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# Improving Drilling Performance By Applying Advanced Dynamics Models

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**Shell Exploration and Production**

Society of Petroleum Engineers
Distinguished Lecturer Program
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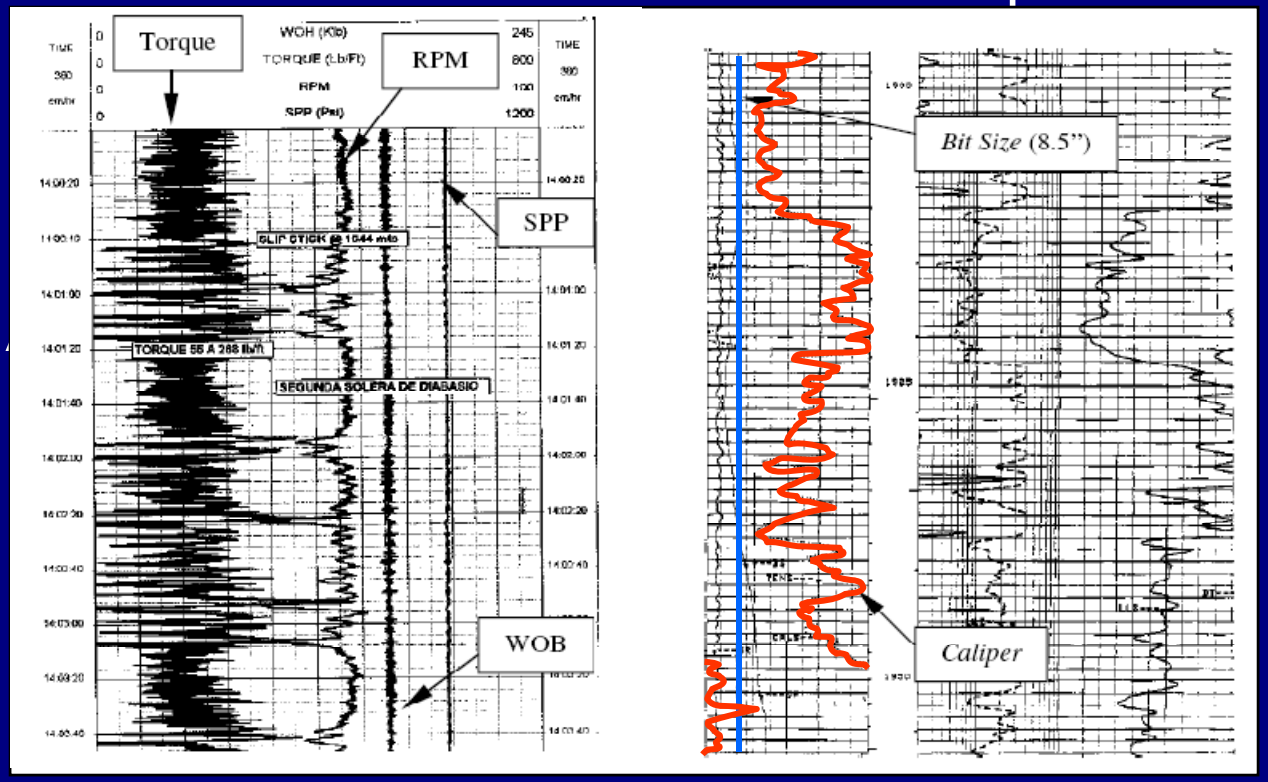
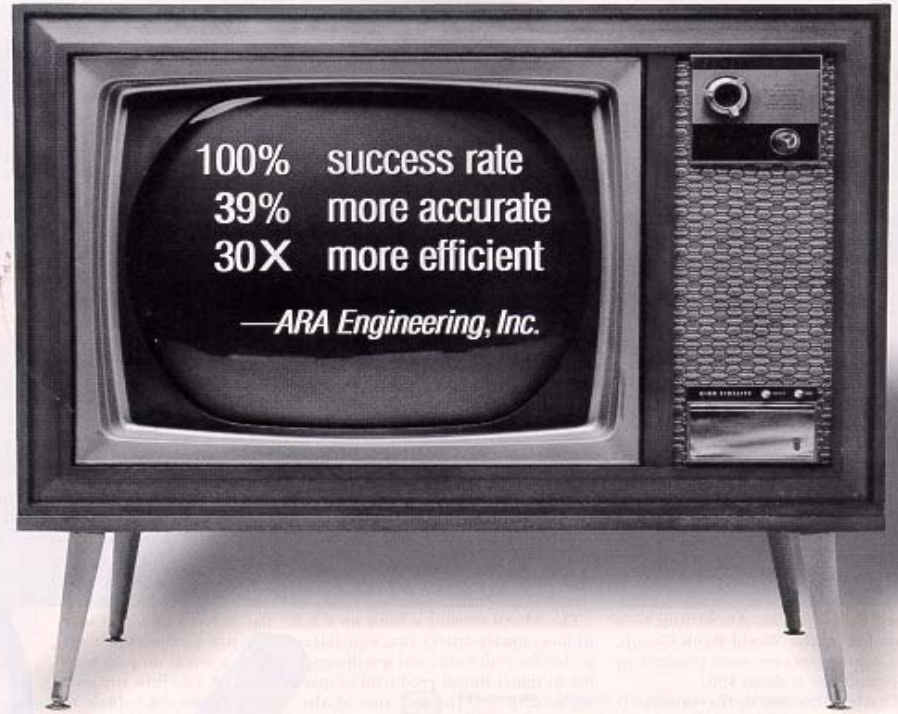
# The Message

- Drilling system vibration affects drilling efficiency
- Uncontrolled vibrations can lead to poor hole quality
- 




Reference: Santos, et al.
"Consequences and Relevance of Drillstring Vibration on Wellbore Stability,"
SPE/IADC 52820

# Considering Engineering Simulation ?




**(Sometimes, your decision is black and white.)**

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*Mainstream CAE Tools:*
*Technical Considerations and Informative Comparisons*,
visit **www.ara-eng.com/special-report.htm**

Reference:
ASME Journal

# Types of Dynamics Models

- Research Models
  - More detailed analyses
    - Bit designs (PDC, RC)
    - BHA design
    - Bit/BHA system performance
  - Nonlinear FEA
    - Beam elements
    - Complex contact geometry
    - Complex vibration inputs
  - Refined load and stress estimates
    - Transient dynamic loads and stresses
    - Post-buckling analyses

Improved computational horsepower has made use of “research” models more practical

# Research Model Applications

- PDC Bit Dynamic Stability
  - Evaluated via laboratory testing
    - Constant speed (often 120 RPM)
    - Increment weight on bit (ROP)
    - Identify transition from “unstable” to “stable”
  - Time consuming and costly
  - Needed a predictive model

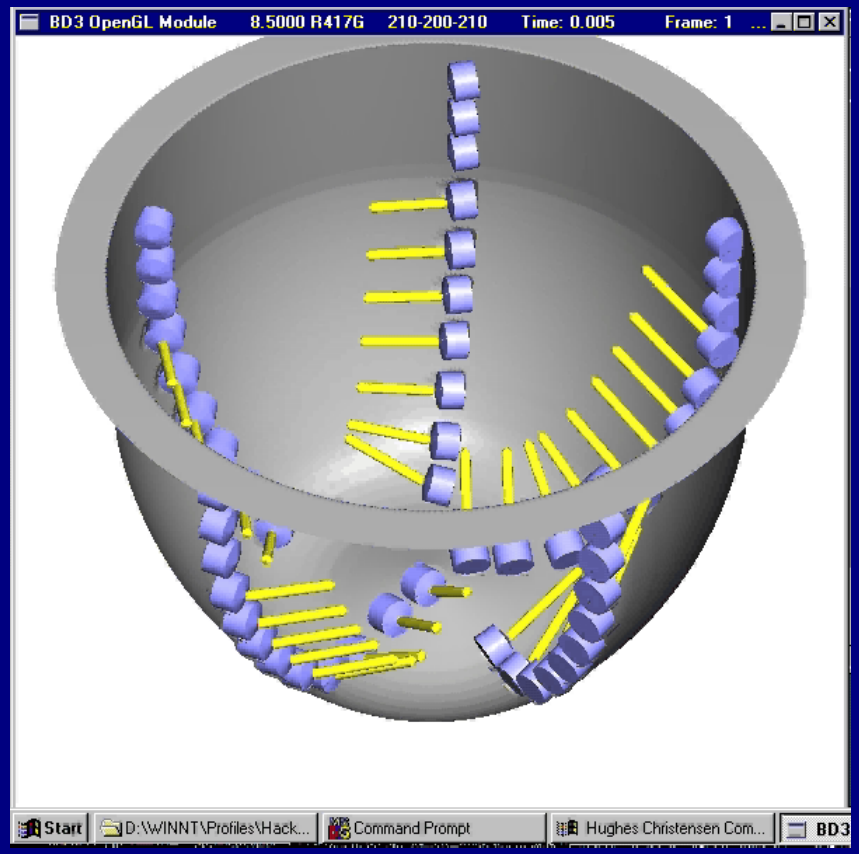
Unstable 8.500-in. M434

Stable 8.750-in. M123

# Bit Dynamics Model

- Stability Prediction
- Dynamic Load Evaluation
  - 120 RPM, 3 ft/hr
  - Force vectors shown in yellow and green

Unstable 8.500-in. M434

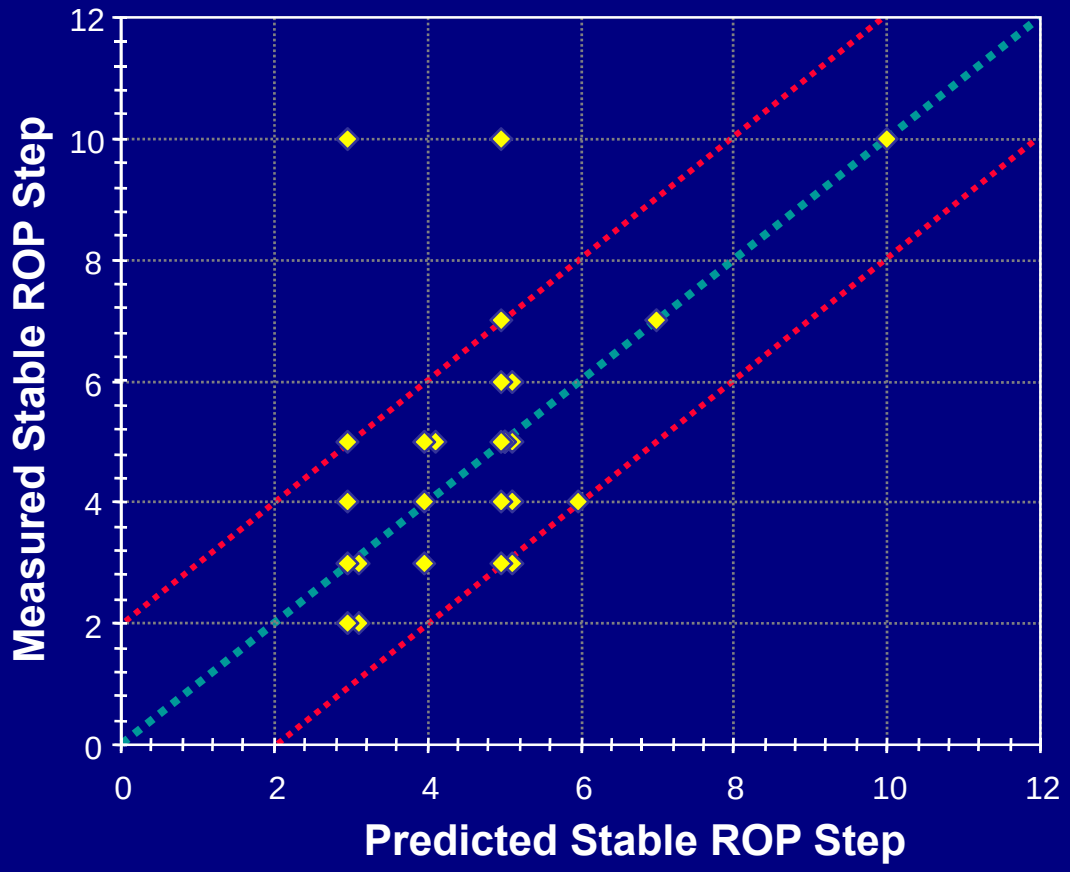


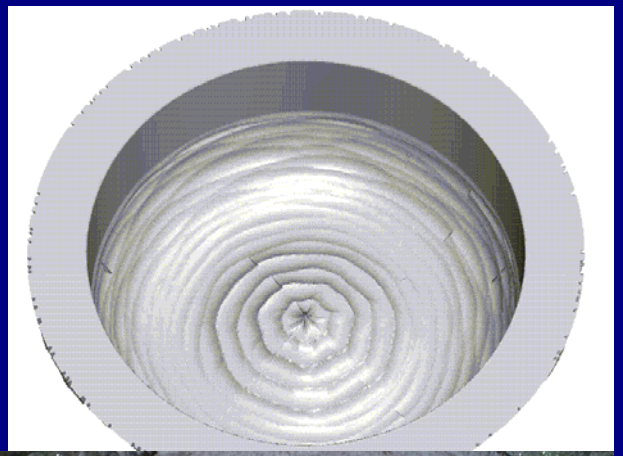

Reference: Hanson, Hansen
"Dynamics Modeling of PDC Bits," SPE/IADC 29401

# If PDC Cutters Could Talk …

# Verification of Stability Predictions

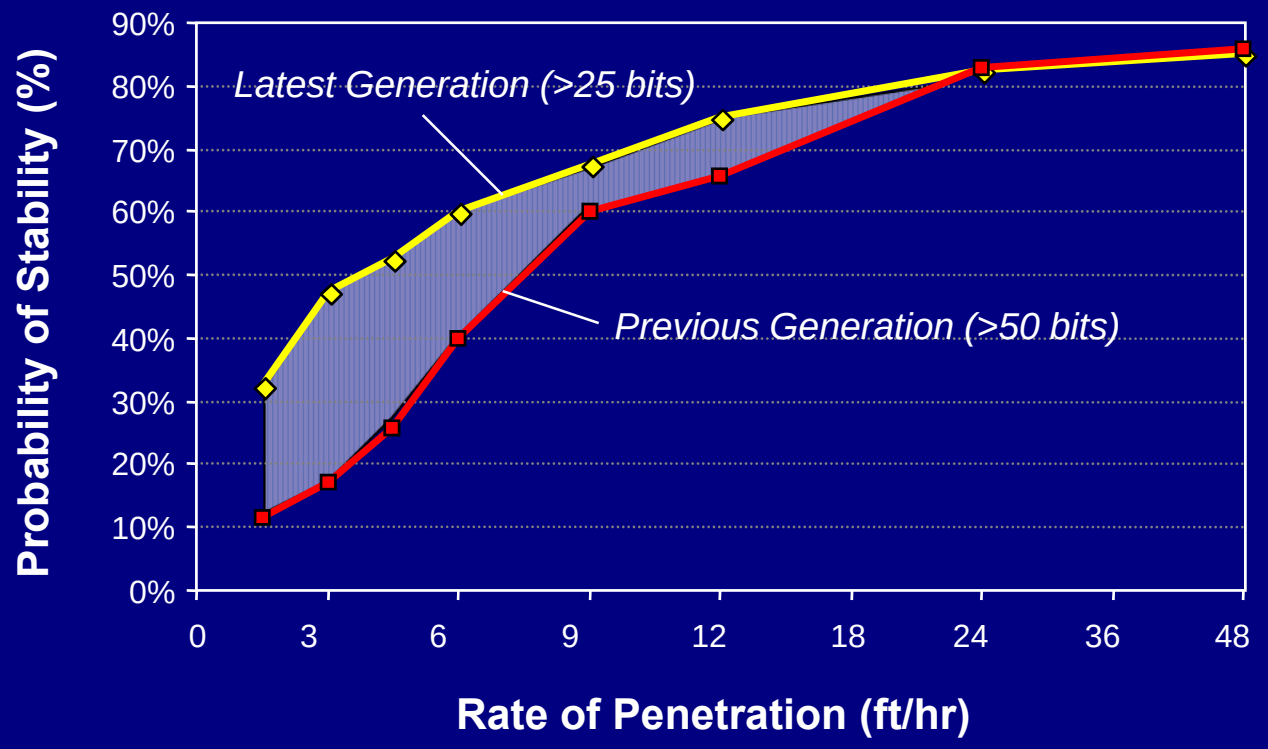
- Laboratory Tests
  - 27 designs, 5.875 to 17.500-in., various IADC classes



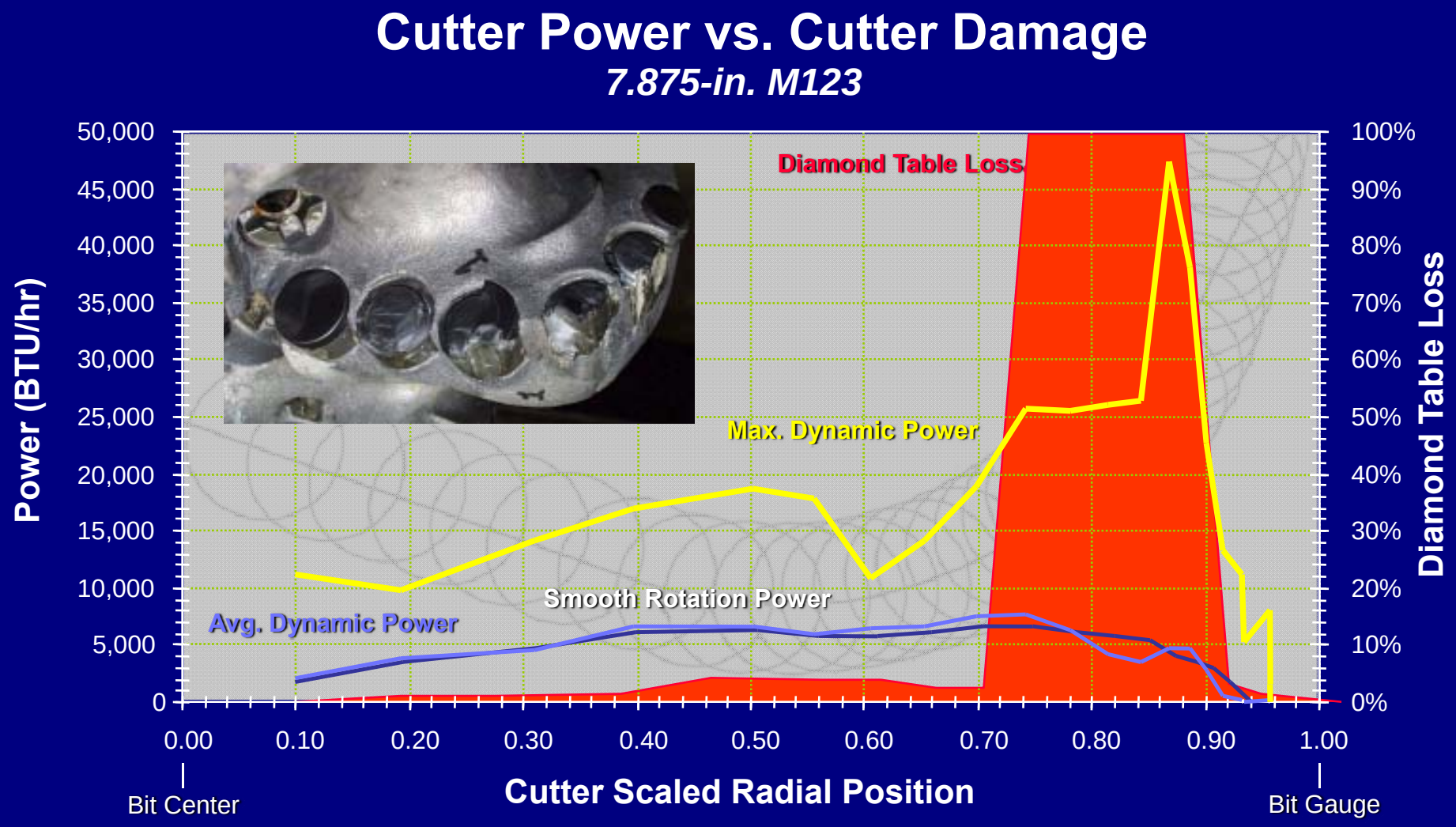



# Improving PDC Bit Stability

- Laboratory Tests
  - Hard limestone ($c_o$=15 kpsi), 120 RPM



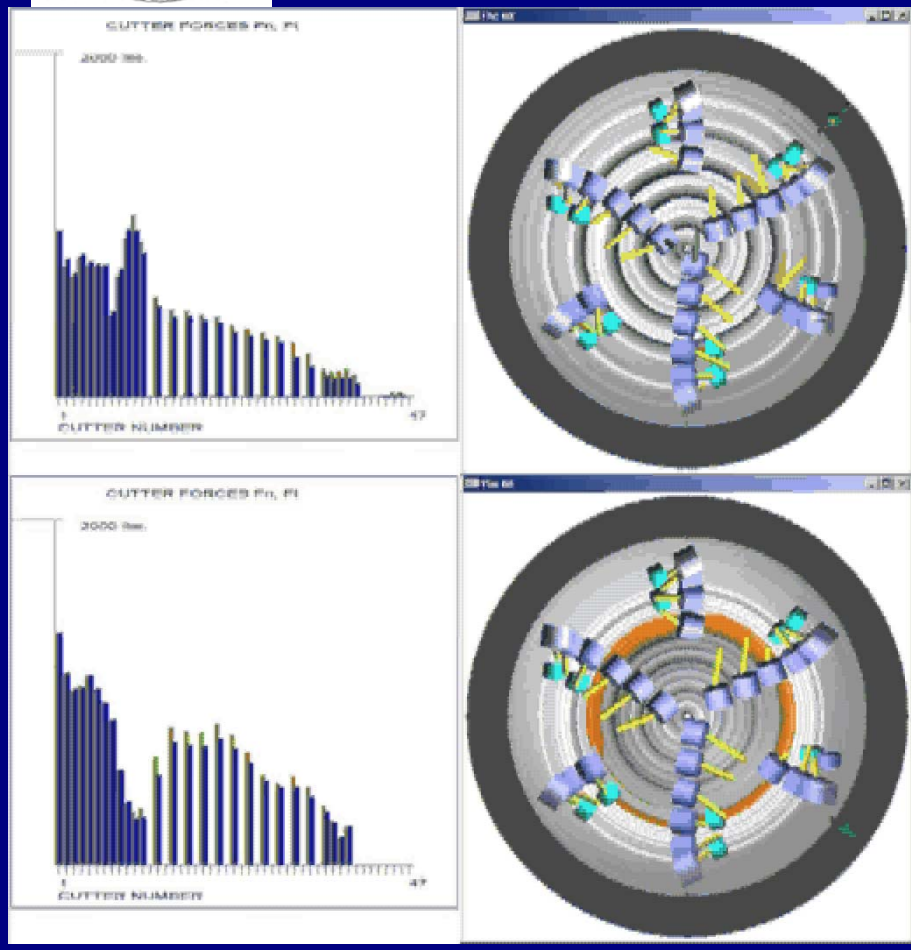
# Dynamic Load Predictions



# Load Predictions Through Beds

- Formation changes affect load distribution


*Segmented core used for laboratory tests*

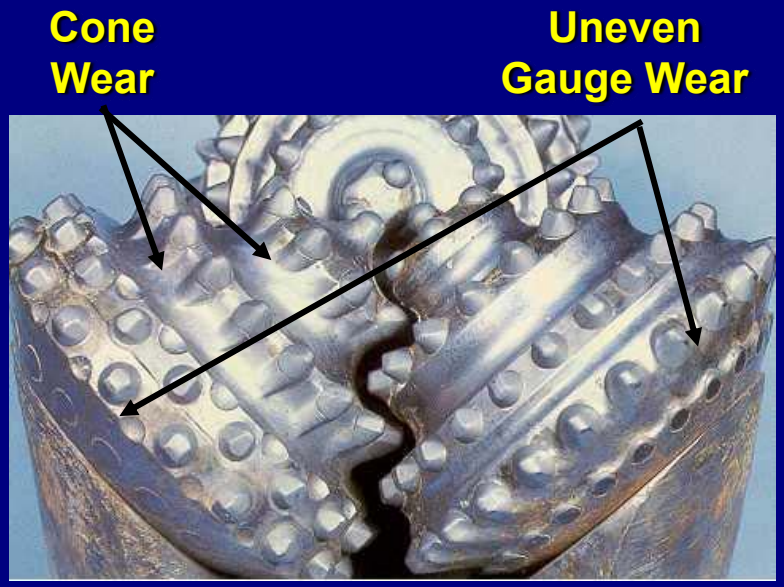


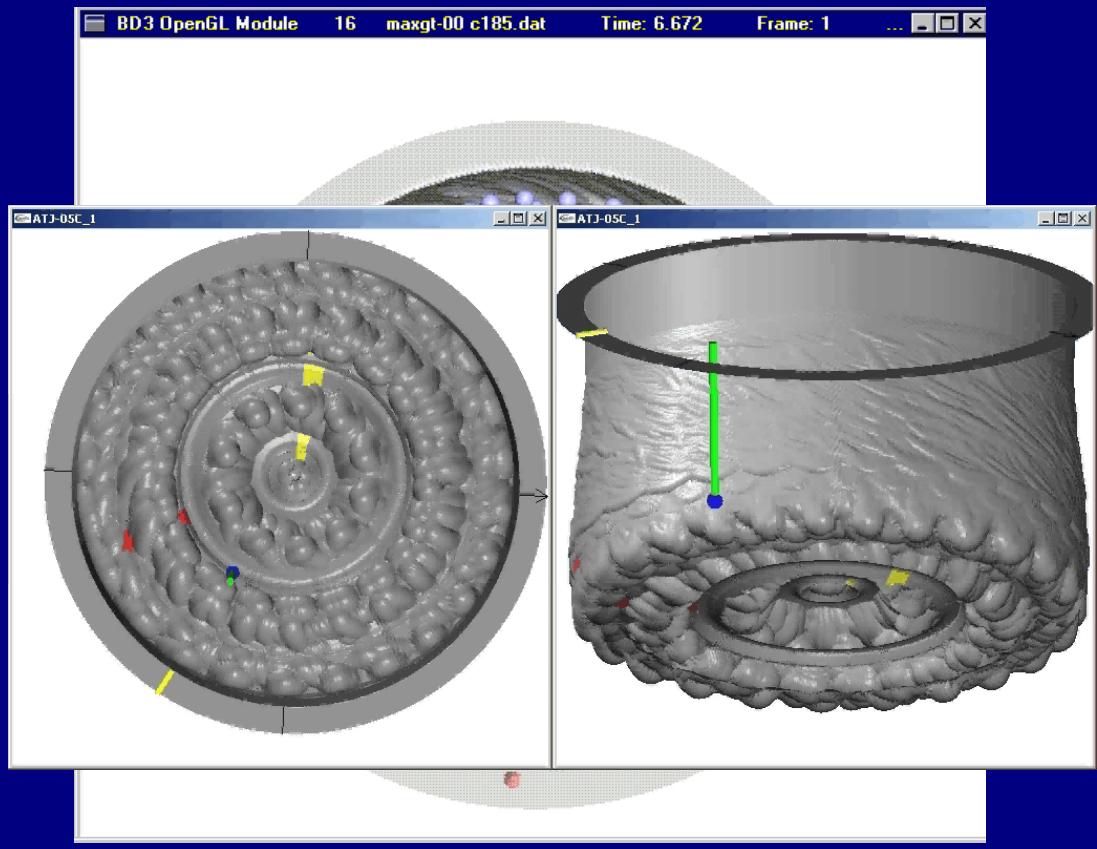

**Soft→Hard**
**(nose)**

**Hard→Soft**
**(cone, shoulder)**

# Research Model Applications ...

- Roller Cone Bit Design
  - Elimination of off-center running tendencies



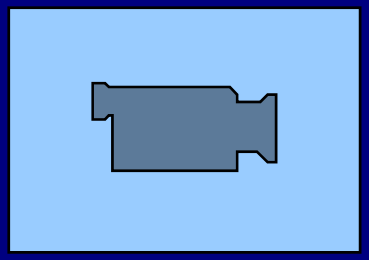
# Research Model Applications ...

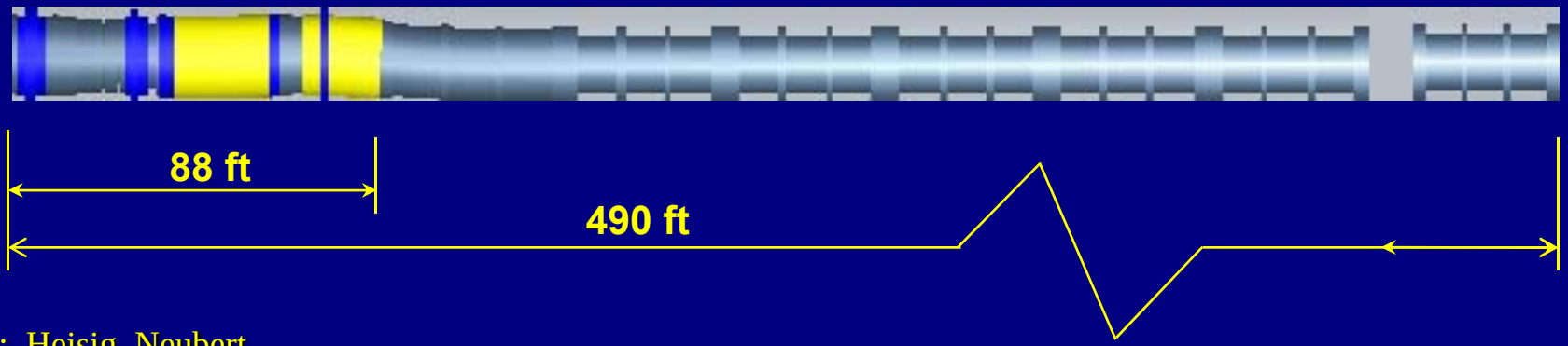
- BHA Dynamic Stability
  - Unbalanced components feed whirl
    - Mass imbalance in collars
    - Eccentric rotor rotation
  - Frictional interaction with wellbore triggers BHA whirl
    - High average accelerations
    - Extreme impacts
  - Needed a predictive model

Whirl caused by mass imbalance

# Drillstring Dynamics Model

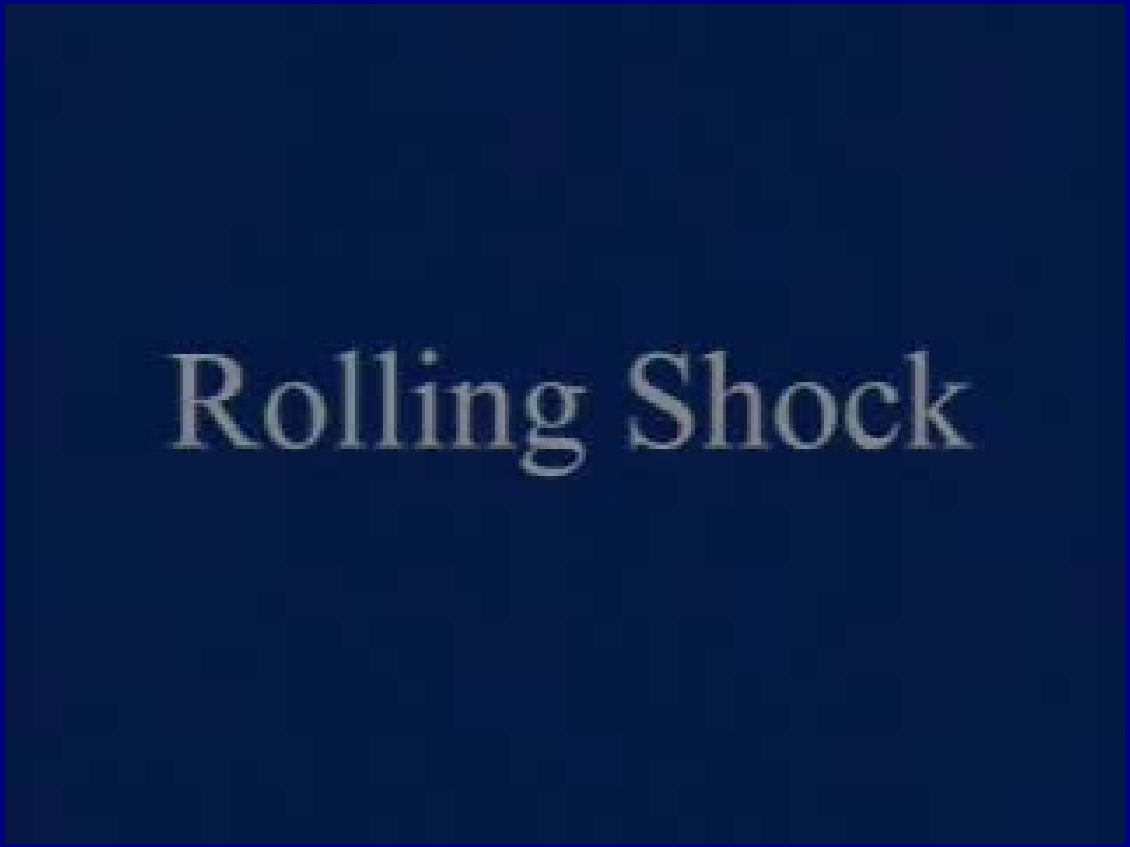
- 8.500-in. Horizontal Hole
  - Instrumented motor
  - MWD tool
  - LWD tool
- Operating Conditions
  - WOB = 22.4 klb
  - TOB = 4.6 klb-ft
  - $\rho_M$ = 11.7 ppg






Reference: Heisig, Neubert
"Lateral Drillstring Vibrations In Extended-Reach Wells," IADC/SPE 59235

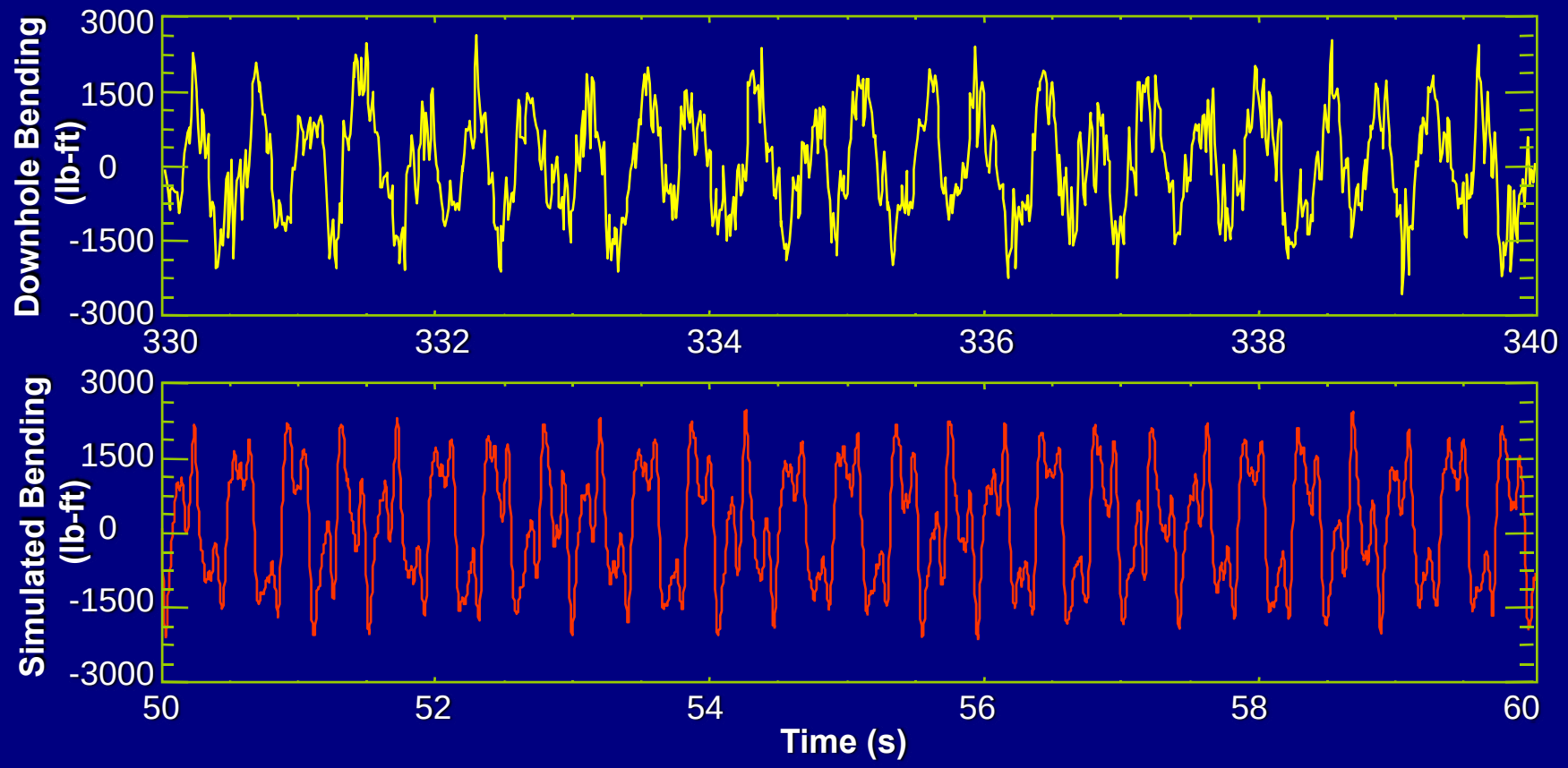
# Laboratory Verification




Reference: Aldred, W.D. and Sheppard, M.C
"Drillstring Vibrations: A New Generation Mechanism and Control Strategies," SPE 24582

# Verification of Bending Predictions

- Controlled Field Tests
  - 12.250-in. hole, RC-STB-MWD-STB-DC
  - Limestone drilling

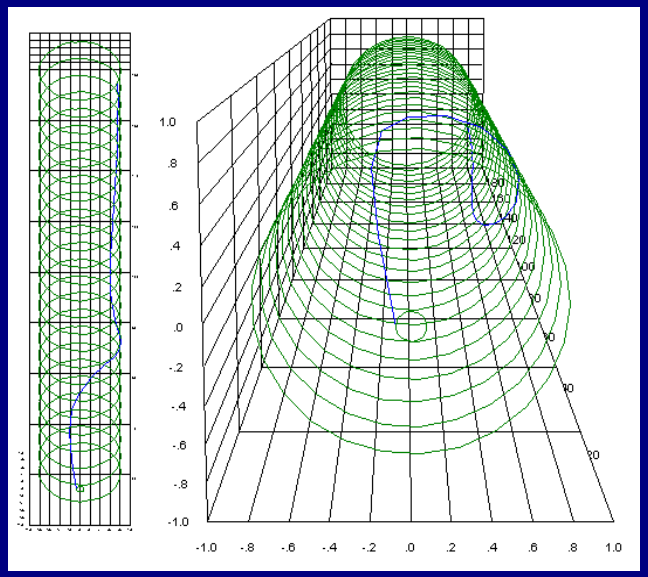


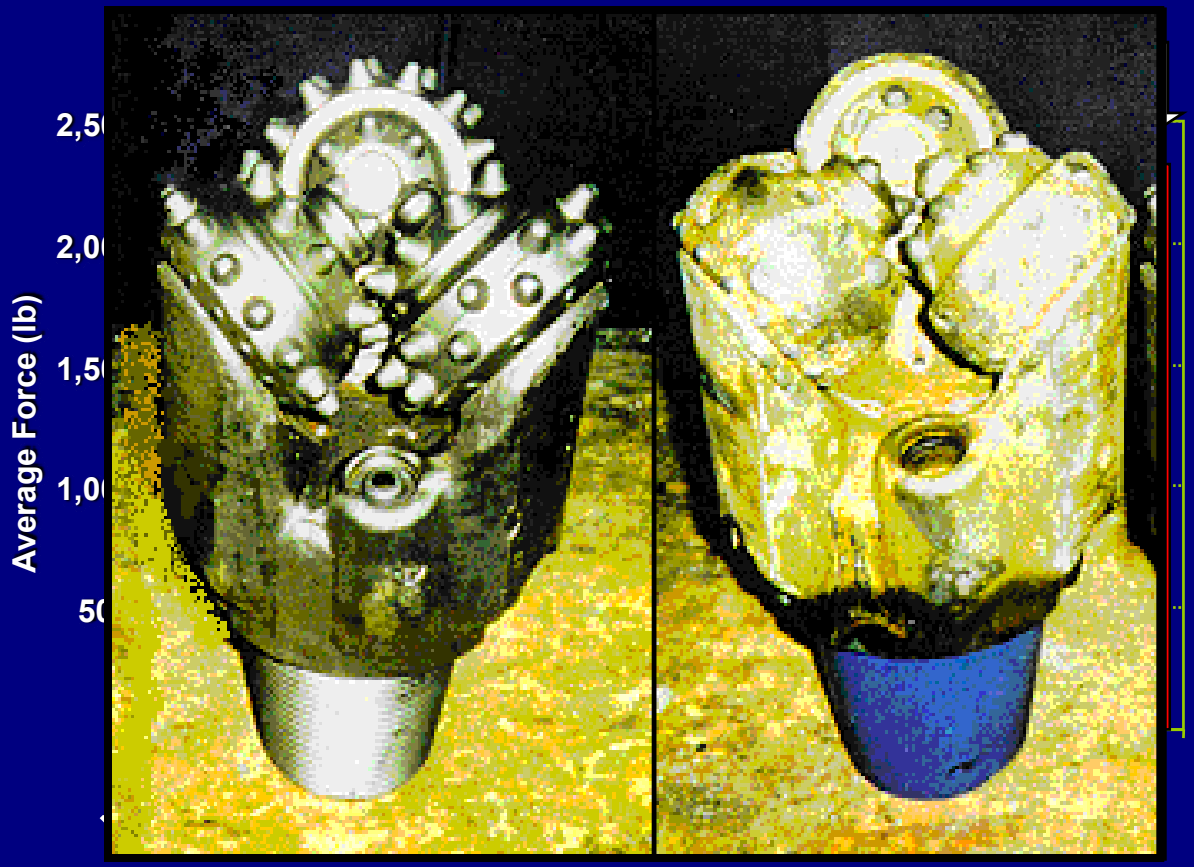
# Research Model Applications ...

- Bit-Drillstring System Performance
  - Effect of BHA vibration on bit loading

# Research Model Applications ...

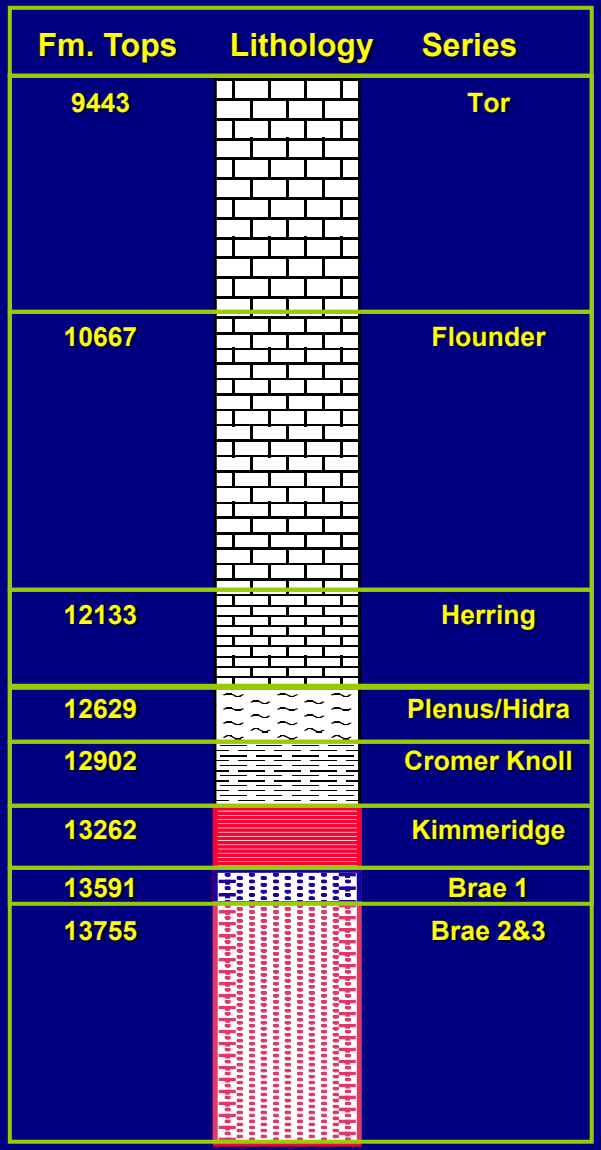
- Bit-Drillstring System Performance
  - The effect of BHA vibration on bit loading
  - Operating parameters for sub-optimal BHAs



# Financial Impact: Improved Bits

- UK North Sea Application
  - Hard and abrasive zones
    - Poor PDC life in offsets
  - Needed to improve in 12.250-in. section

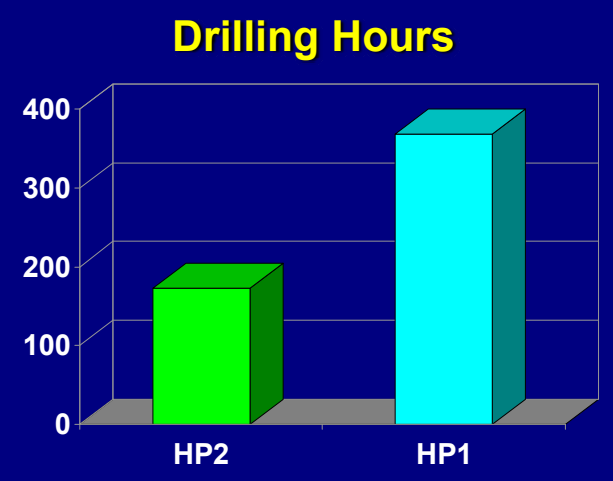



# 12.250-in. Section Performance

- Focus Well
  - New designs drilled further and faster

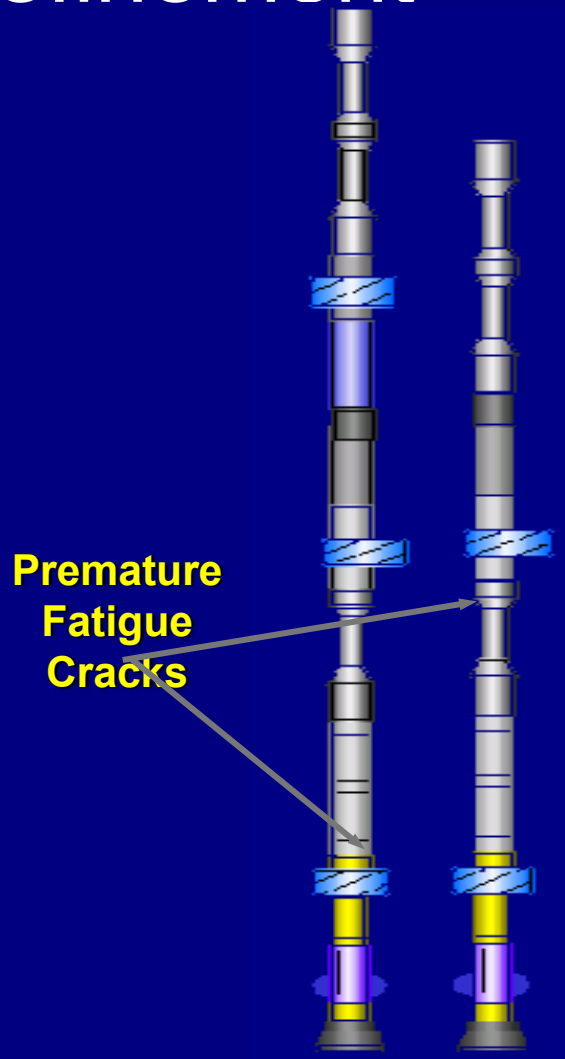
| Bit Type | Depth Out (ft) | Drilled (ft) | Hr. | Avg. ROP (ft/hr) | Cost/ft (US$/ft) |
|---|---|---|---|---|---|
| Standard 1.1 | 13,535 | 49 | 11.7 | 4.1 | 2,274 |
| New 609 | 13,930 | 395 | 30.1 | 13.2 | 467 |
| New 408 | 14,437 | 507 | 42.2 | 12.0 | 476 |
| New 608 | 14,820 | 383 | 38.3 | 10.0 | 686 |
| Standard 1.2 | 15,013 | 193 | 32.1 | 6.0 | 897 |
| Standard 2.1 | 15,128 | 115 | 14.3 | 8.0 | 1,049 |

- Versus Offset
  - Section drilled in half the time
- Savings
  - US $663 per foot
  - US $816,282 for section



# Financial Impact: BHA Refinement

- Norwegian North Sea Application
  - 6,000-10,000 ft horizontals in reservoir
  - Geosteering to stay above O/W contact
  - Soft sands, some calcite cemented zones
  - Could not steer PDC bits on motors
  - RS systems potentially offered step change
- Early Challenges
  - Bit performance
  - RS system durability
- Multidisciplinary Focused Study
  - Advanced models used for both bit and RS system refinement




Reference: Fiksdal, Rayton, Djerfi
"Application of Rotary Steerable System/PDC Bits … ," SPE/IADC 29401

# 9.500-in. Hole Section Performance

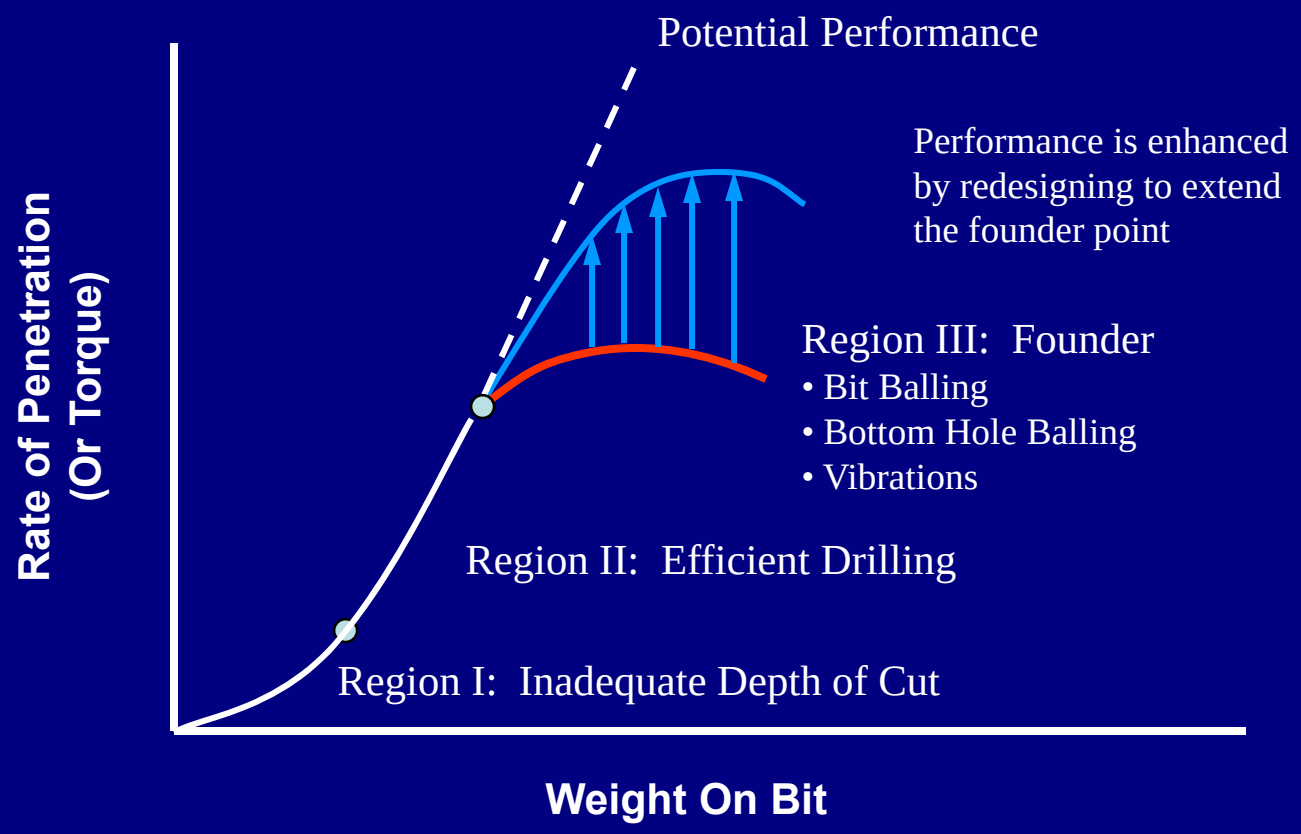
| Description | Before Study | After Study |
|---|---|---|
| Average interval length | 8,856 ft | 8,856 ft |
| Calcite stringers | 7% | 7% |
| Number of runs | 8.5 | 5 |
| Run length | 1,273 ft | 2,102 ft |
| Bit runs | 10.4 (6.7 RC, 3.7 PDC) | 4.6 (0.9 RC, 3.7 PDC) |
| ROP | 35.1 ft/hr | 67.2 ft/hr |
| BHA component failures | 3.5 | 1.9 |
| **Failure Distribution** | | |
| < 25 circulating hours | 25% | 14% |
| 25 - 75 hr | 18% | 14% |
| > 75 hr | 57% | 72% |

- Improved Drilling Efficiency
  - Improved bit performance
  - Improved RS BHAs
  - Savings approach US$1MM per well based on drilling time

# Summary

- Advanced dynamics models are useful for planning
  - Bit design optimization
  - BHA design optimization
- Advanced dynamics models are useful while drilling
  - Lessons learned provide insights into improved operating parameters
- Advanced dynamics models are useful for post-analysis
  - Evaluation of downhole vibration measurements
  - Failure analysis of drilling system components
- Advanced dynamics models improve performance
  - PDC bit efficiency and durability
  - RC bit efficiency and durability
  - LWD tool durability
  - Hole quality

# The Next Challenge




Reference: Dupriest and Koederitz
"Maximizing Drill Rates with Real-Time Surveillance of Mechanical Specific Energy," SPE/IADC 92194

# Questions?