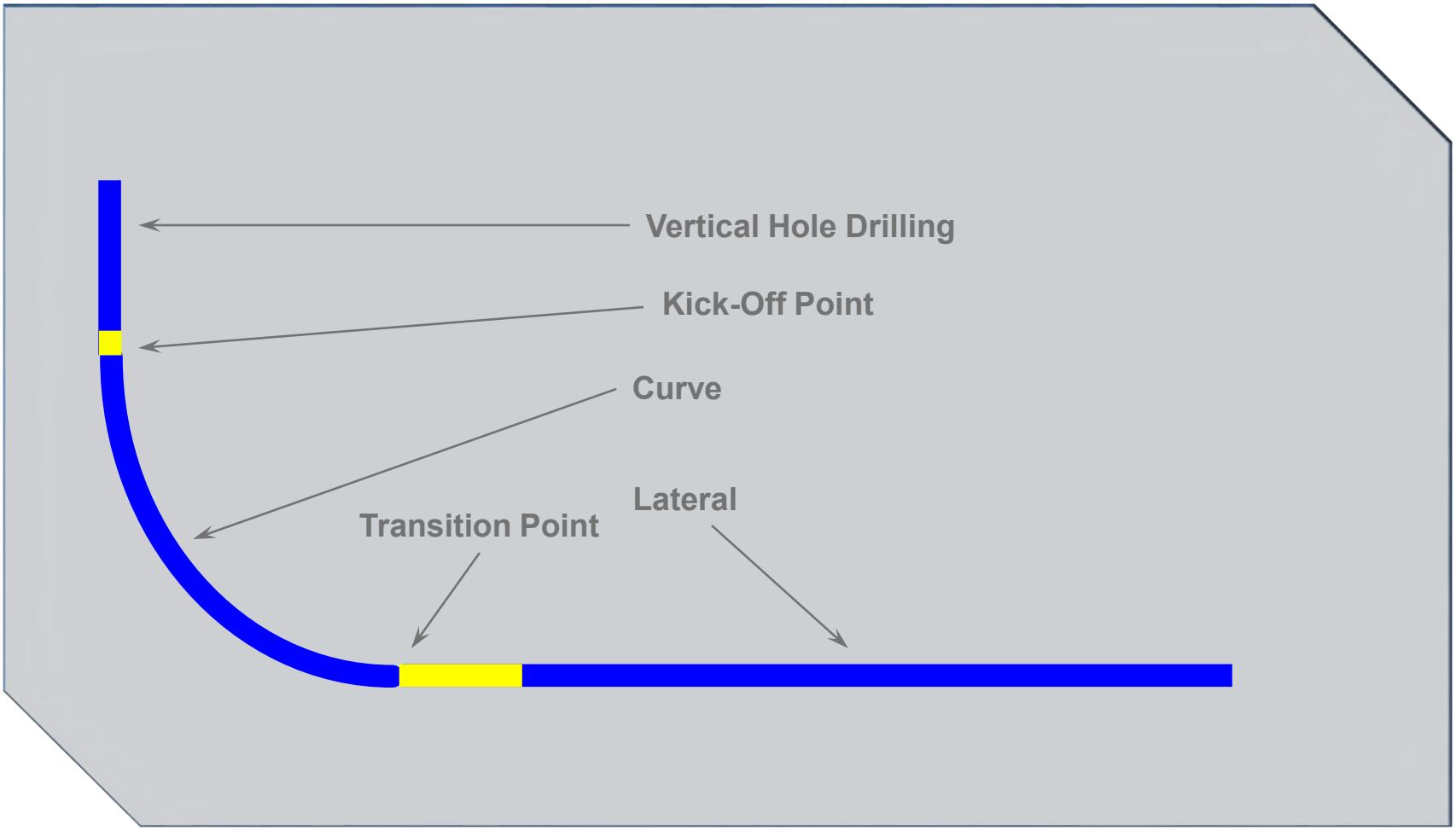
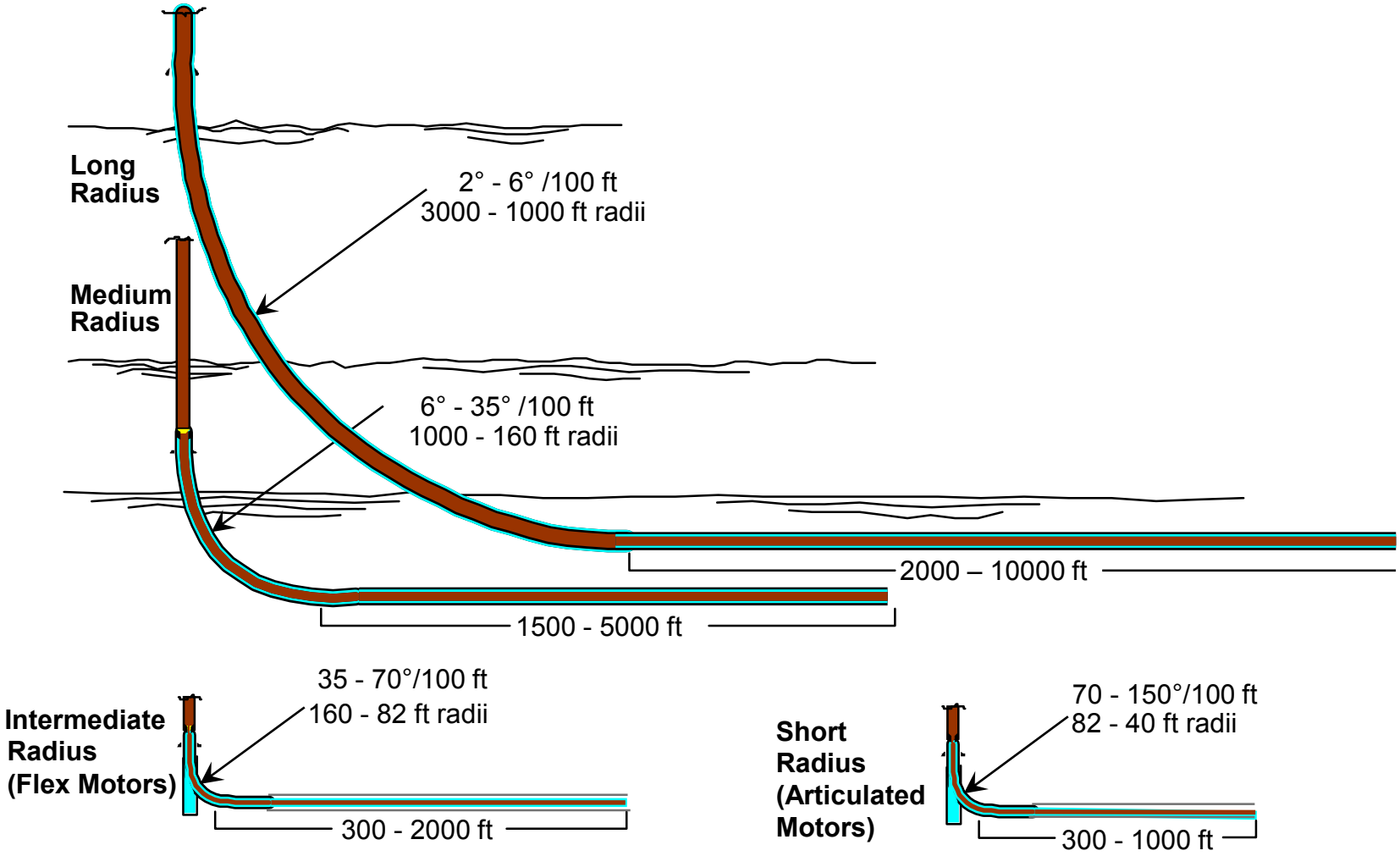
Directional Drilling Bottom Hole Assembly Design and Stabilizer Application Presentation

JA OILFIELD MANUFACTURING, INC.

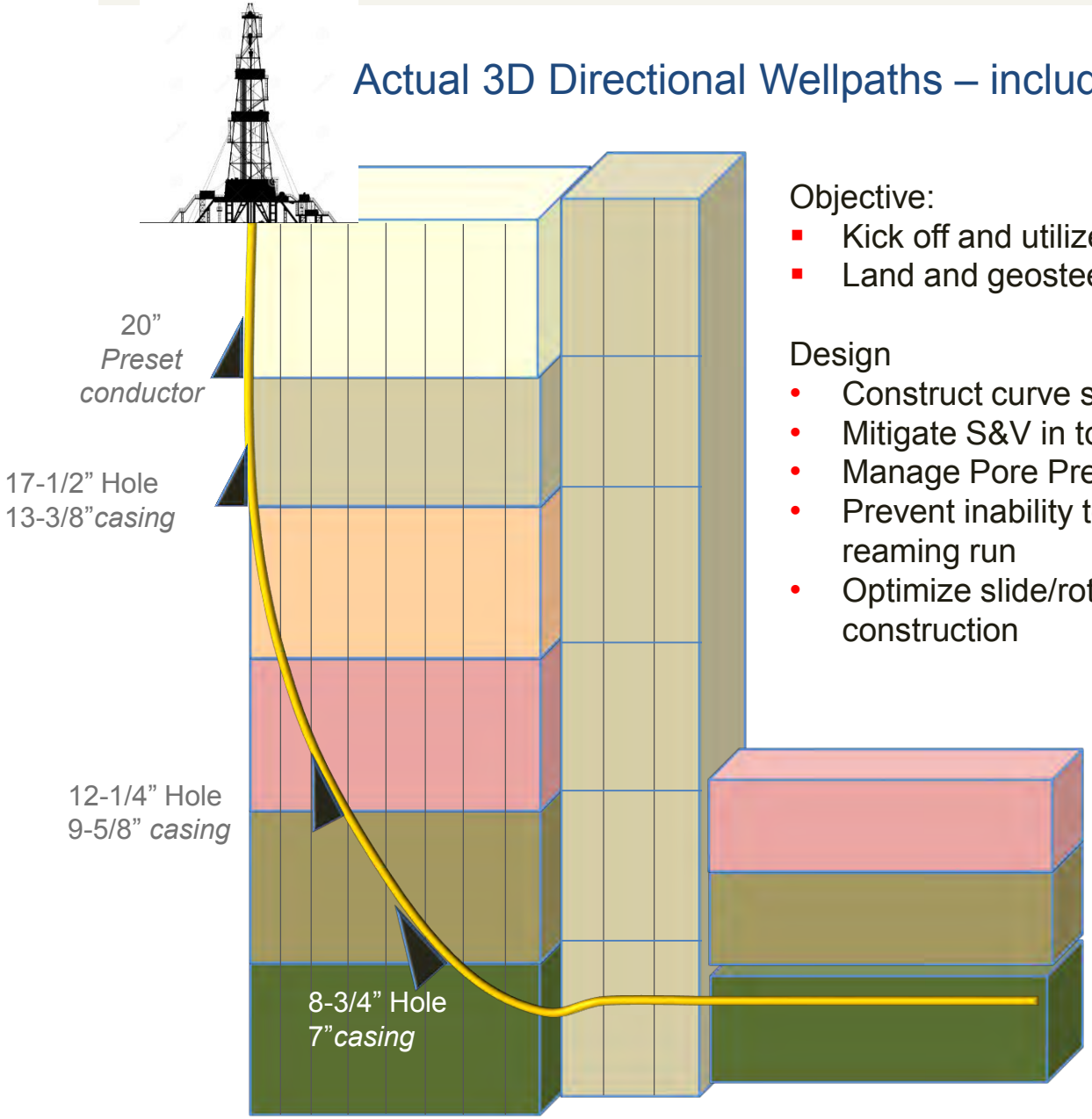
The 3 hole segments of a Directional Path



Directional Wellpath Geometry Nomenclature



Actual 3D Directional Wellpaths – including Geosteered Lateral



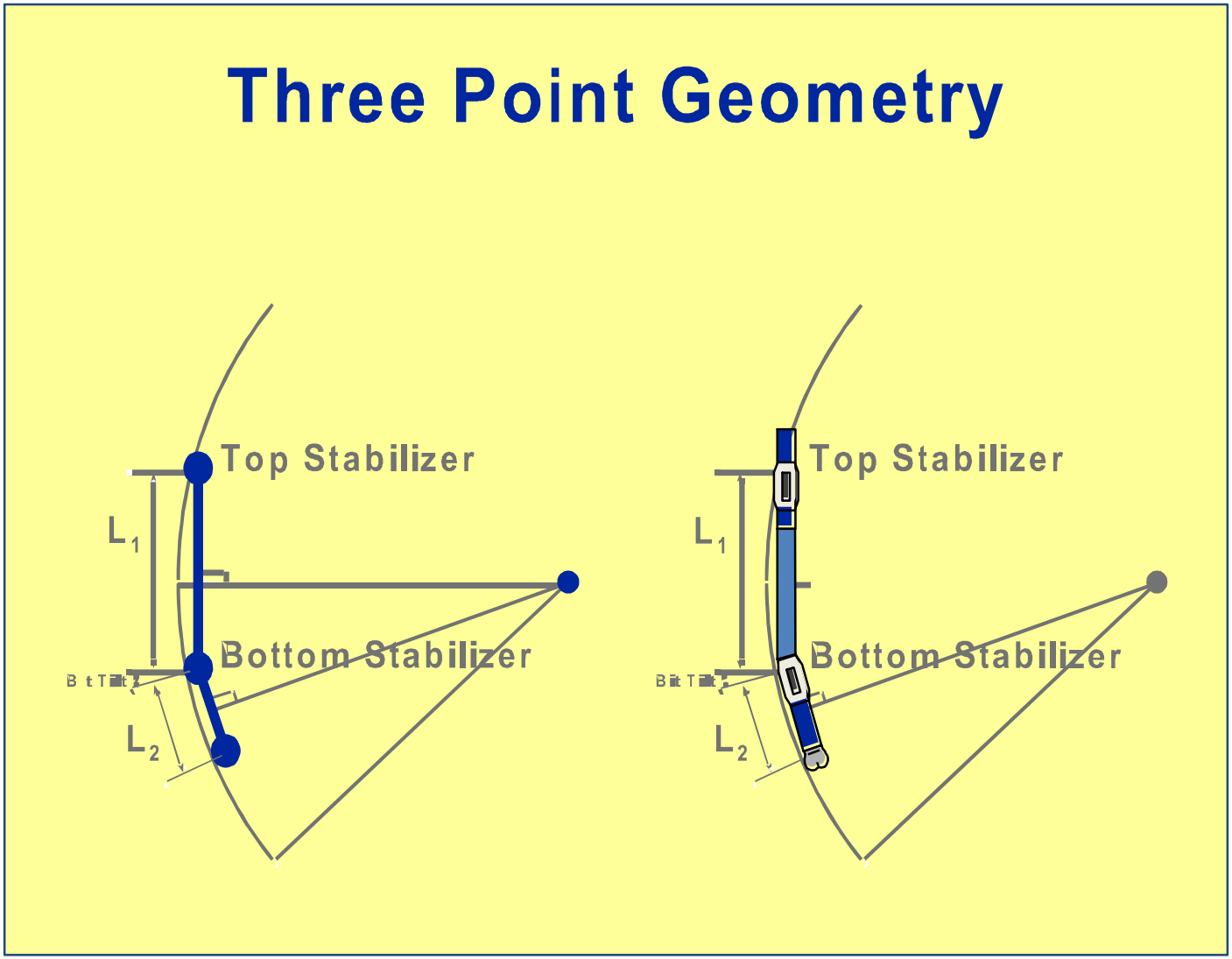
Objective:

- Kick off and utilize no greater than 10 deg/100 ft
- Land and geosteer 16,000 ft. lateral

Design

- Construct curve section to land at target TVD
- Mitigate S&V in tophole to achieve ROP
- Manage Pore Pressure transitions
- Prevent inability to run casing ► dedicated reaming run
- Optimize slide/rotate drilling modes for curve construction

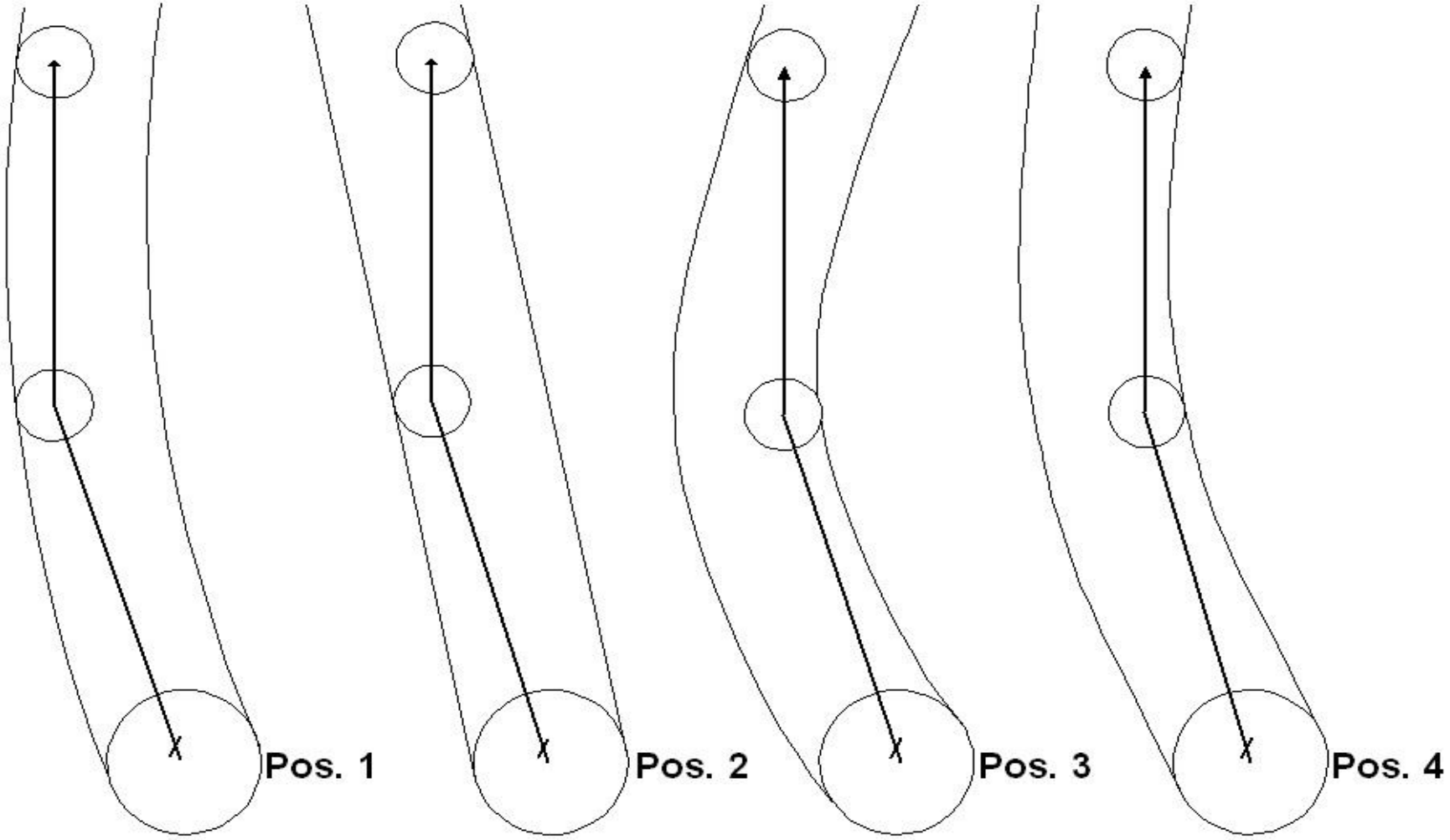
3 Point Geometry



Methods of Defining 3-Point Geometry of a Directional BHA to get Predictable, Repeatable Results

- The description of an arc is “any three points not in a line”
- The radius of that arc is determined by the misalignment of and the distance between the three points that form that arc.
- To define an arc such as produced during directional drilling you must be able to predictably and reliably describe and calculate that arc by having three fixed or determined points by design of the BHA and its subsequent points that form the arc for predicted curvature.
- The three points needed in that arc for it to be predictable are the Bit, Motor Bearing Hsg. Stabilizer and NorTrak Stabilizer on top of the motor.
- If you do not have all three of these points fixed in the BHA, then it will be the bit, lower point of the motor that is touching and point above the motor that is tangent to the wellbore and this is constantly changing.

Geometric Build Up Rate Calculation



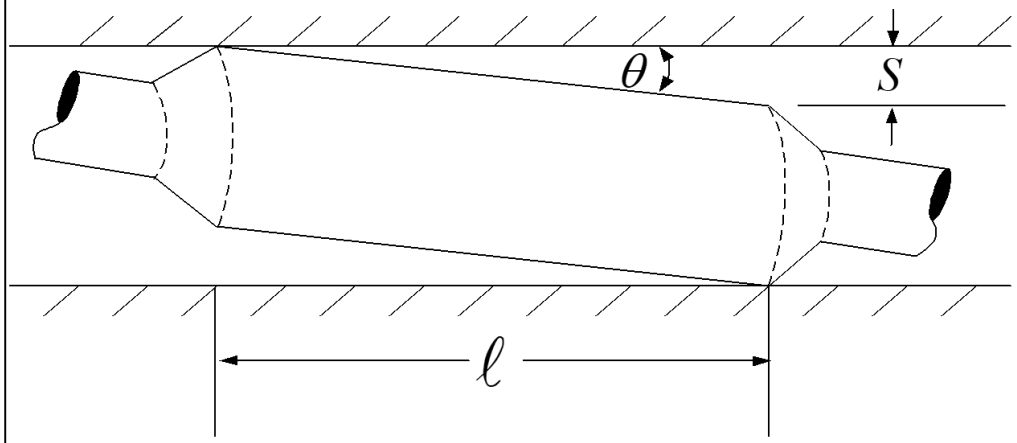
Build in an inclined hole TFO = 0°

Kick Off From Vertical

Max. Possible Build Up Rate

Dropping in an inclined hole TFO=180°

Stabilizer Jamming Angle



S = Diametrical Clearance - Inches
ℓ = Length of Stabilizer Blade - Inches
θ = Stabilizer Jamming Angle - Degrees

$$\left(L = R\theta(rad)\right)$$

$$S = \ell\theta\left(\frac{\pi}{180}\right)$$

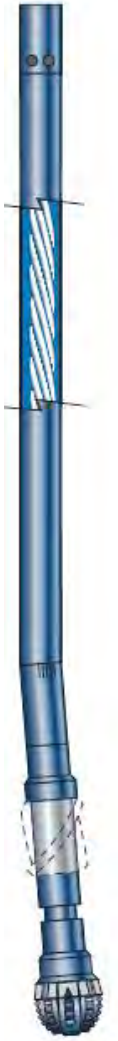
$$\boxed{\theta = \frac{180\,S}{\pi\ell}} \quad \text{Degrees}$$

Frequently Asked Question About Stabilization

1) Will they make sliding difficult?
2) Will they lower my DogLeg Severity (DLS)?
3) Will they cause mechanical sticking to occur?
4) Will they slow me down?

Best Practice Proven Answers

1) No, stabilizers do not make sliding dificult
2) Stabilizers do not reduce ability to achieve target DogLeg Severity (DLS)?
3) No, stabilizers do not cause mechanical sticking if hole cleaning and tripping practices are employed
4) No, stabilizers will not adversely impact ROP if placed and selected correctly



SLICK VS. STABILIZED

Outlaw Directional

6 3/4” 7/8 5.0 STAGE

ABH = 1.83° (2.12°)

SLICK

SURFACE RPM = 40 RPM

ACTIVE GAUGE PDC

MWD STAB = FORGET IT

REDUCED HOLE SIZE

TORTUOUS UNDERGUAGE HOLE

CASING RUNNING HELL!!

Tier 1 Provider

6 ¾” 4/5 7.0 STAGE

ABH = 1.15° (1.5° Max)

¼” UBHS, ¼” SS

SURFACE RPM = 80 RPM

SMOOTH RUNNING PDC

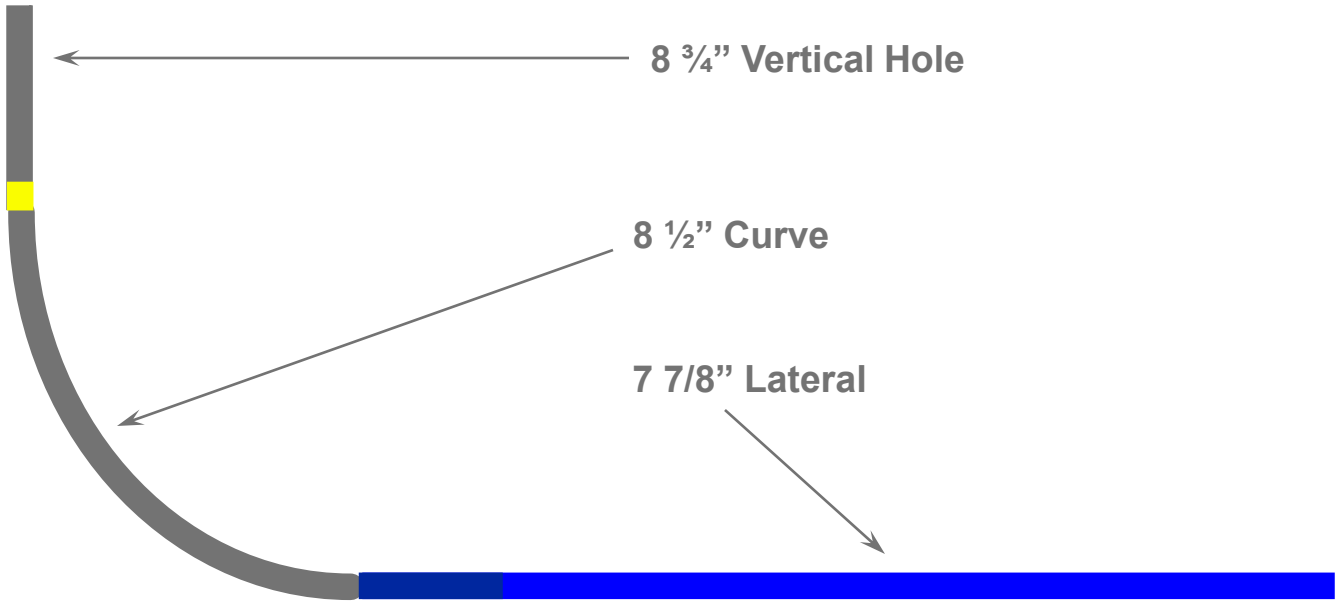
MWD STAB = AS NEEDED

SAME HOLE SIZE

GUN BARREL HOLE

SPOILER ALERT

Remember! If you start slick, you finish slick!



.. Be prepared to Ream down and patiently Ream Up

Downhole Drilling Motors and Directional Well Services

- Provides one of the most powerful drilling motors in the market
  - Conventional and Even wall Power Sections
  - Adjustable Kick-off (AKO) with Reinforced Thread Design and Wear pads
  - Fixed bend housing available
  - Titanium drive-shafts
  - *JA Oilfield developed an 8” Power Section with a 9-1/2” Bearing Section*
    - *High penetration rates*
    - *Longer drilling runs*

4.3/4” - 6.3/4” – 7-7/8” – 8” – 9-1/2” Motor Sizes

Top sub with float valve and/or mud screen

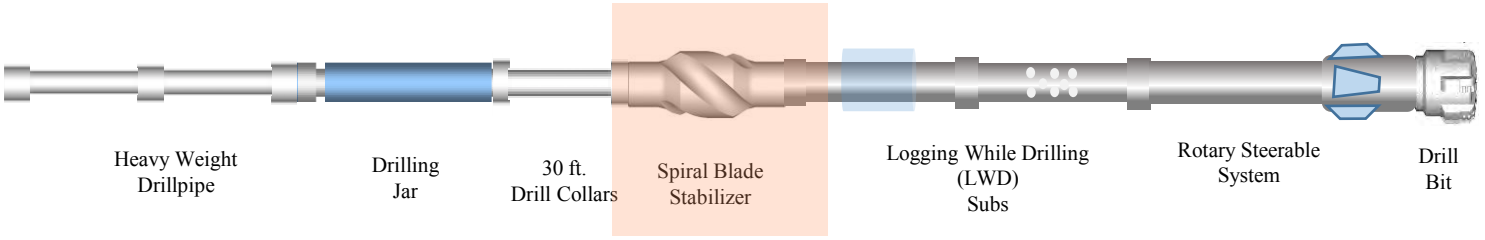
Bearing assembly with diamond bearings or advanced ball bearings

Rugged drive train

Stator/Rotor Configuration for application specific torque and speed requirements

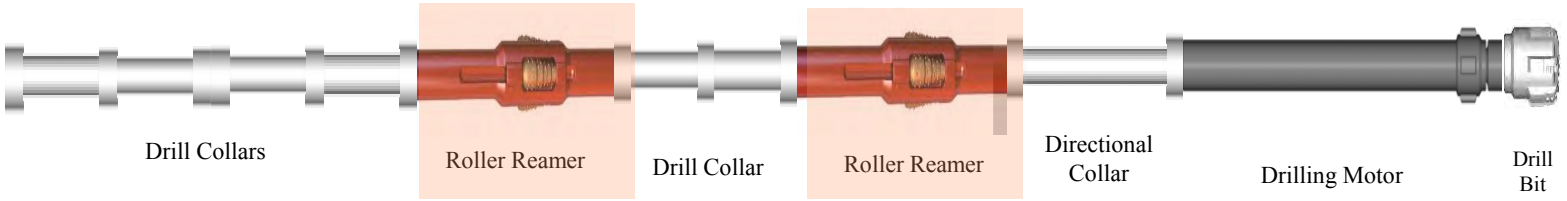
AKO, Straight Housing or Fixed Bend

Typical drilling Bottom Hole Assemblies (BHA) - Rotary Steerable System (RSS)



Rotary Steerable System

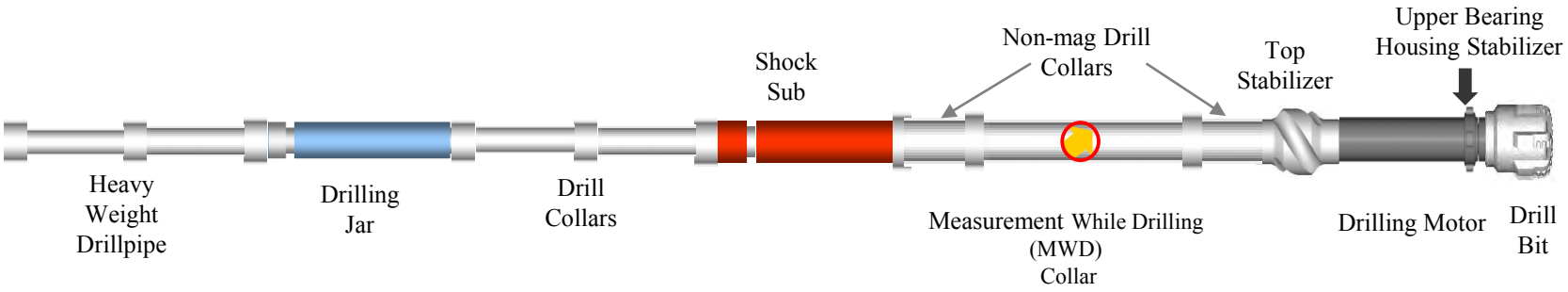
- Kick-off and curve section (Build-up rate up to 7 degs/100)
- Angle hold in tangent section
- Geosteer lateral section



Hole reaming and conditioning BHA assembly

- Drilling motor with Extension(Straight) sleeve (Zero angle) optional
- Directional collar for MWD
- Minimum 3x drill collars for moderate flexure when reaming curves

Typical drilling Bottom Hole Assemblies (BHA) - *Downhole Motor System - Stabilized*



Directional BHA (Motor – Fixed-bend or AKO) System

- *Kick-off and drill curve section (Build rate up to 12 degs/100 ft)*
- *Angle hold tangent section*
- *Geosteer lateral section*

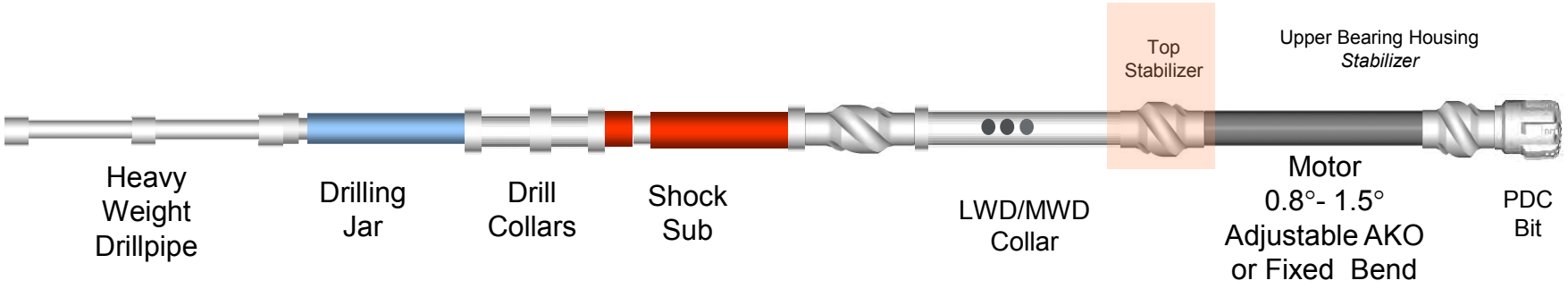
Hole reaming and conditioning BHA assembly

- *Kick-off and drill curve section (Build rate up to 12 degs/100 ft)*
- *Angle hold tangent section*
- *Geosteer lateral section*

Typical drilling Bottom Hole Assemblies (BHA) - *Downhole Motor Systems – Slick vs. Stabilized*

Drilling Motor – Slick Configuration – Pendulum – Angle-build Tendency

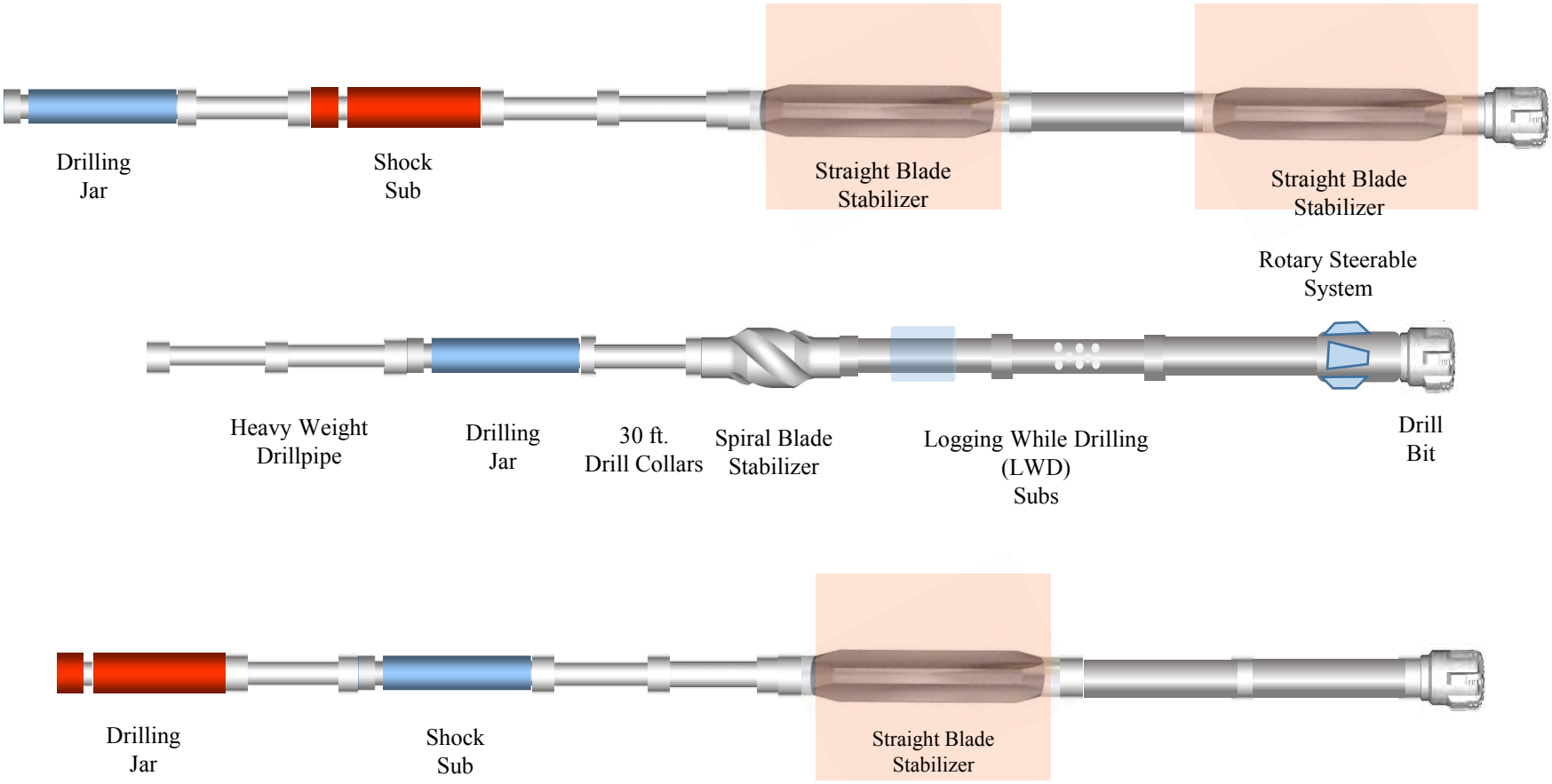
- *DC – Drill Collar*
- *RMR – Roller Reamer or Full gauge String Stabilizers*

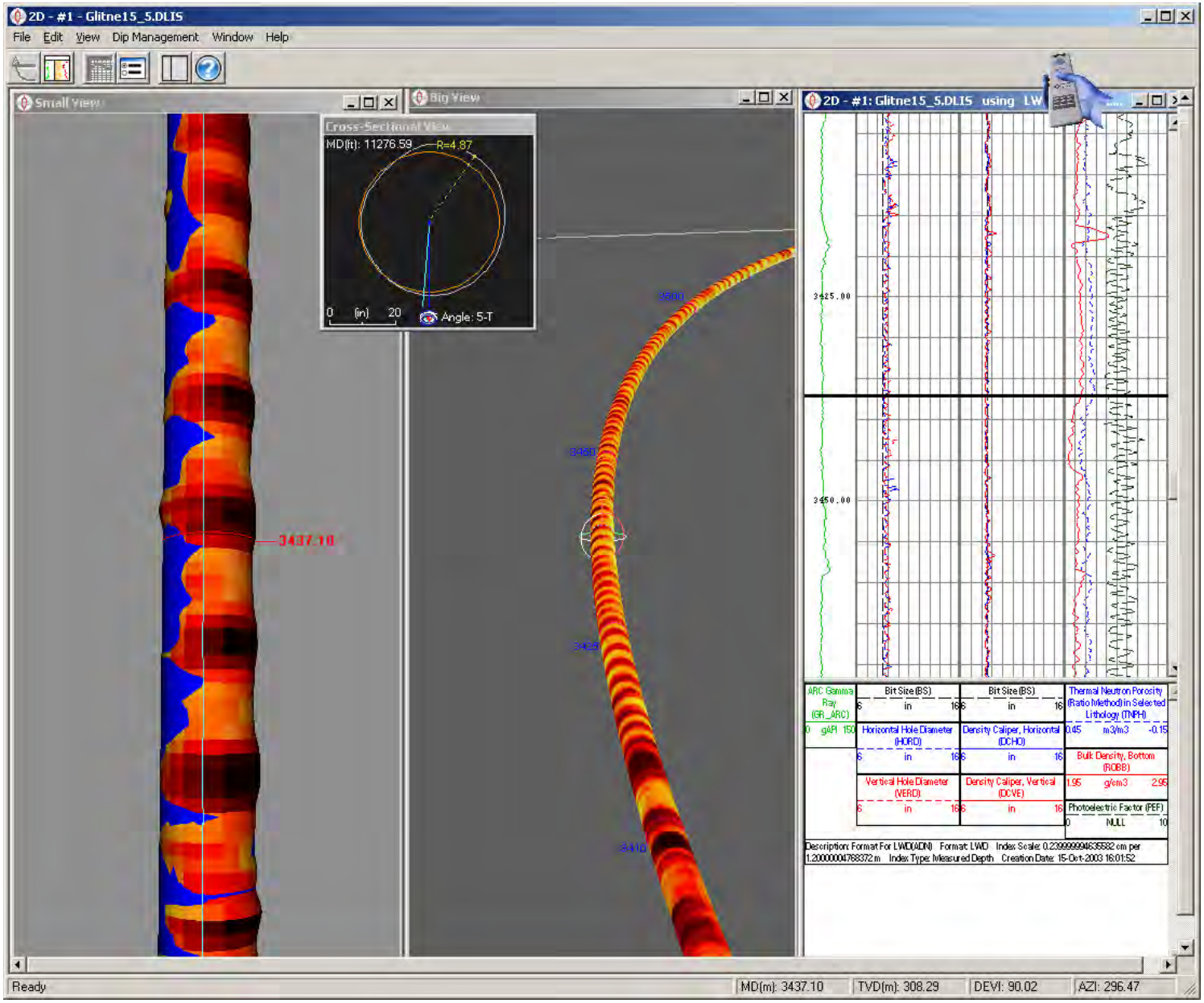


Drilling Motor – Stabilized Configuration – Angle-hold tendency in rotary mode

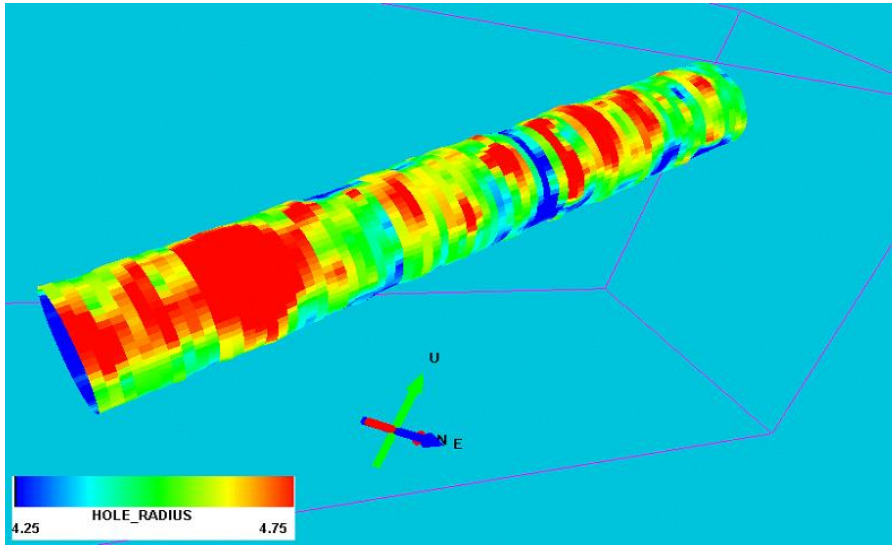
- *Fixed bend or AKO Motor with undergauge UBH Stab(1/4") and Top Stab DC(1/8") – Drill Collar*
- *Non-mag LWD/MWD Collar and Stabilizer*

Typical drilling Bottom Hole Assemblies (BHA)
- *Surface Hole and Hard Rock Drilling*



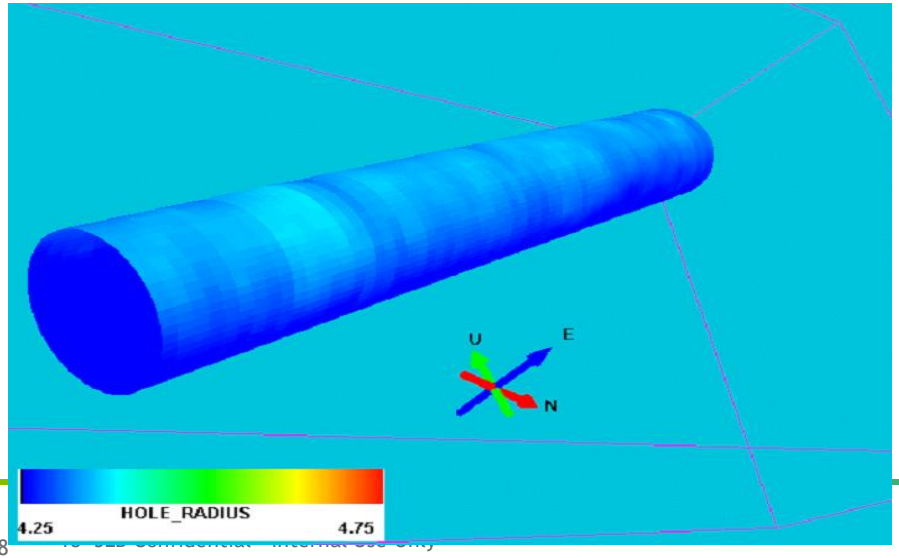

2D - #1 - Glitne15_5.DLIS
File Edit View Dip Management Window Help
Small View
Big View
Cross-Sectional View
MD(ft): 11276.59
R=4.87
0 (in) 20
Angle: 5-T
3437.10
2D - #1: Glitne15_5.DLIS using LW
3425.00
3450.00
ARC Gamma Ray (GR_ARC)
Bit Size (BS)
Horizontal Hole Diameter (HORD)
Density Caliper, Horizontal (DCHO)
Thermal Neutron Porosity (Ratio Method) in Selected Lithology (TNPH)
Vertical Hole Diameter (VERD)
Density Caliper, Vertical (DCVE)
Bulk Density, Bottom (ROBB)
Photoelectric Factor (PEF)
Ready
MD(m): 3437.10
TVD(m): 308.29
DEVI: 90.02
AZI: 296.47

Hole Quality PDM vs PowerDrive



Motor

Micro doglegs > 14° /100’



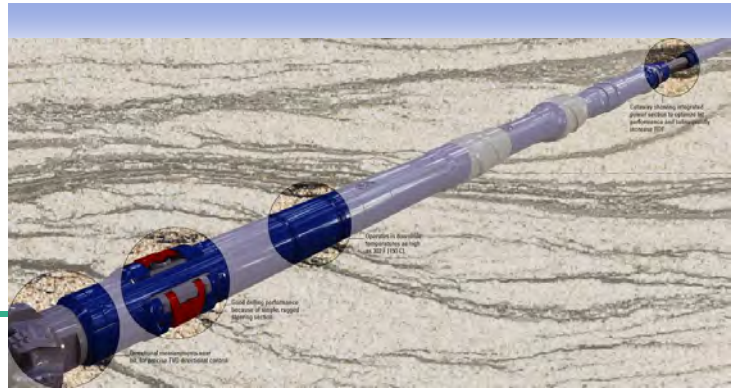
PowerDrive

Micro doglegs < 2°/100 ’

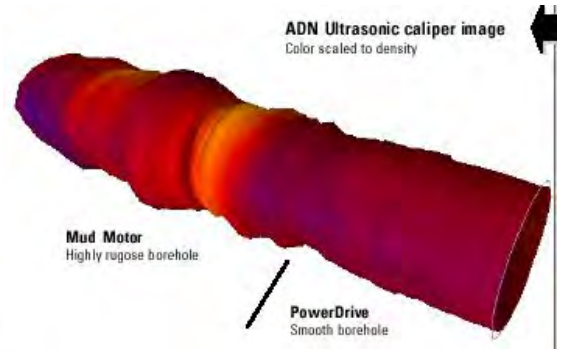
Tier 1 - US Land

- Drill with Fully Stabilized BHA

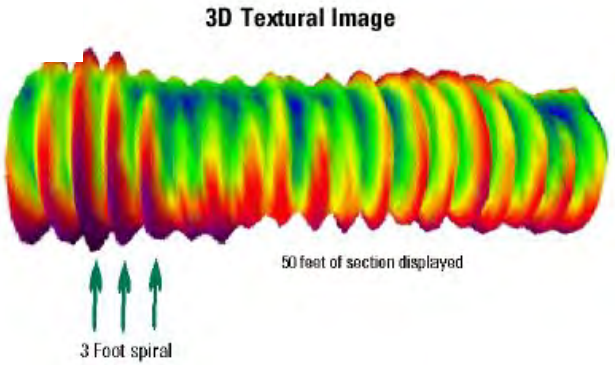
Goal: Getting Completions to bottom 1st time



Sonic Images of Hole Quality



3D Textural image of ultrasonic data



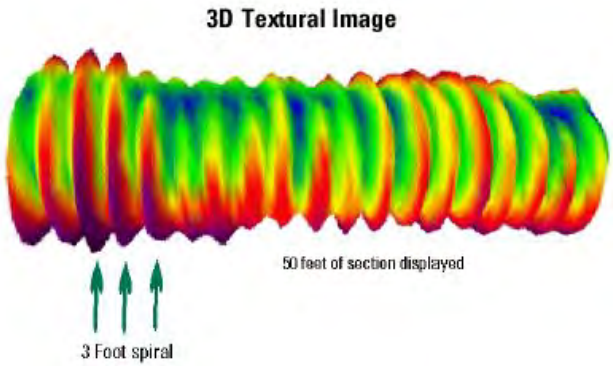
Smooth profile

Good gauge

No spiralling

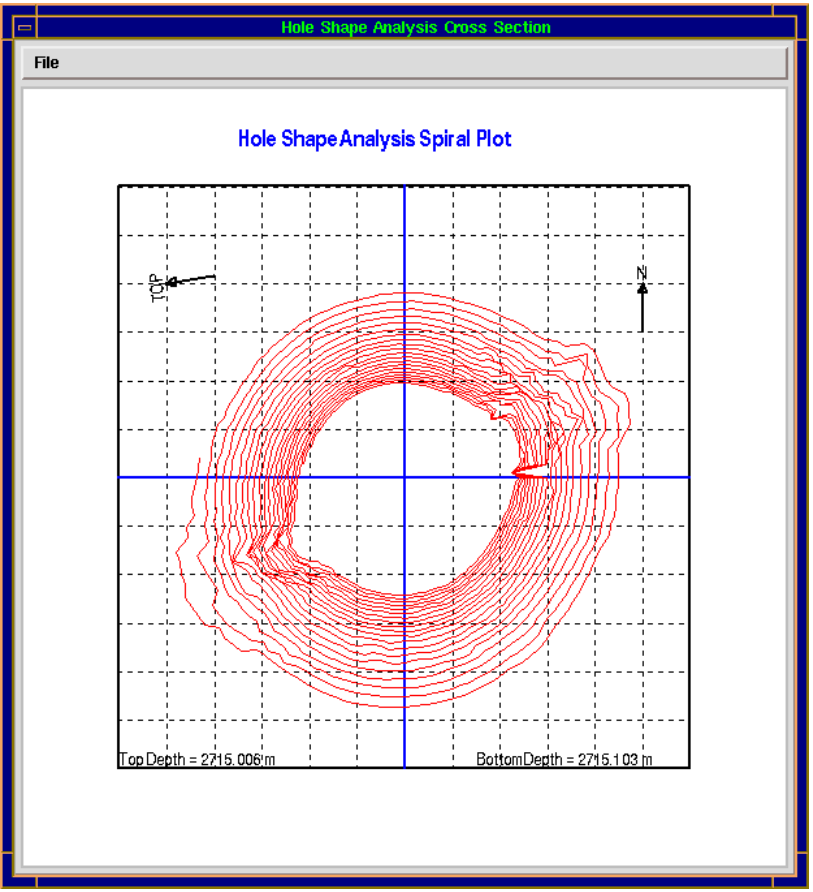
Reduced cuttings beds

Sonic Images of Hole Quality

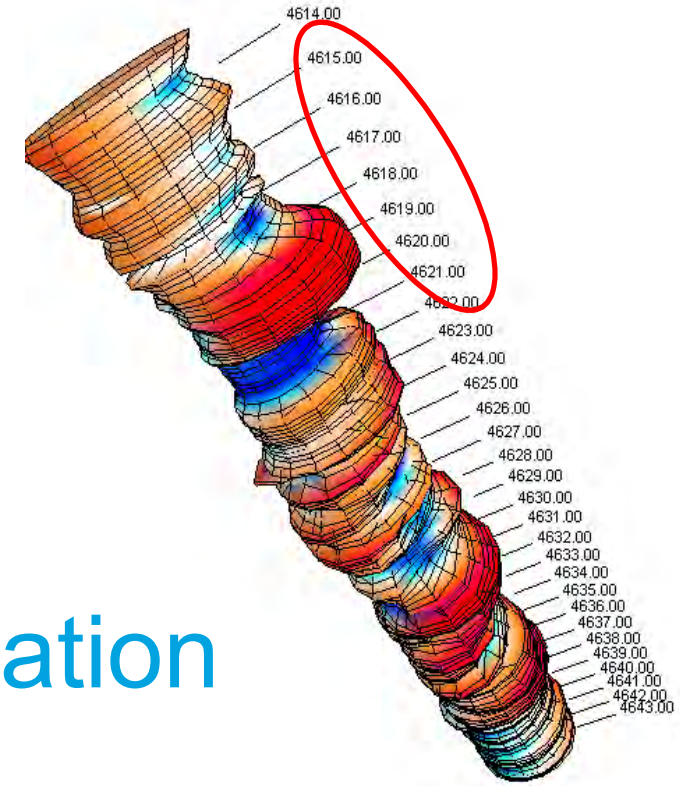


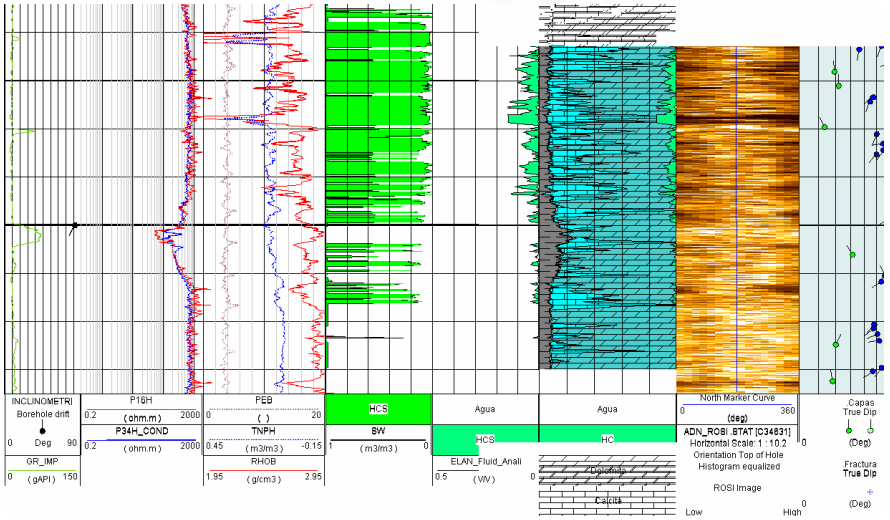
Long Gauge PDC/Diamond Impreg Bit

Caliper - 3D Visualization



Caliper - 3D Visualization





Product Line & Services

- Drilling Performance Equipment and Tools
  - Downhole Drilling Motors
  - Shock Subs
  - Drilling Jars
  - Stabilizers
- Hole Quality Enhancement Tools
  - Near Bit Reamers (Bit Sub)
  - Hole Openers
  - Roller Reamers
- Bottom Hole Assembly/Work String Components
  - Steel Drill Collars
  - Non-Mag Stainless Steel Drill Collars
  - Heavy Weight Drill Dipe
  - Tri-collars
- Machine Shop/Services
  - Tool Design and Manufacturing
  - Drill String Component Repairs
  - NDT Inspection (DS-1 Standards)

Drilling Performance

- Drilling Jar & Energizer
  - Hy-Powr™ Series
    - Double-Acting Hydraulic Only
  - Proven performance and reliability to demanding US drilling requirements
- Performance Features
  - Unique metering process and large capacity reservoir compensates for the decrease in oil viscosity as the jar is fired repeatedly, ensuring consistent impact
  - Jarring direction, duration and impact intensity controlled from the rig floor
  - Full bore design minimizes pressure losses and provides wireline tool bore access
  - Jar may be run in compression or tension, providing optimized placement in the string
- Application Note
  - Drilling conditions where the risk of differential sticking, hole sloughing or other potential stuck-in-hole problems exists
  - When downhole tools, directional and MWD / LWD equipment are utilized in the BHA. Extended long reach directional and horizontal applications may require multiple jars for maximum effectiveness

Drilling Performance

- Shock Sub
  - Tympanum™ Series
    - Incorporates design enhancements from peer offerings
    - Industry leading shock response performance over extended dynamic range
    - Offers heavy load and light load spring configurations
  - Performance Features
    - Progressive Shock Damping and shock load dissipation system
    - Reduces bit bounce; extends bit life
    - Absorbs destructive axial shocks from causing MWD/LWD failures
    - Improves penetration rates
    - Optimal short sub length; neutral effect on BHA directional attitude

Hole Quality Enhancement

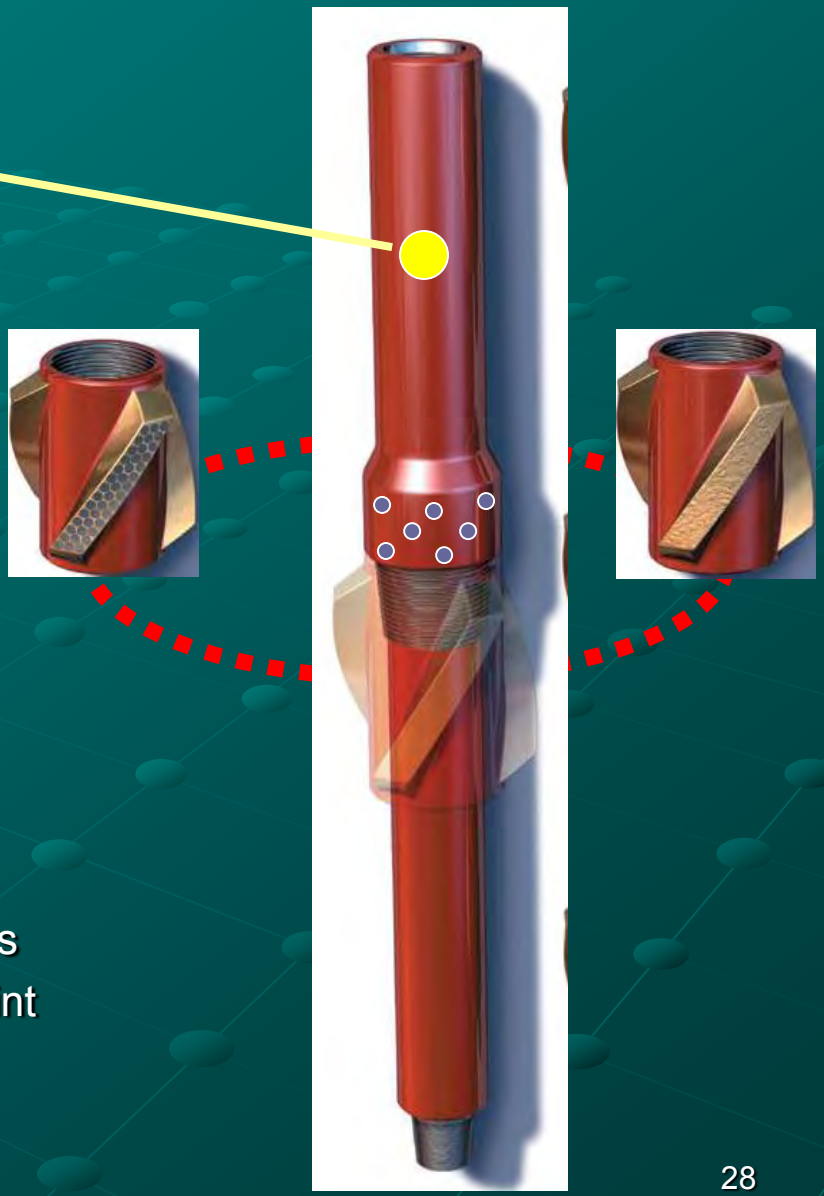
JA OILFIELD MANUFACTURING, INC.

Customer's Most Popular

- Bit Sub
  - Designed to run between the bit and the mud motor enabling you to ream directly behind the bit on any directional job
  - No moving parts to fail or lose in the hole
  - Reaming at the bit offers gauge hole and reduces torque at bit
  - Improves motor orientation with reduction of torque
  - Short-body design – bias neutral and will not affect ability of directional motor to build or drop
  - *Also doubles as a bit guage indicator when torque increase detected on surface*
- Application Note
  - Run behind the bit to ream while drilling
  - 3-rows of tungsten-carbide inserts/synthetic diamond for abrasive formations or smooth PTA hardfacing for hard formations
  - Can be run in Packed-Hole Assembly as a near-bit reamer

Rig Replaceable Sleeve Stab

- RapiDSwap™ Features
  - One piece “armored” mandrel manufactured from high strength heat treated alloy steel
  - By design feature ample tong space for recutting connections
  - To offer greater versatility Sleeve and Mandrel designs made to be interchangeable with similar brands of rig replaceable stabilizers
  - Stabilizer sleeve blades can be dressed with:
    - Smooth PTA - ***recommended***
    - Tungsten Carbide Inserts
- Application Note
  - Versatile and economic in remote locations
  - Complements Directional Motor Three Point Contact



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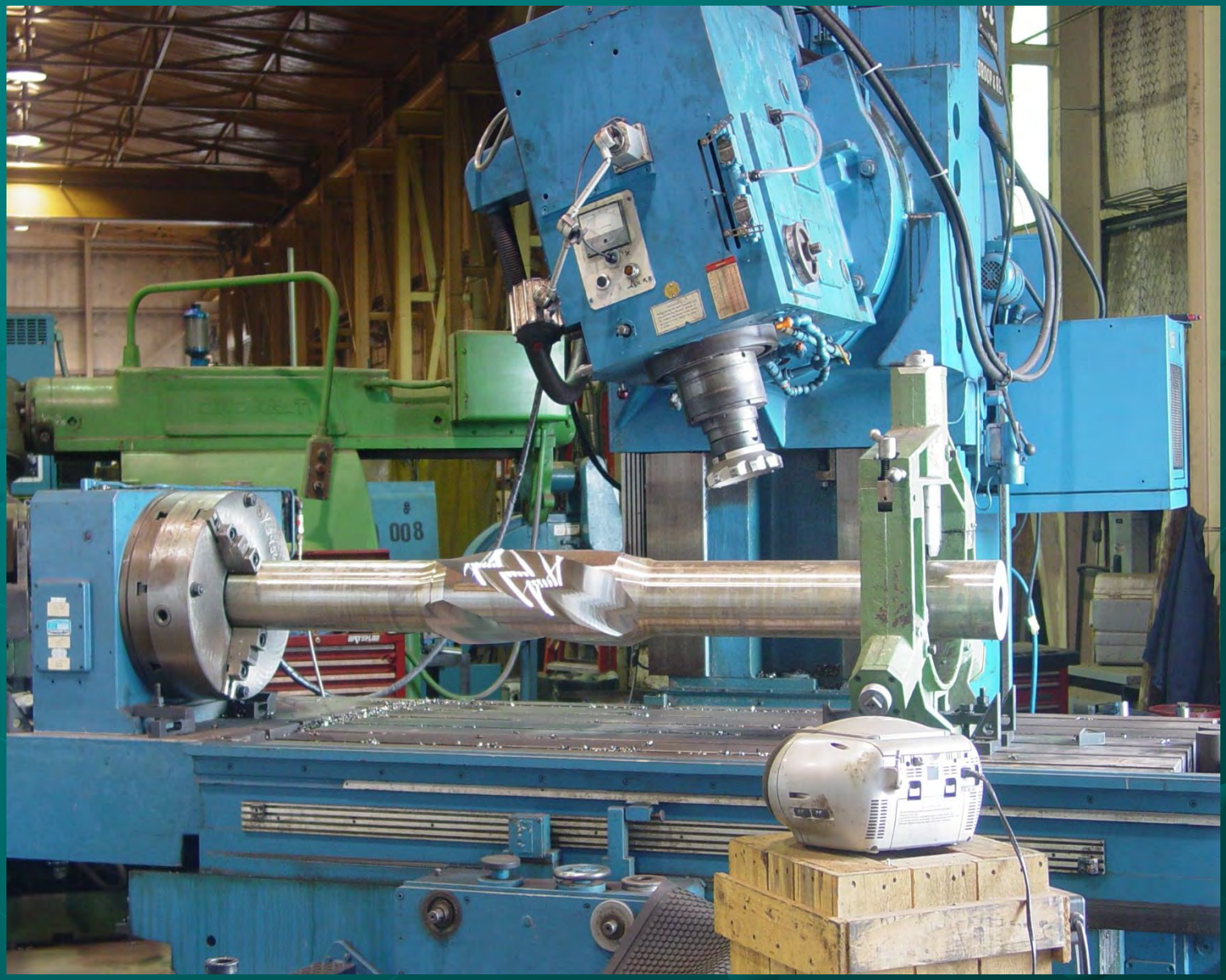
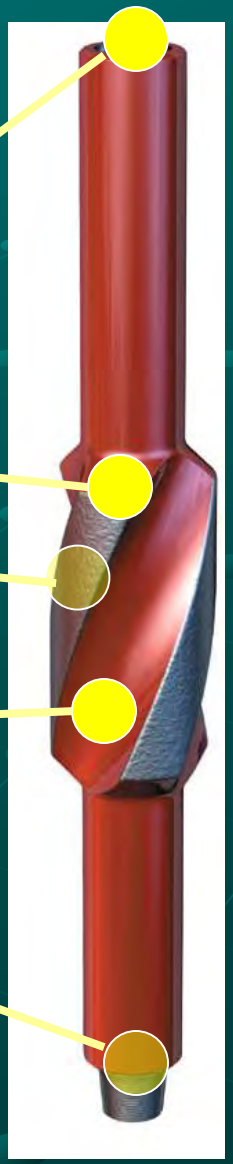


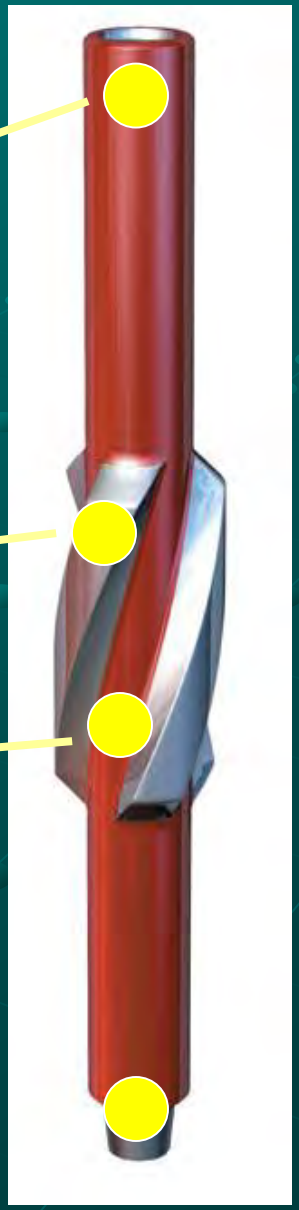
Integral Blade Stabilizer

- Stabilizer Features
  - Chassis made from one-piece 4145H high strength alloy steel OR Non-Mag Stainless Steel
  - Near bit or String Stabilizer design
  - Offer ample tong space for recutting connections
  - Three or Four blades CNC-machined either full-wrap or half wrap
  - Choice of hard facing include:
    1. **Plasma Transfer Arc (PTA)**
    2. **Tungsten Carbide Inserts or Compacts**
    3. **Lasercarb or Cladding**
  - Optimized fluid passages for cuttings removal
  - *Rotary Steerable Design Option offered with relaxed spiral design and extended taper*
- Application Note
  - Improve directional BHA dynamics
  - Packed hole arrangement – NSTB-STRB-STRB



Welded Blade Stabilizer

- Stabilizer Features
  - Chassis made from one-piece 4145H high strength alloy steel OR Non-mag Stainless Steel
  - Welded precision-formed blades
  - Three or Four blades CNC-machined either full-wrap or half wrap
  - Hardfacing Options
    - **Plasma Transfer Arc (PTA)**
    - **Tungsten Carbide Inserts or Compacts**
    - **Lasercarb or Cladding**
  - Optimized fluid passages for cuttings removal
  - Available from 4-1/8 in. to 24 in. sizes
- Application Note
  - Soft to Medium-hard formation
  - Mostly top-hole sections

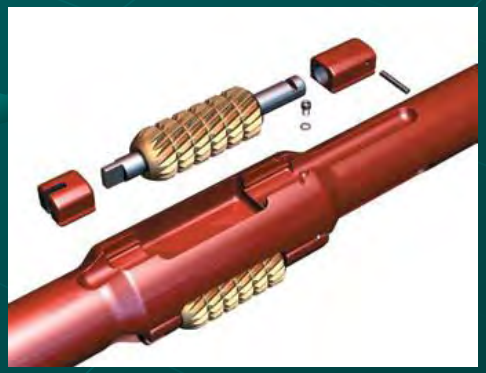


Reamers

- Reamer Features:
  - Offer the three-point 3RXC and 6RXC mud-lubricated roller reamers
  - Easy rig floor replacement of cutters and parts
  - Formation-matched reamer models
    - Type “VHM” – soft formations – soft lime and shale
    - Type “QHM” – medium to hard formations - chert
    - Type “KHM” – aka Knobby are for hard formations
- Application Note
  - Three point 3RXC configurable for near-bit placement
  - Six point 6RXC offer greater stabilization and reaming
  - Run between drill collars to augment stiffness
  - Most effective in reducing torque by converting sliding contact friction into much less rolling contact friction.

VHM QHM KHM

- Changing Cutters
  - Drive out spring pin and cutter pin
  - Replace cutters
  - Safety glasses, Hammer and Drive Bar only tools needed at rig site

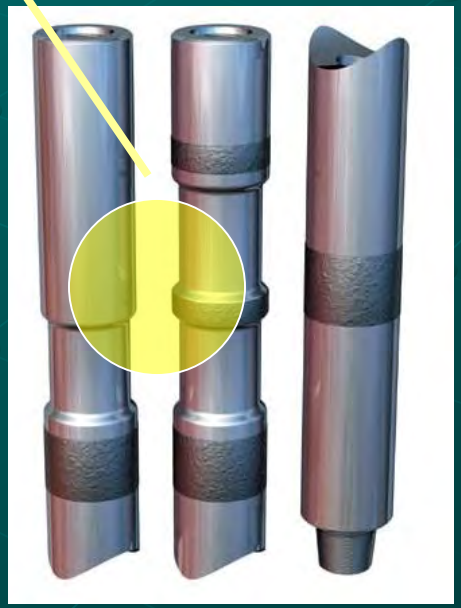


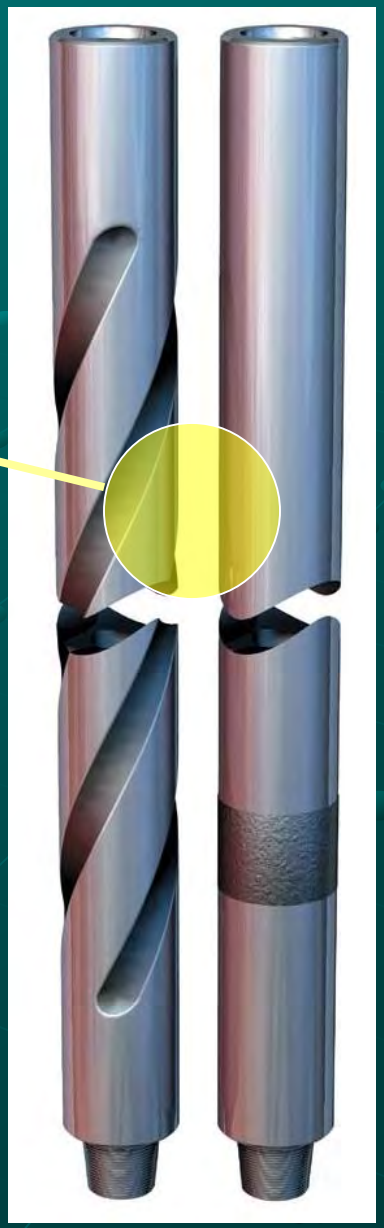
Bottom Hole Assembly/ Workstrings

- Steel Drill Collars
- Non-mag Stainless Steel Drill Collars
- Heavy Weight Drill Collars
- Tri-Collars and Square Drill Collars

Steel Drill Collars

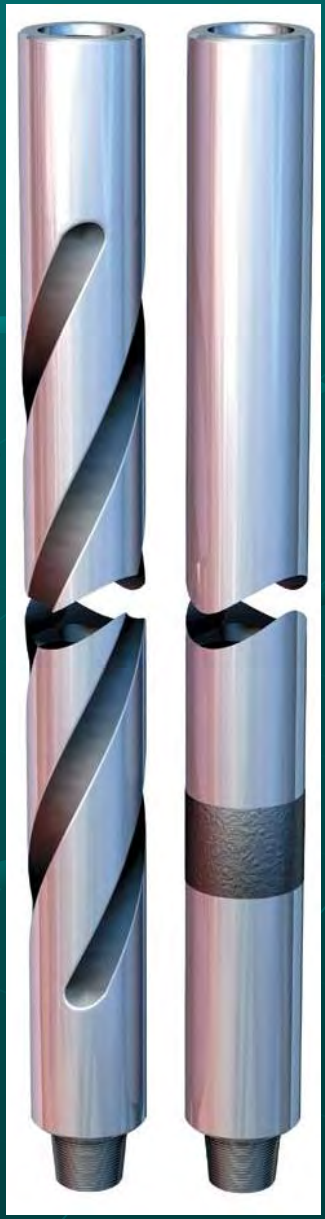
- Steel Drill Collars
  - Manufactured from 4145H Modified, Quenched and Tempered Steel
  - Bores are held to close tolerances by Computer Numerical Controlled (CNC) Trepanning process and drifted to API specifications
  - Connections are kemplated to prevent galling
  - Thread roots are cold rolled to provide longer fatigue life
  - Offered in both slick and spiraled O.D.
- Special Drill Collar Features
  - Incorporate API relief groove on pin: Bore-back on Box
  - Machine Slip and Elevator Recesses to reduce drill collar handling time
  - Carefully applied hard-banding material flush to 1/32" above collar O.D.
- Application Note
  - In formations where differential sticking risks are high, spiral drill collars reduce wall contact





Non-Mag Stainless Steel Drill Collars

- Non-mag Stainless Steel Features
  - Made from specially configured Non-mag stainless steel alloys developed for oil-field application from:
    - Scholler-Bleckmann :– P Series 550 - 580
    - Jorgensen Forge :– NMS-100 - 140
    - Carpenter Materials :- 1515HS
    - Thyssen Krupp :- AMAGNIT 501
  - Magnetic permeability no greater than 1.009
  - Shot-peened ID to prevent stress corrosion cracking in H_2S and high Chloride well-bores
- Application Note
  - See JA Oilfield Manufacturing Inc. catalog for guide to Non-mag selection and placement



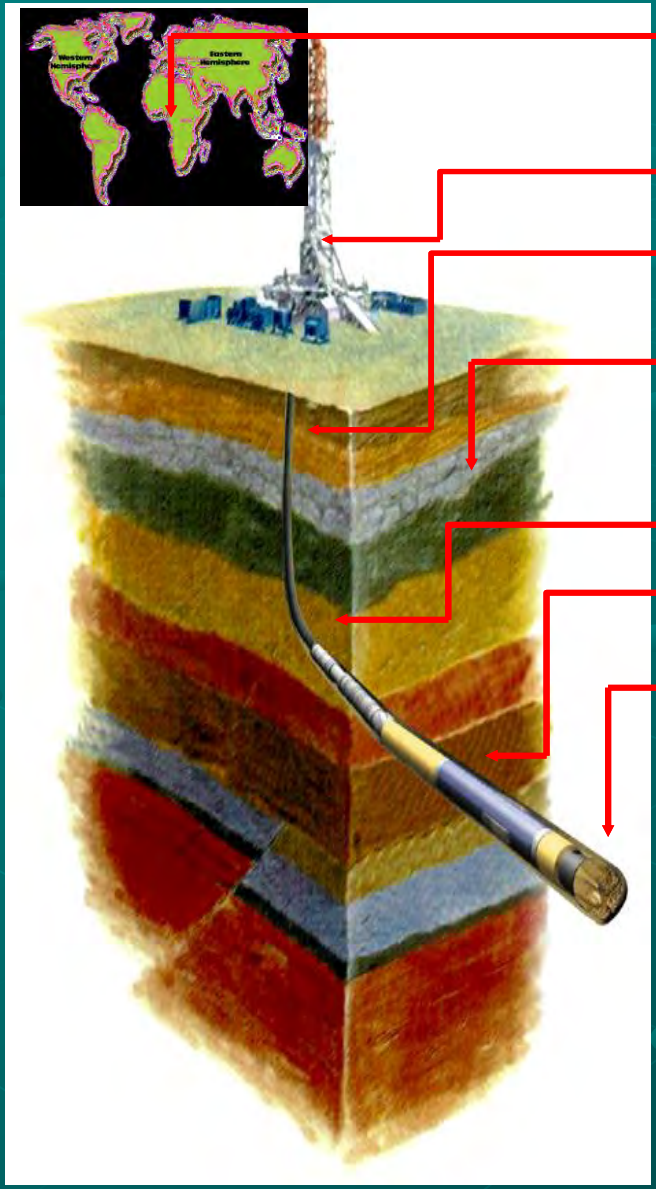
Heavy Weight Drill Pipe

- Heavy Weight Drill Pipe Features
  - Intermediate weight drill-string member with drill-pipe dimensions for handling
  - Long tool joints provided with hard-banding provide extended space to recut the connections
  - The center upset protects the tube from OD wear by providing stand-off for tube from the hole wall, while reducing the risk of differential sticking
  - The API Bore Back Box feature is standard for the box connection
  - Cold rolled thread roots on all Hevi-Wate drill pipe connections to increase connection's ability to resist fatigue cracking
  - Hevi-Wate drill pipe can be picked up with the drill pipe elevators, for fast efficient handling on the rig floor

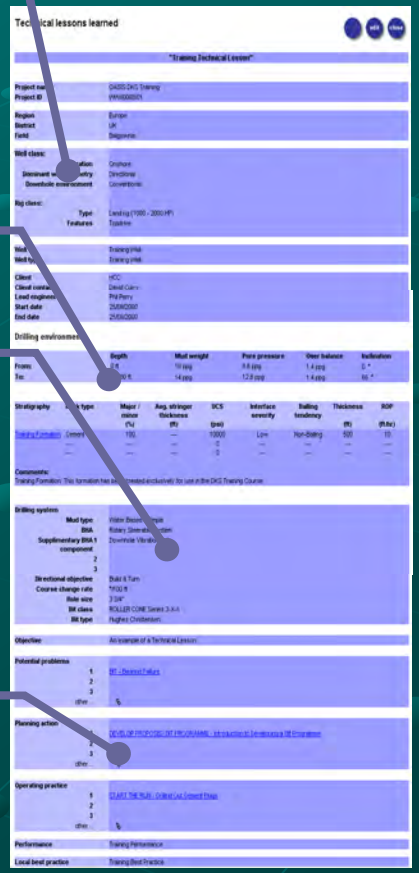
How Are We Organized?

- Market and Customer Knowledge
- Business and Machine Shop
- Sales and Manufacturing Operations

Market Knowledge



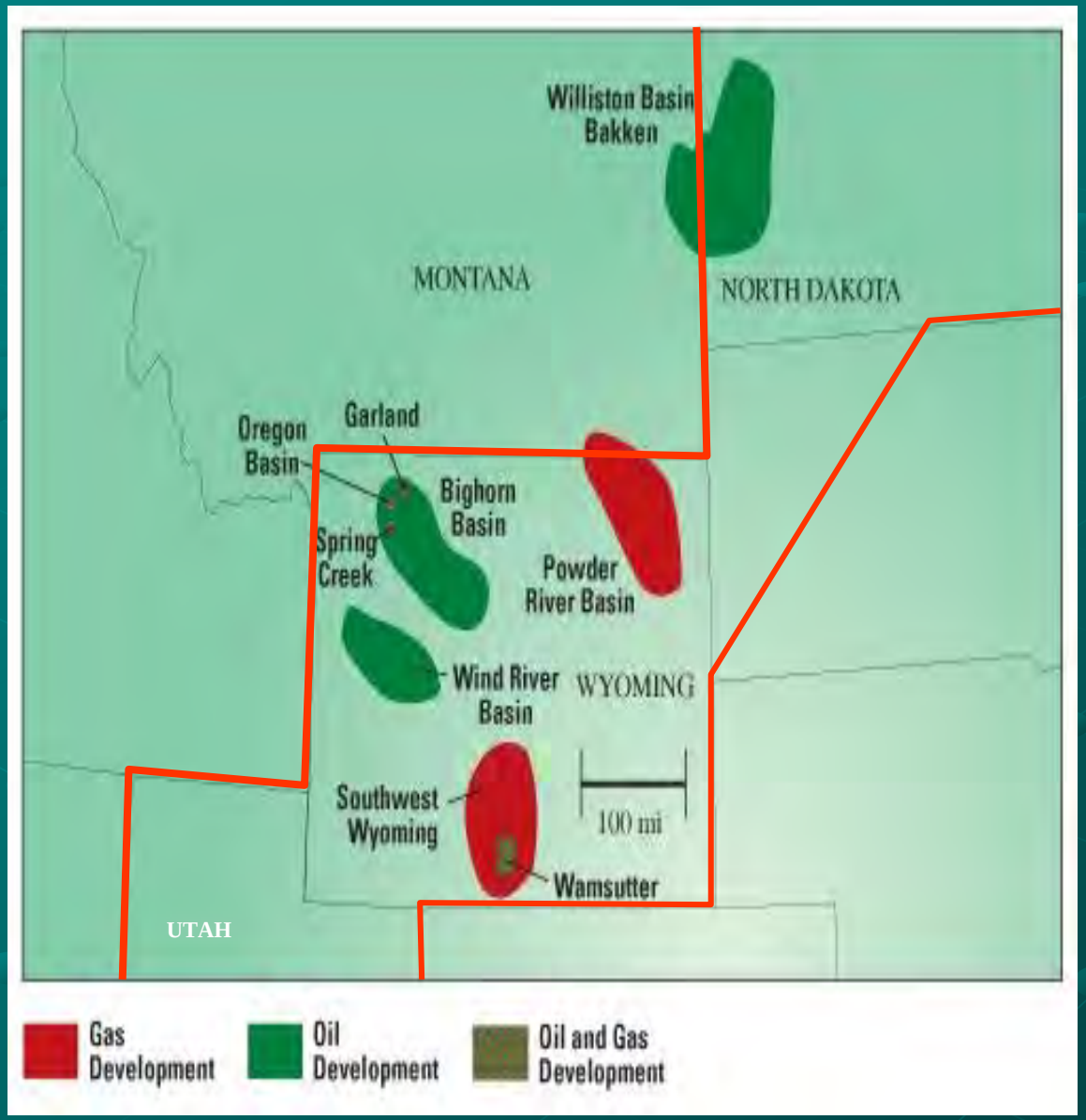
- Location - Region/Country
- Client Details
- Rig Class
- Well Class
- Stratigraphy
- Drilling Environment
  - Mud System
  - BHA & Components
  - Directional Objectives
  - Bit Selection
- Drilling Guidelines
  - Problems
  - Planning
  - Operating Practices
- Performance
- Local Best Practice



Service Value – Performance Proposition

- Reduce Cost/Foot
  - Improve Penetration Rate
  - Increase drilling efficiency and overall progress rate
  - Extend tool service life – min. tool count per hole section
  - Reduce trips
- Risk Management
  - Minimize drilling related problems through:
    - specialized tool design
    - superior materials used in tool manufacture
    - detailed planning and risk analysis
    - share best practice and proven local tool application scenarios

Utah/Wyoming/North Dakota



Region A

- Apache
- Cimarex
- Citation
- ConocoPhillips
- EOG
- Gasco
- Oxy
- Dominion
- Marathon Oil
- Ultra
- Ovintiv
- BP
- Devon
- Unit Petroleum

Region A – Market Attributes

- Geology/Formation
  - Wyoming
    - Jonaa Field, Mesa, Wamsutter & Baggs

- Drilling Challenges
  - Hole Drift/BHA Walk
  - Premature Bit failure from bit bounce
  - Stick/Slip produces overtorqued BHA connections
  - Poor ROP

- BHA Preferences
  - Wyoming – Most companies in Jonaa Field & Mesa Areas constantly experimenting with Drilling Procedures with varying BHA configurations.
    - Several companies have started using Tri-Collars and assessing effectiveness
    - In Wamsutter, Baggs and Riverton areas occasional use of stabilizers and reamers.
  - Utah – companies drill with directional and vertical BHA and some slick. Some stabilizers, reamers and shock-sub application
  - North Dakota – Slick BHA preferred because of salt in the Bakken Shale. Tri-collars offer stabilization and stiffness with less connections. Stabilizers and Flex-collars used in laterals.

Colorado/Kansas/Oklahoma/Arkansas

Region B

- Marathon Oil
- Chevron
- Apache
- Chesapeake
- Cimarex
- Samson
- Devon
- ConocoPhillips
- OXY
- Unit Petroleum
- Williams
- Oxy
- ExxonMobil
- Forest Resources

Region B – Market Attributes

- Geology/Formation

Western Oklahoma	South Central	Eastern Oklahoma/Arkansas	Colorado Rockies
Dolomite	Upper Atoka	Woodford Shale	
Douglas Fork	Wapanucka	Jackfork	
Hog Shooter	Jefferson		
Red Fork	Woodford		
Atoka	Sylvan		
Granite wash	Viola		

- Drilling Challenges
  - Hard rock drilling – ROP difficulties
  - Abrasive Formations
  - Vibration – Axial (Bit Bounce) – Lateral (Shoulder Wear)
  - Maintaining Vertical Hole Angle
  - Stuckpipe

- BHA Preferences

Western Oklahoma
- IBS – String Stabilizer
- Roller Reamers
- Drilling Jar
- Bit Sub

Eastern Oklahoma/Arkansas
- IBS – String Stabilizers – x2 (note premium pricing on stabilizers)
- Roller Reamers – when drilling fluid changed to mud with air drilling
- Drilling Jar
- **Turbo Tool**/DOG Sub/Torque Sub?

Colorado Rockies
- IBS – String Stabilizers – x2 (note premium pricing on stabilizers)
- Roller Reamers – when drilling fluid changed to mud with air drilling

North & W. Central Texas, South Central Texas

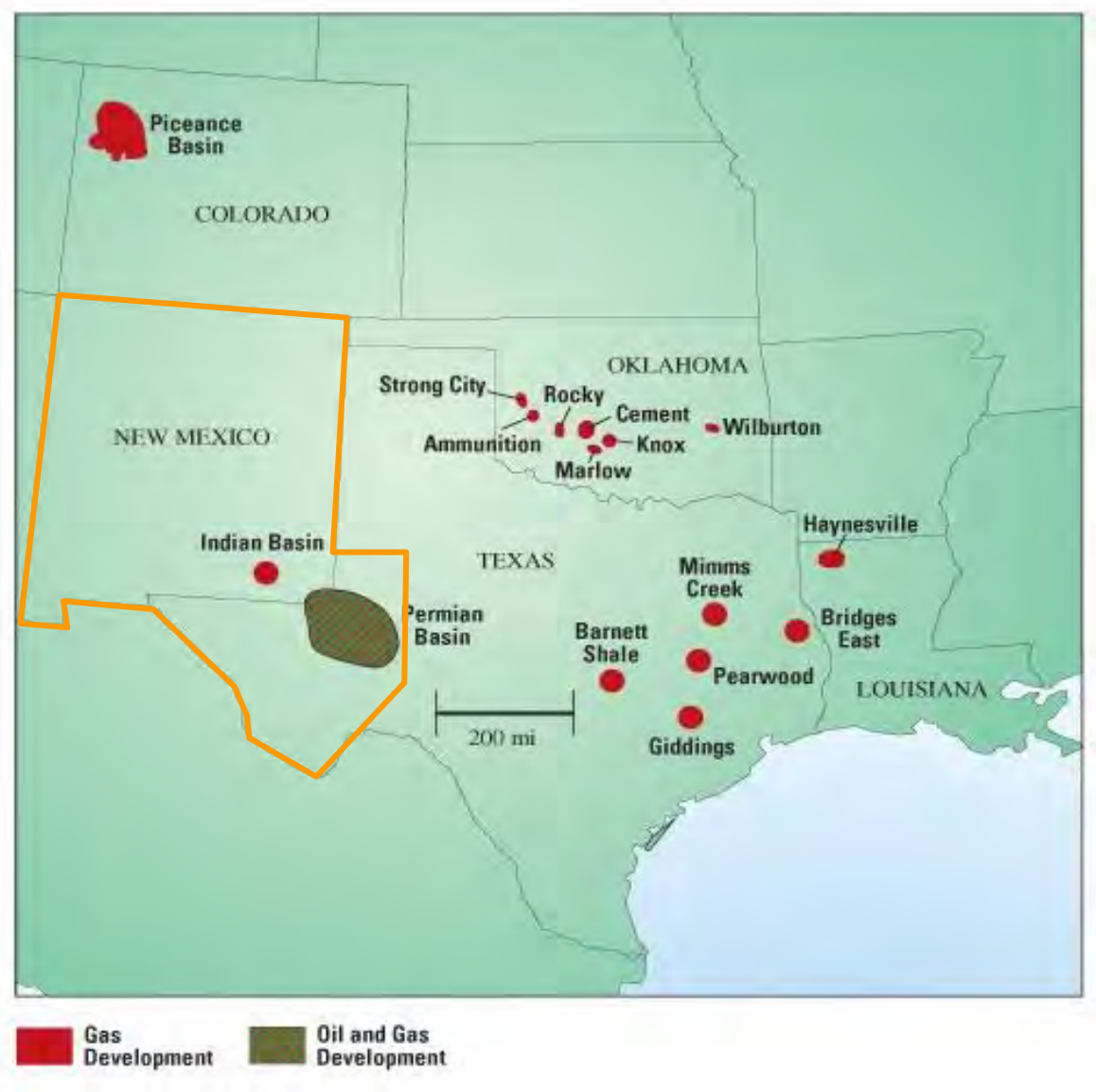
Region C

- ConocoPhillips
- Marathon Oil
- Devon
- Republic
- Ovintiv
- EOG
- Quicksilver
- XTO
- Oxy
- Williams
- Exxon
- Chesapeake

Region C – Market Attributes

- Geology/Formation
  - Upper Barnett/Atoka/Strawn/Lower Barnett
  - Viola Eastward/ Ellenburger Westward
- Drilling Challenges
  - Lost Circulation
  - Tight Formations
  - Most Issues are bit problems
- BHA Preferences
  - Directional/Horizontal
  - **Turbo Tool**
  - Stabilizers
  - Nortrak Style Stabilizers
  - Shock Sub
  - Reamers
  - Non Mags

New Mexico/Southwest Texas



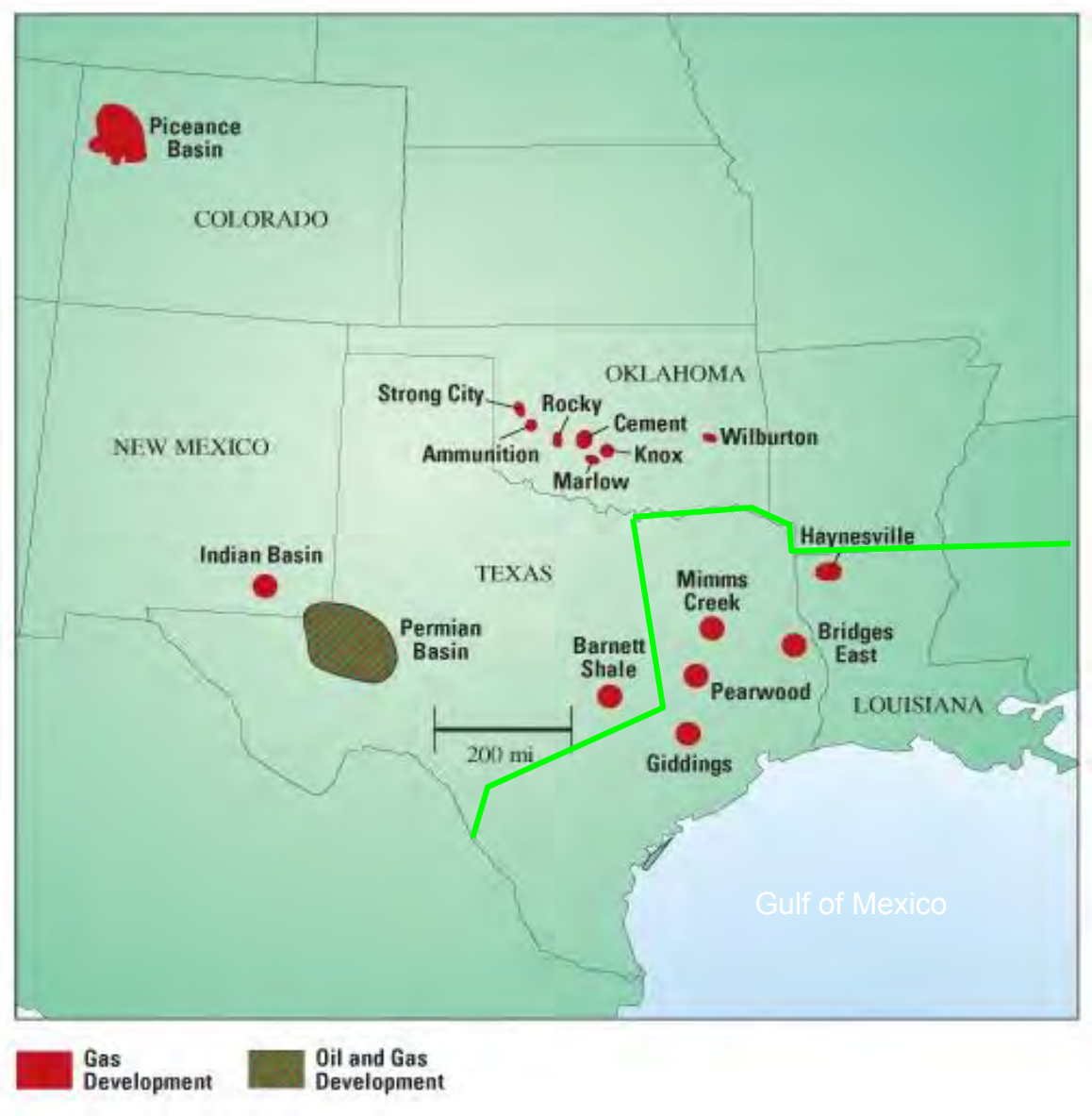
Region D

- Devon
- Marathon Oil
- EOG
- XTO
- Chesapeake
- Ovintiv
- Quicksilver
- Range
- Williams
- ConocoPhillips

Region D – Market Attributes

- Geology/Formation
  - San Juan - Mesa Verde
    - Point Lookout/Menefee/Cliff House formation & Dakota
  - Permian Basin
- Drilling Challenges
  - Low pressure gradient / air drilling techniques
  - Limestone & Sandstone formations
  - Hard Abrasive formations even for PDC
- BHA Preferences
  - Fixed bend short Bit-to-Bend Motor
  - Deep Kick-off requires high build rate to land well – 10 – 12 degs/100 ft
  - RSS for geosteering
  - Drillable Subs

East Texas/N. Louisiana/Gulf Coast



Region E

- ConocoPhillips
- Paloma Resources LLC
- Chevron
- Marathon Oil
- Ovintiv
- XTO
- EOG
- Devon
- Samson Lonestar

Region E – Market Attributes

- Geology/Formation
  - Travis Peak/Cotton Valley Shale
  - Highly Abrasive
- Drilling Challenges
  - Excessive Wear – Stabilizer Blades
- BHA Preferences
  - Stiff Assemblies for Top Hole/Directional for Intermediate Hole
  - Welded Blade Stabilizers
  - Stabilizers – IBS with Premium Hard Facing
  - Turbo Tool

References

- Wellbore Integrity Solutions Drilco Handbook
- Baker Hughes Inc. Motor Handbook
- Drilling Engineering Manual – Baker Hughes
- JA Oilfield Stabilizer Engineering Drawings
- JA Oilfield Reamer Engineering Drawings
- Sonic Image Logs
- Azimuthal Caliper Logs
- ShaleXP