability

Functional, NOT Physical Properties

- All CTFs must be analyzed
 - No Isolated Discussions
 - Always Holistic Evaluations
- **ROP, Durability, and Longevity**
 - Definitions
 - Type of Relationships
- ROP Vs. Longevity
- Longevity Vs. Durability
- Durability Vs. ROP

SPE/IADC 91423



Project	Footage	ROP	Dull Grade	Comment
A	6000 ft	90	4:6:TD	
B	6000 ft	70	2:3:TD	
C	6300 ft	50	1:2:TD	
D	7000 ft			



ROP Vs. Durability Field Case Discussion

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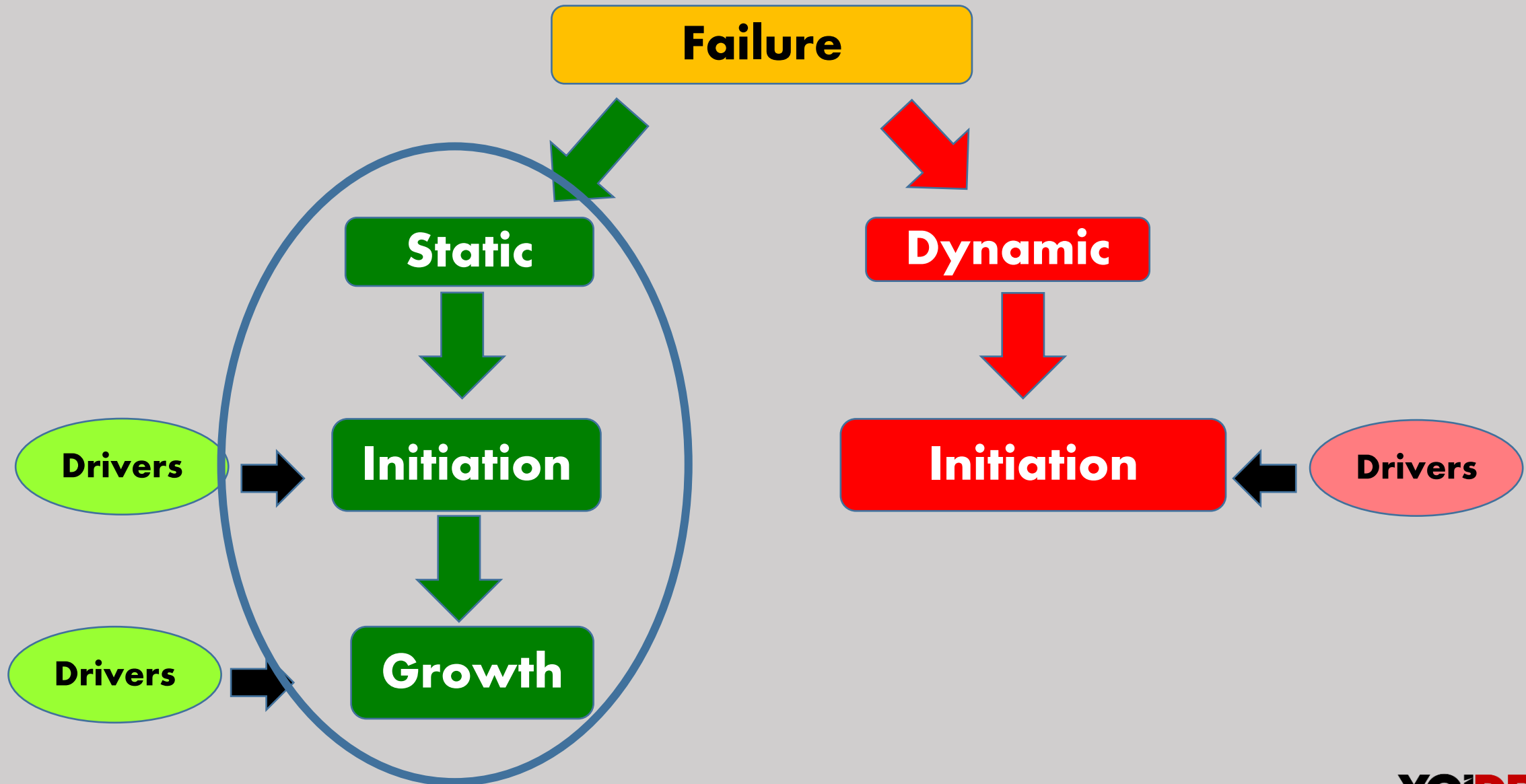
Bit Type/Group	Depth In (ft)	Footage	WOB (klbs)	RPM	GPM	Number of Runs	ROP (ft/hr)	Dull Grade
Best PDC-Y	5398	3217	27	210	595	1	81.4	4-6-WT-A-X-I-BT-FM
PDC-Y Average	6549	1222	16	185	560	10	45.9	2-3-FM
Competitor Average	6456	2897	26	226	541	402	57	3-3-FM
Best PDC-N	5369	3481	20	225	588	1	102.4	1-1-FM
PDC-N Average	5431	3190	27	220	580	15	81.2	2-2-FM



Failure Modes

- **Dynamic and Static**
 - **Failure and Durability are Different Properties**
 - **Anticipation in Planning ... Application Based Discussions**
 - **Drivers Must Always Be Identified**
 - **Anticipated Vs. Actual**
 - **Dull Grading is Subjective ... Focus on Pictures**
- **Dynamic is Driven by Vibrations**
 - **Note all Possible Sources**
- **Static is Driven by Heat**
 - **Heat is Dependent on Depth of Cut (DOC) and Friction**
- **Time Effects on Failure Modes**
- **Parameter Requirements**

Failure Modes



ROP & Depth of Cut (DOC)

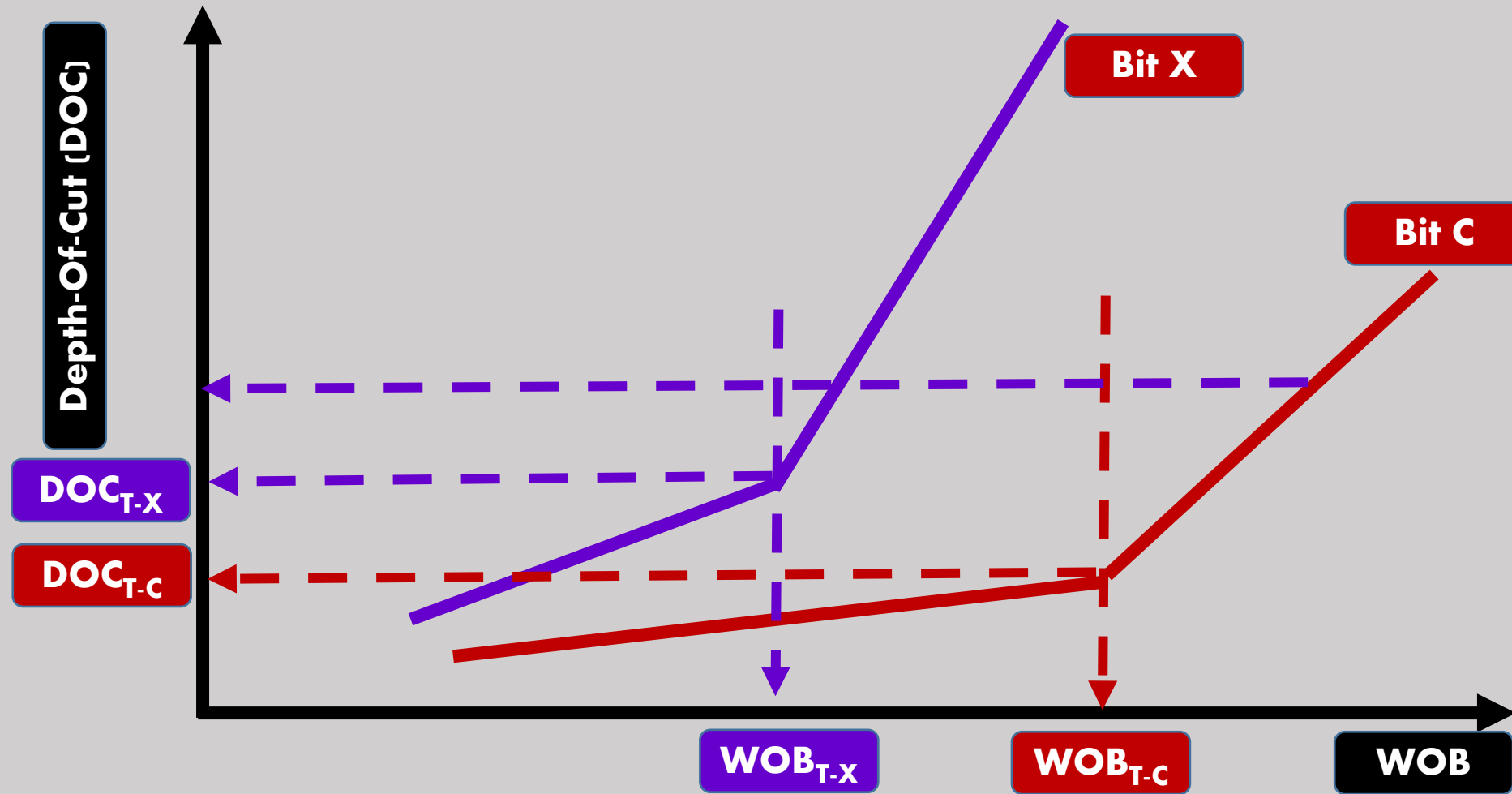
Some Clarifications

$$DOC \left(\frac{in}{rev} \right) = 0.2 \times ROP \left(\frac{f}{hr} \right) / RPM(rpm)$$

- **ROP and DOC are Different Parameters**
- **ROP depends on WOB, RPM, Flow Rate, HSI**
- **DOC Depends on only WOB**
- **When ROP increases TQ may Increase (Note Driver)**
- **When ROP increases, DOC may not increase**
- **When DOC increases TQ always increases**
- **When DOC increases, ROP always increases**
- **DOC cannot be determined from ROP**
- **ROP May NOT change the Rock Failure Mechanism**
- **DOC dictates the Rock Failure Mechanism**

DOC Vs. Drilling Efficiency

Identical Conditions (also RPM is Constant)



ROP Vs. WOB (Similar Conditions and RPM)

8 ½" Laboratory Tests in Carthage Limestone

SPE/IADC 84354

Type	Blade Count	Nozzle Count	Bit Profile	Back Rakes Cone/Nose/Shoulder/Gage	Cutter Sizes
Bit X	8	6	Long Parabolic	5&10/15/20&25/30	13mm
Bit M	9	6	Medium Parabolic	15/20/25/30	13 and 9mm
Bit N	8	6	Medium Parabolic	15/20/25/30	13, 11 and 9mm



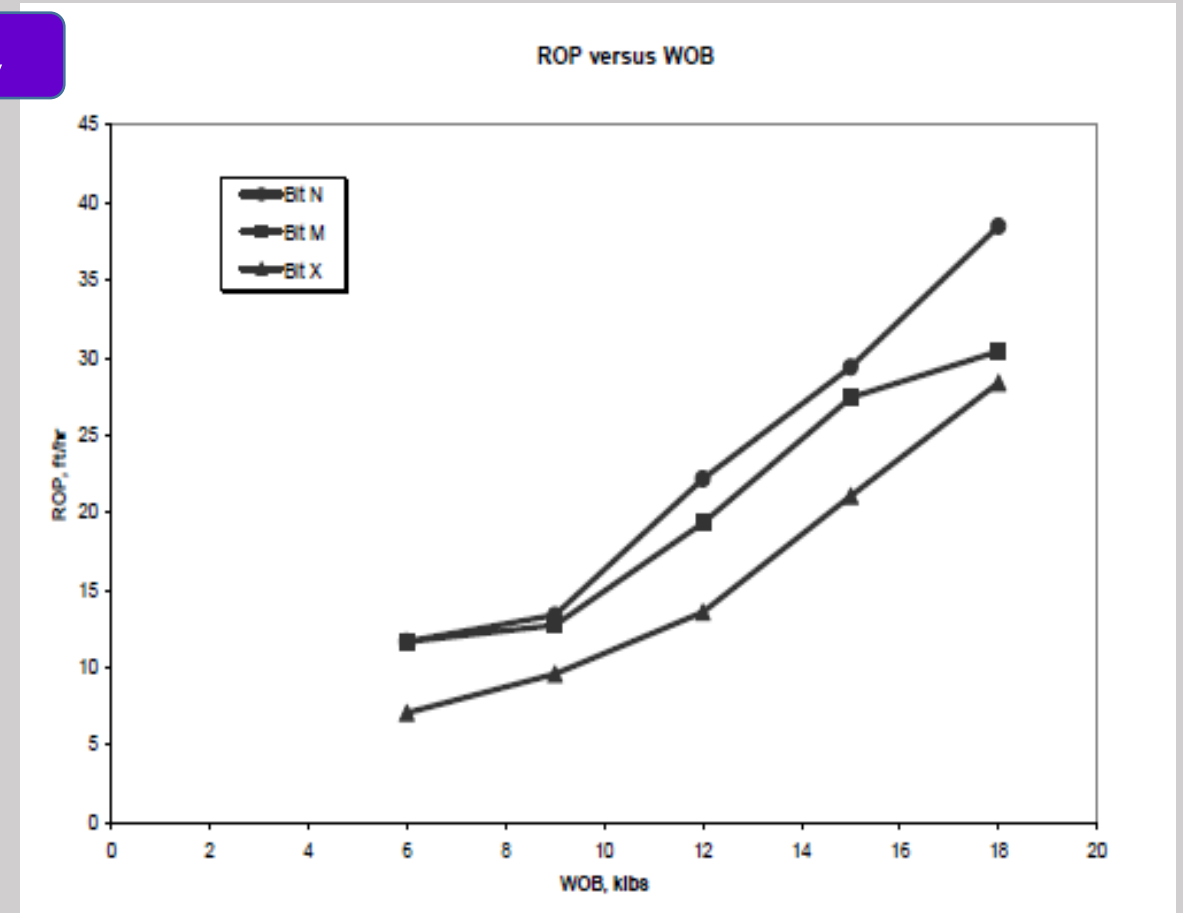
Bit X



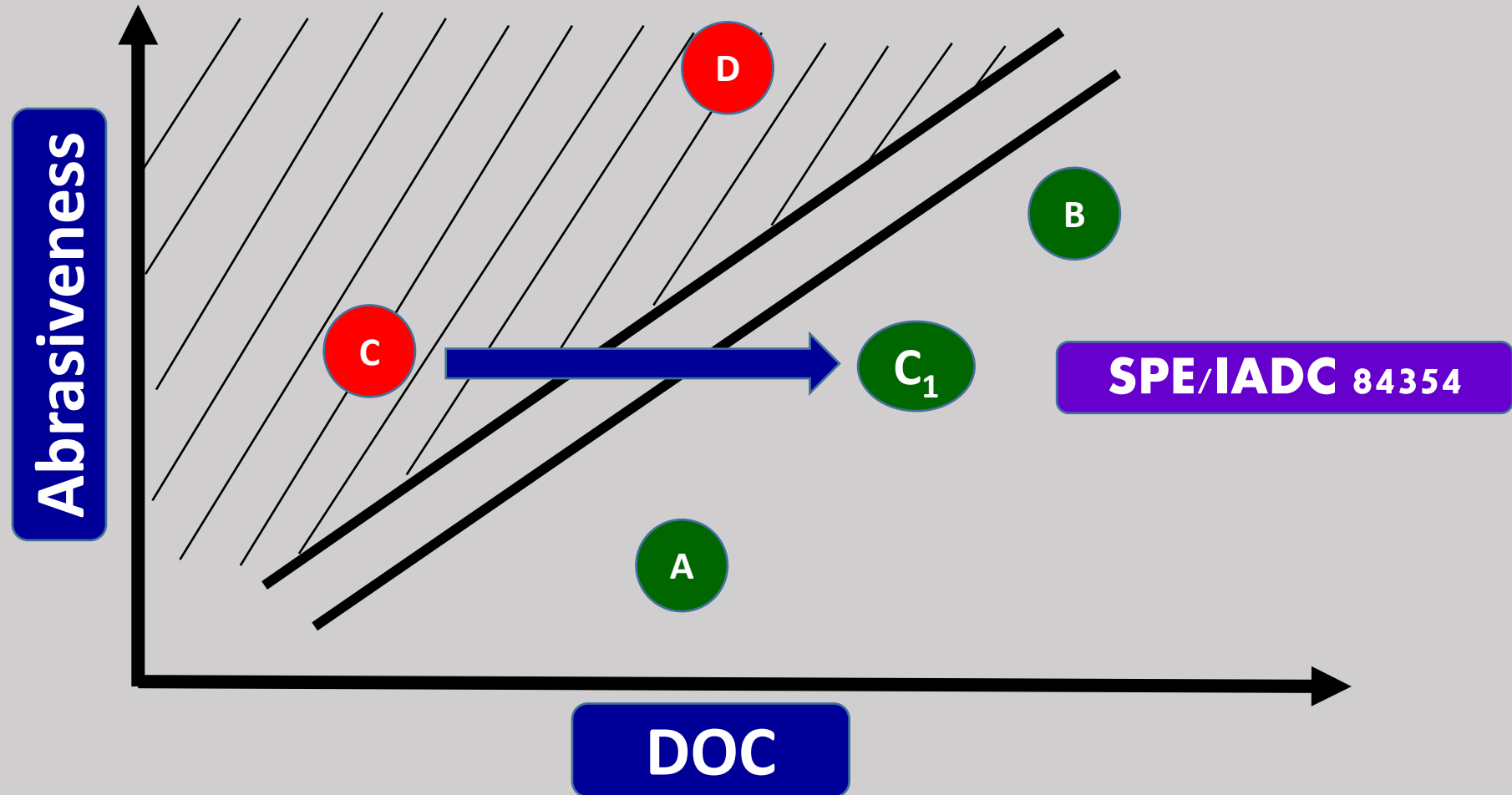
Bit M



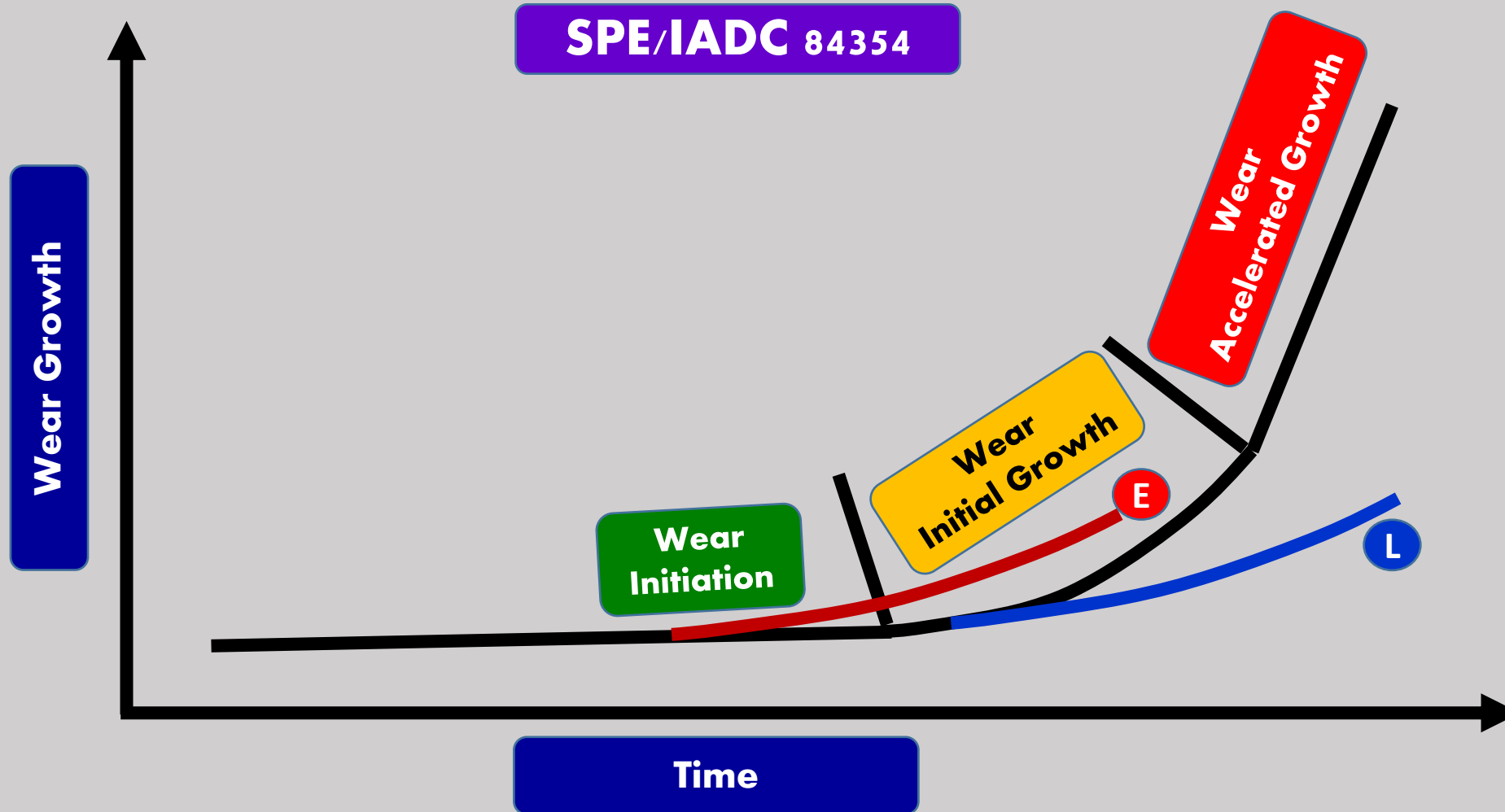
Bit N



Heat Diagram Threshold Efficiency Vs. Wear Initiation (Constant RPM)

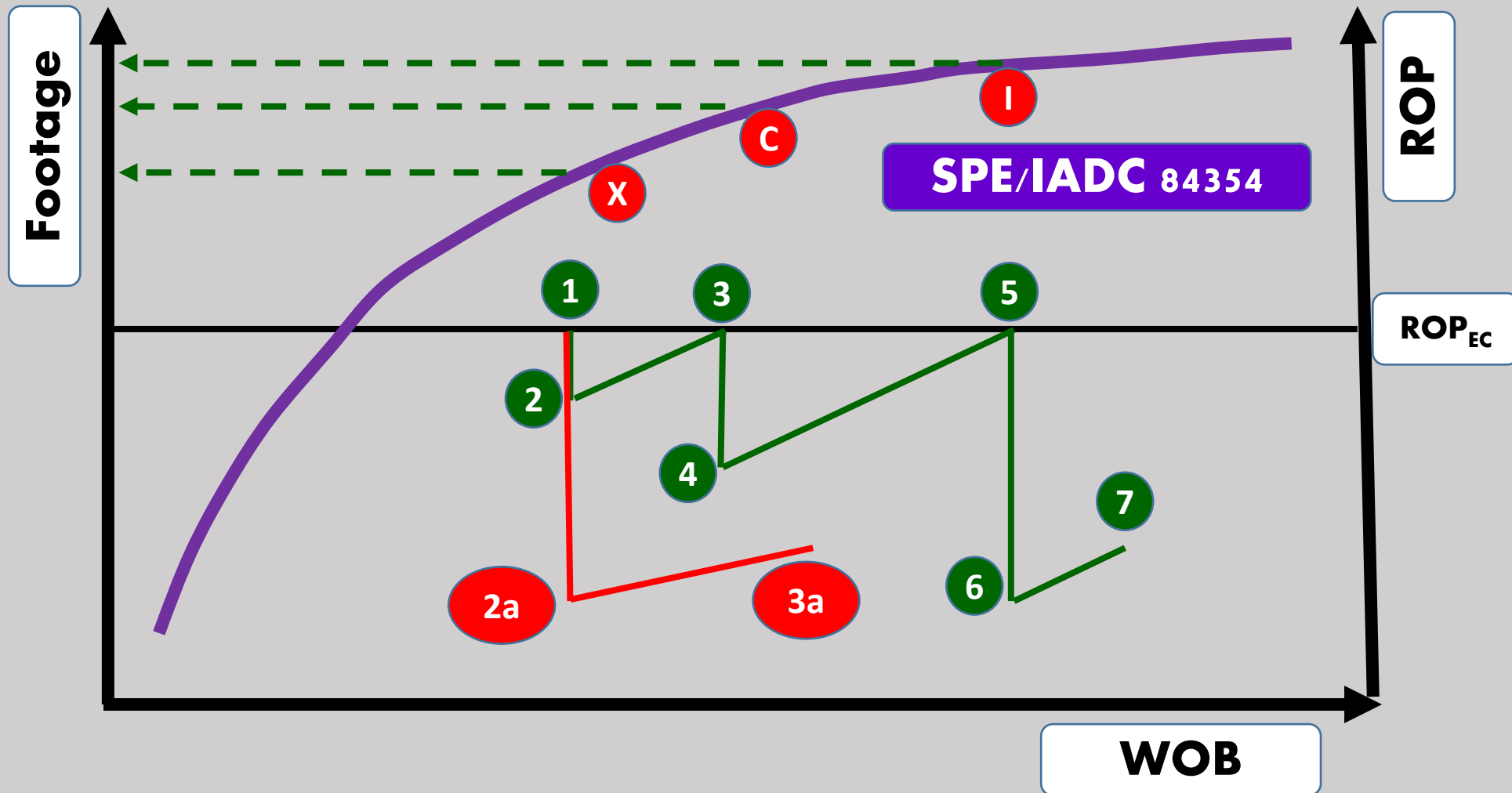


Wear Growth Vs. Time



Failure and Parameters Implications

Static (Wear) Vs. Dynamic (Impact)



Dull Grades

Static and Dynamic Failure Modes



Static Failure (Wear)

SPE/IADC 67698



Dynamic Failure (Impact)

SPE/IADC 128288

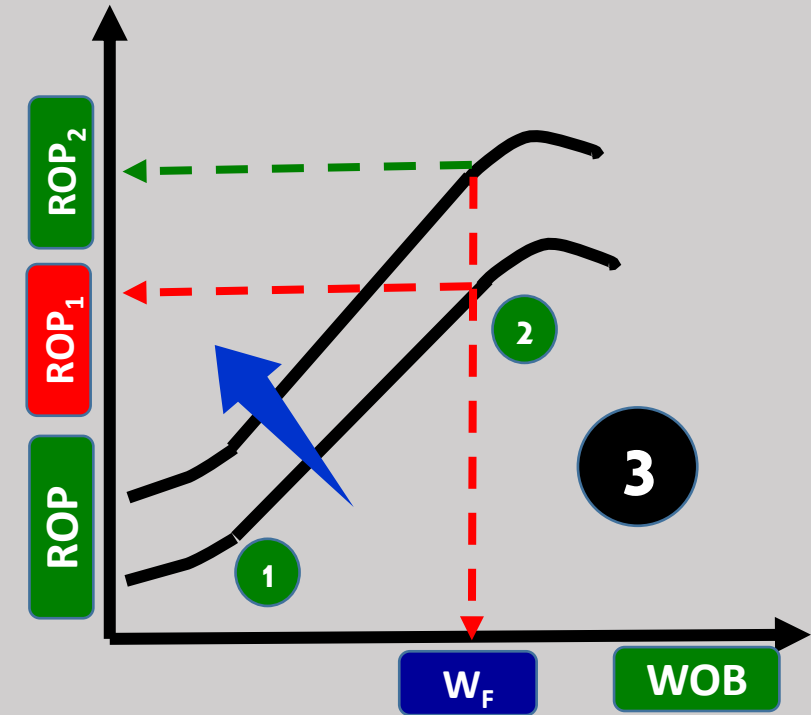
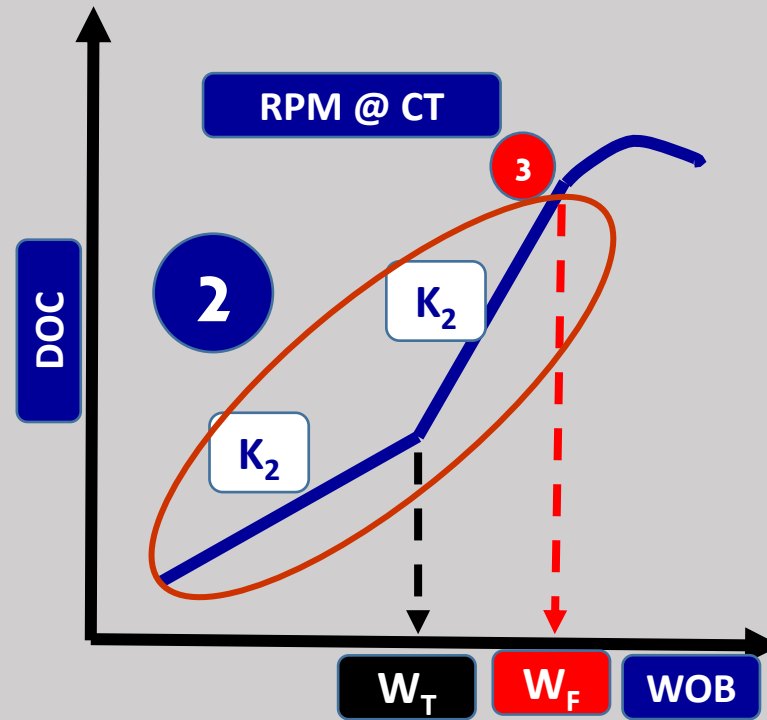
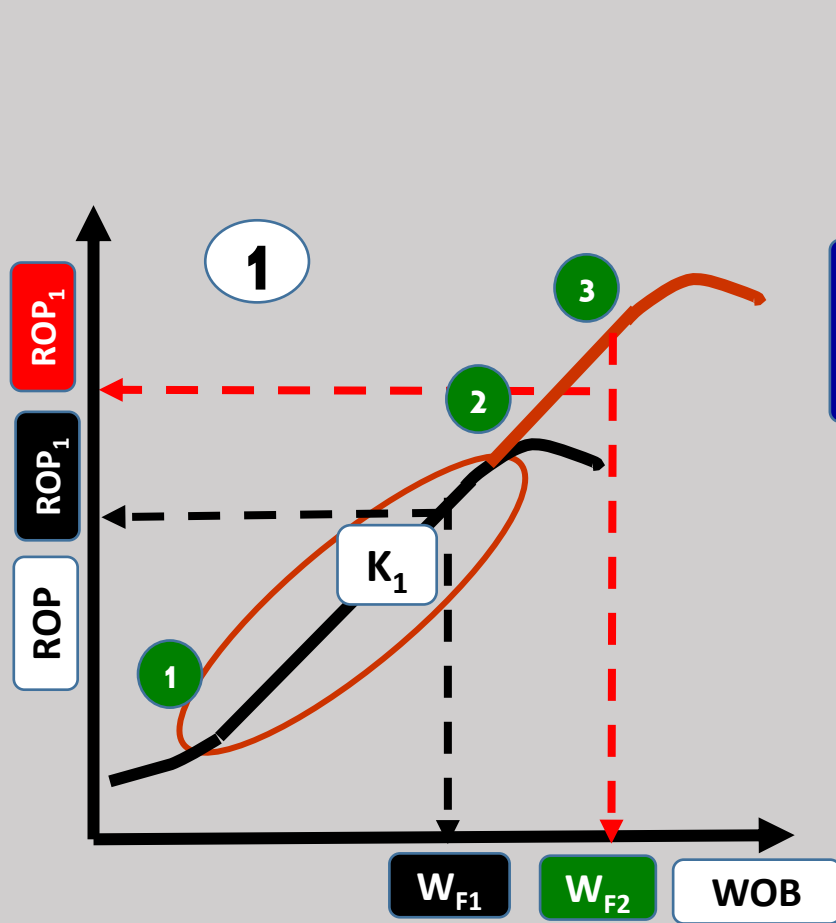
Failure Modes

Way Forward

- **Failure Types (Expectations in Planning)**
 - i. **Impact Damage @ Dynamic**
 - ii. **Impact Followed by Accelerated Wear (Dynamic Followed by Static)**
 - iii. **Wear @ Static**
 - iv. **Wear Followed by Impact (Less Common)**
- **Wear is Preferential Failure Mode**
 - **Time Dependent Failure (Longer Time to TOOH)**
- **Impact Damage is Rapid**
 - **Shorter Time to TOOH (Note Formation Drillability)**
- **Note Drilling Mechanics Effects**
- **Anticipated Dulls Vs. Actual Dulls (Applications Effects)**
- **Best Operational Parameters**
 - **Lowest WOB to Shear (Note Impact on BHA Design)**
 - **Lowest ROP to Smooth Torque (Note Effect on Wear)**

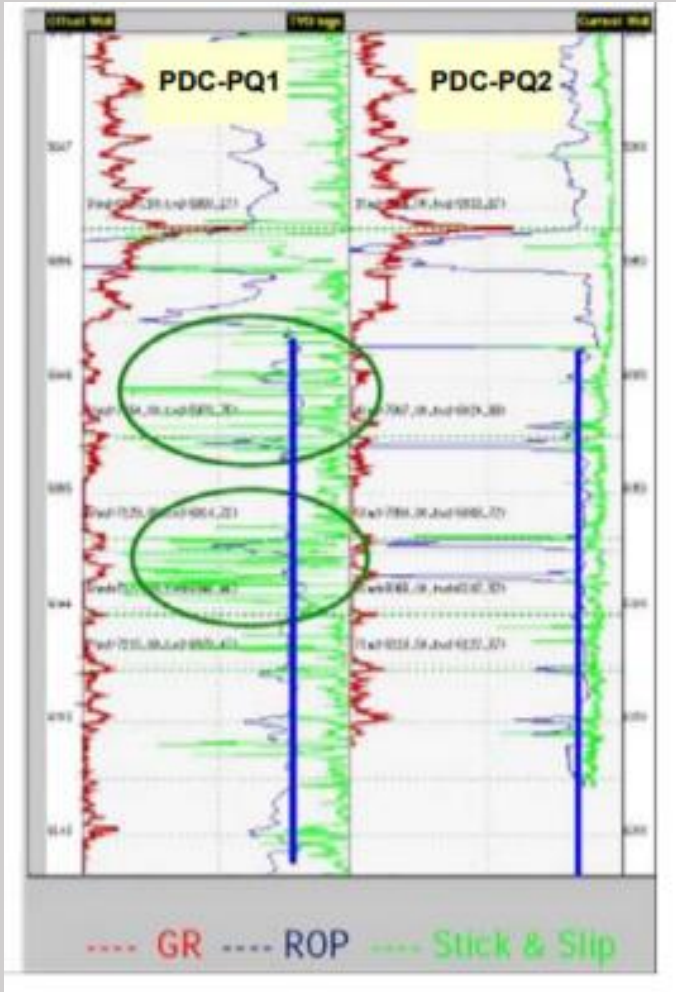
Limiter Diagram Vs. Efficiency Diagram

Functional Differences Vs. MSE @ 100% Efficiency



- i. 1 vs. 2
- ii. 1 to 3

RSS (Push Vs. Point) Functionality and Effectiveness



Push Specialized Bit (PDC-PQ₁)
Bit Used on Point RSS
See Drilling Dynamics



Point Specialized Bit (PDC-PQ₂)
Bit Used on Point RSS
See Drilling Dynamics

SPE/IADC 98931

Rotary Steerable Push Vs. Point Systems (Comments)

- **RSS Applications Vs. RSS Drilling**
 - **Applications Definitions**
- **Tool Functionality and Dynamics**
- **Dominant Vibration Modes**
 - **Push @ Torsional**
 - **Point @ Whirl**
- **Different Bits Needed Due to Functionalities**
- **Point Type Bits Can Be Effective on Push Tools**
 - **Note Well Profiles (RSS Drilling)**
- **Push Bits are Compromising on Point Tools**
- **Note Other Tool Benefits and Limitations**
 - **Operational Medium on DLS Capabilities**

Directional Drilling @ PDM

ROP Maximization, BHA Count Vs. % Slide Time

- **Challenges**

- **Low Average ROP**
- **Poor BHA Hold Performance**
- **High Slide %**
- **Multiple BHAs**
- **High Instantaneous ROP**
- **Hole Cleaning**
- **Poor Dull Grades**
- **Stuck BHAs**
- **Section Lengths ~ 9800ft**
 - **Tangent Sections**
- **High Cost Per Section**
- **New Bit Technologies**

SPE/IADC 50557



Dull from Drilling Campaign (12 1/4")

Stakeholder Discussions

Risk Analysis and Comments

- **Formation Drillability**
 - **Soft with Very Hard Streaks**
- **Increased Section Lengths**
 - **10% Increase**
- **Hold BHA Characteristics**
- **Improved Hole Condition**
- **Drill Bit Analysis**
- **Improved Stability**
- **Enhanced Durability**
- **Drilling System Compatibility**
- **Reduce Slide %**
- **Increase On-Bottom Time**
- **Higher Section ROP**

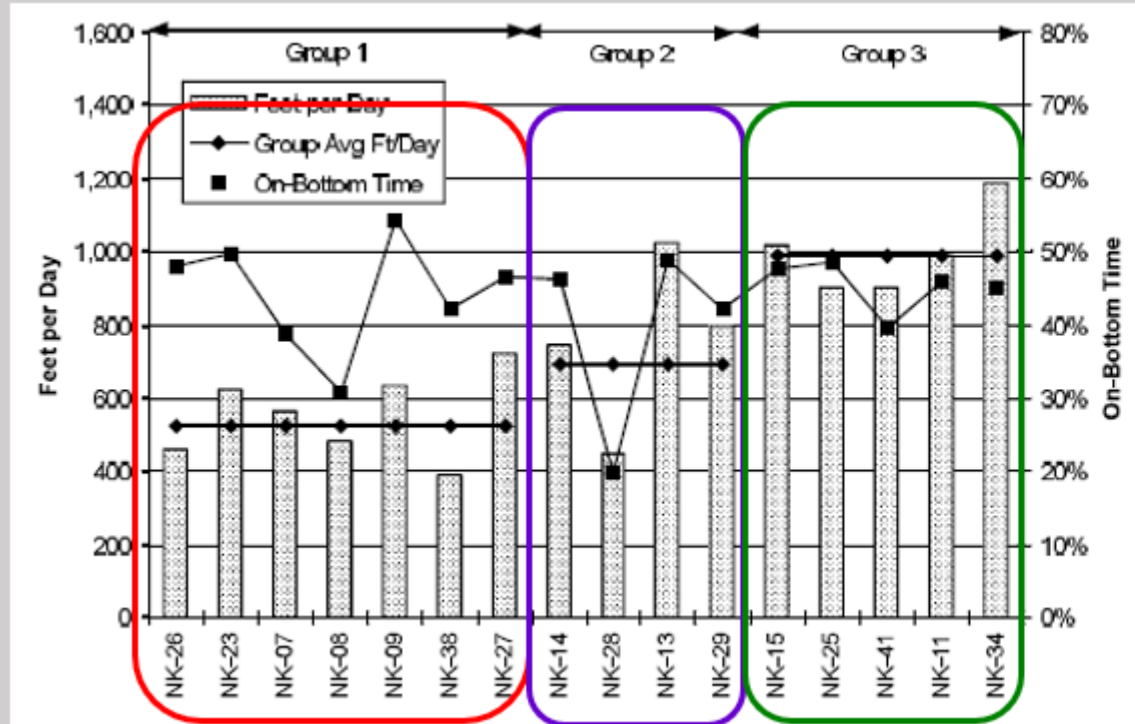
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Dull From New Solution (12 ¼")

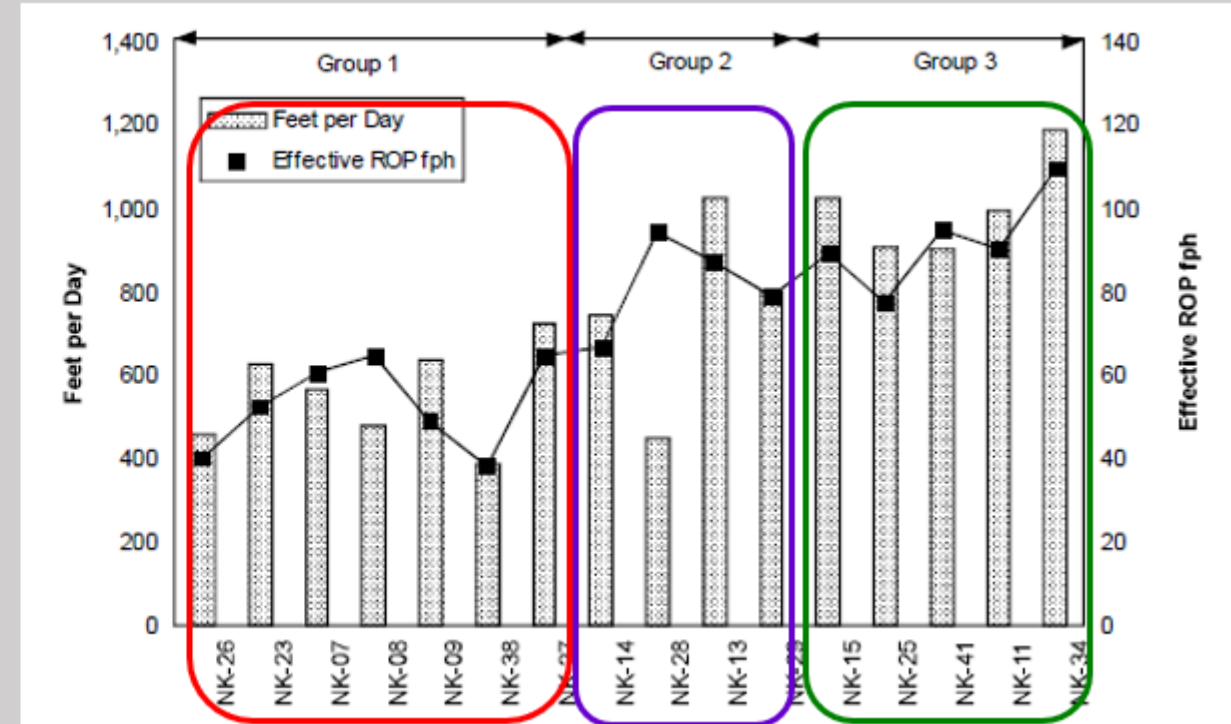
Performance Comparisons Offsets Vs. New Solution

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Offset

New Solution

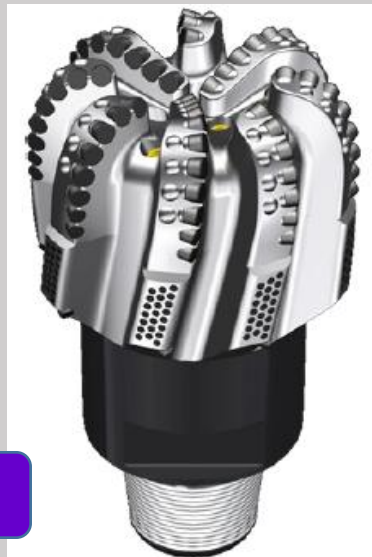


Offset

New Solution

Bit Types Vs. PDM Bend Size Effects on ROP, Durability, Vibrations and DLS

BHA Design, Behavior, Drilling Parameters Roadmap and Tolerance is Critical



SPE/IADC 168014

Tomorrow (Yes, NOW)

Path to Automation

- **Applications Classifications**
- **Drilling System Effects**
- **Drilling Modes and Implications**
- **Anticipated Challenges and Correlations**
- **Drilling Parameter Effects**
- **Big Data Analysis**
- **Field Testing**
- **Parameter Trends and Behaviors**
- **Parameter Comparisons**
 - **Actual Vs. Expected**
- **Machine learning**
- **Trend Predictions**
- **Calibration and Consistency**

Engineering



Optimization



Automation

Conclusions

- **Performance Drilling must enable Project Cost Reductions**
- **Operational Efficiency is More Important than Mechanical Efficiency**
- **Performance Improvement Solutions Must be Achieved Holistically**
- **Drilling System Compatibility Must Always be Established**
- **Benchmarking Must Be Executed at Normalized Input Parameters**
- **Failure Analysis and Understanding is Critical for Engineering Solutions**
- **ROP Maximization MAY not May Not Reduce Operational Costs**
- **ROP is one of Several Cycle Time Factors, NOT the Cycle Time Factor**
- **Cycle Time Factors Must Be Identified and Ranked for Different Projects**
- **Cycle Time Reduction WILL reduce Operational Costs**
- **MSE needs a separate Conversation...**
- **Automation MUST be Pursued NOW (Pre-Requisites are Very Important)**



- **XCI**Drill Technology (XCI) offers pioneering expertise in drilling efficiency enhancement, operational success and cost reduction, through **X**cellence in **C**ycle Time **I**mprovement. These objectives are achieved through systematic and collaborative deployment of:
 - Performance Drilling Solutions & Strategies
 - Project Planning and Operational Execution Training
 - Data Analytics for Drilling Automation
- XCI's proficiencies and holistic approach to drilling systems evaluations covers Deepwater, Conventional and Unconventional assets. Our innovative, effective, and cost saving solutions improve drilling efficiency, reliability, and well construction processes.
- **X**cellence in **C**ycle Time **I**mprovement is our passion

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