

Directional Drilling Techniques

= Part-3 =

California oil rush

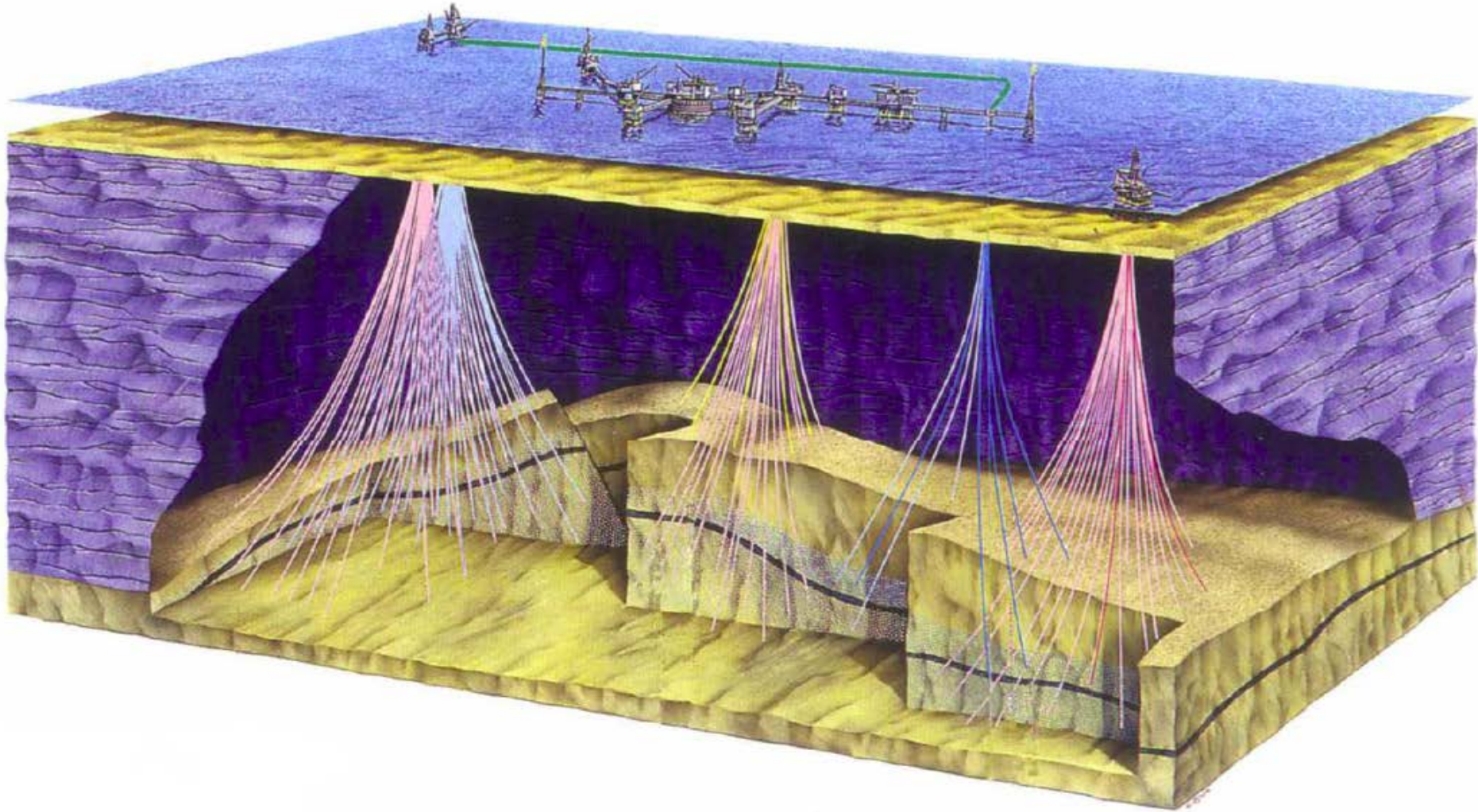


**Long Beach, Kalifornien,
Küstenbohrungen um 1930**



**Erster Openhole Single Shot Survey,
Long Beach, Kalifornien**

Today's major application

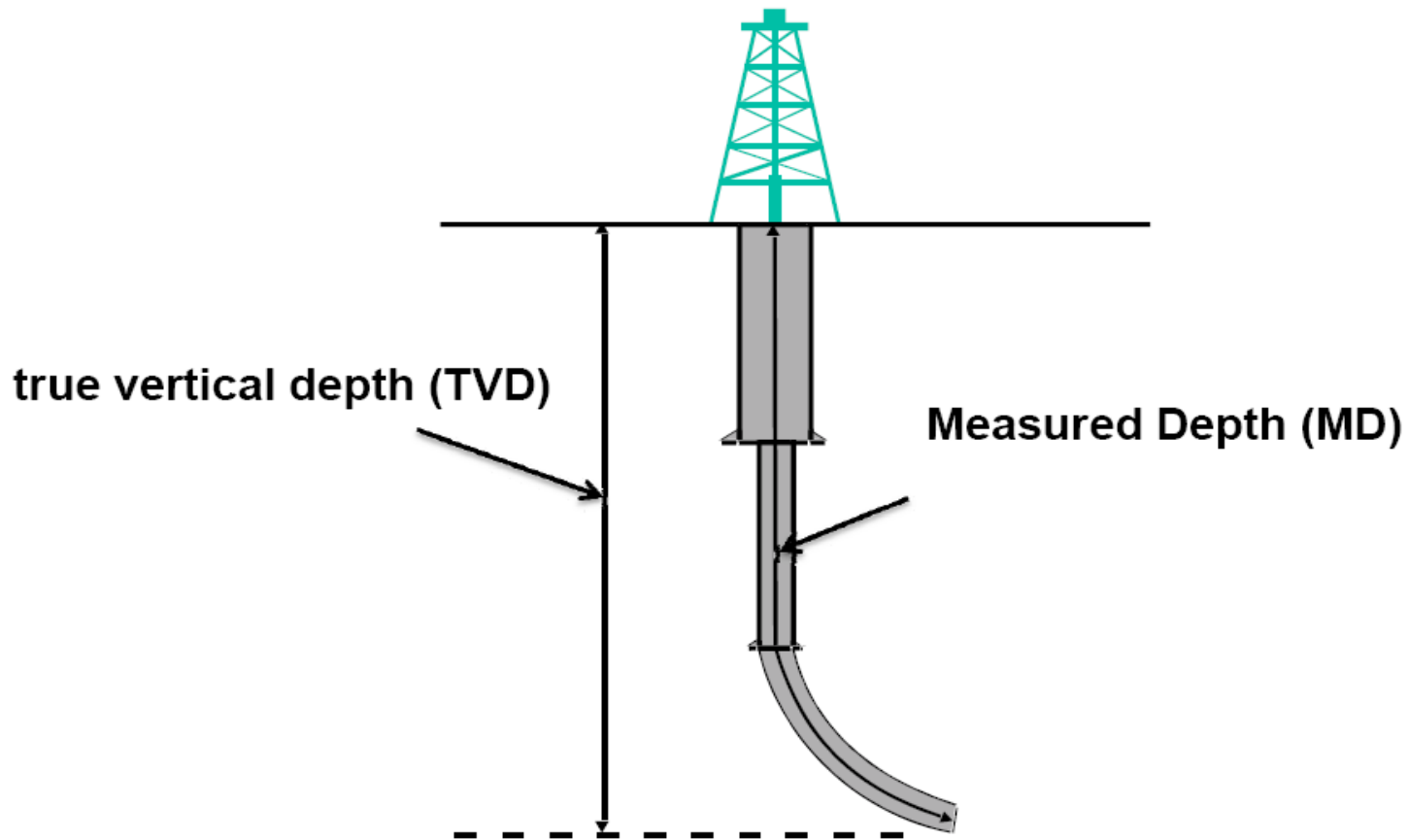


Enabler for offshore oil & gas field development + **33%** world production

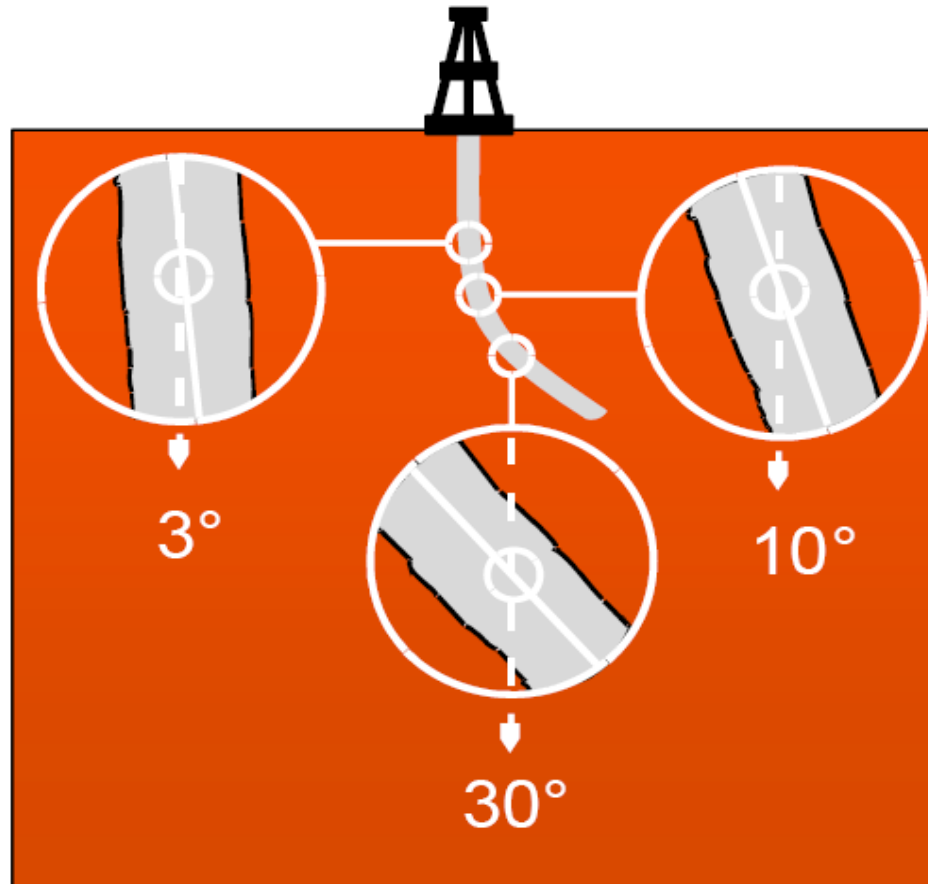
Grundlagen der Richtbohrtechnik

Basic terms in Directional Drilling

Borehole deviation

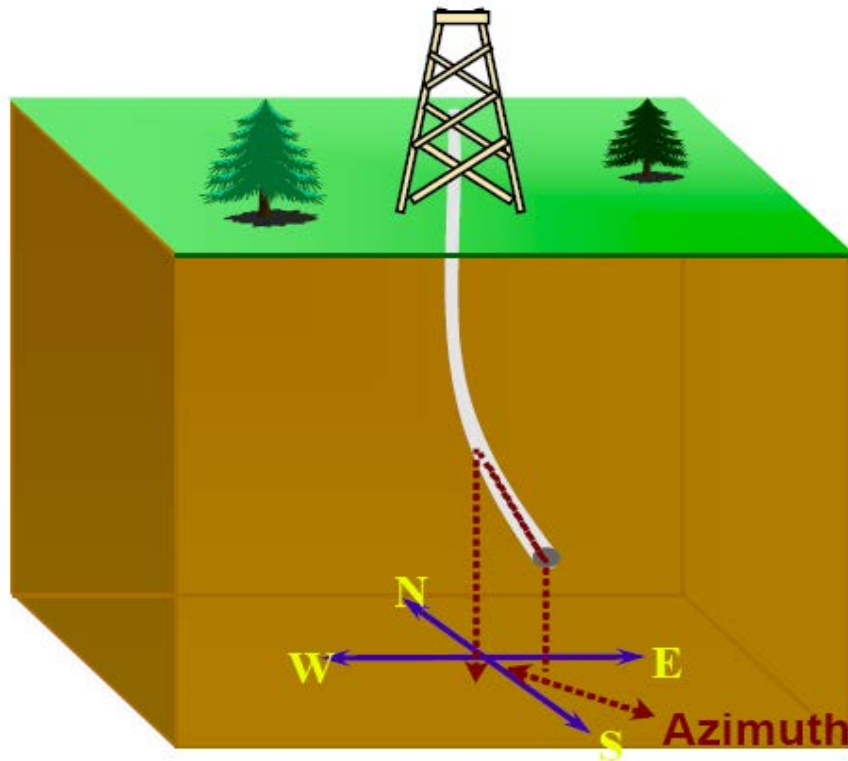


Hole inclination (from vertical)



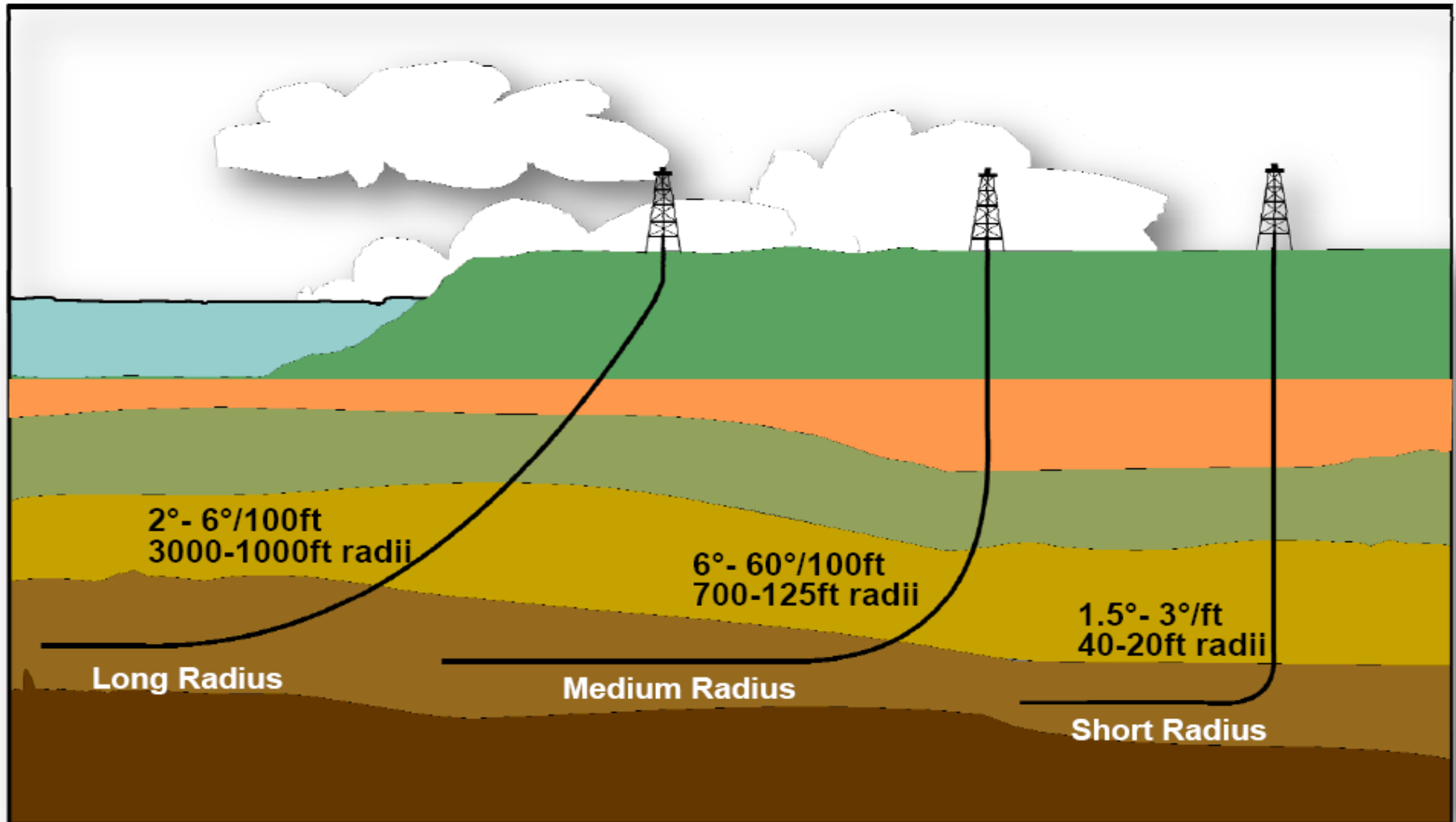
**Drift - Degrees from Vertical to High Side
(Vertical Plane)**

Hole Orientation (to North)

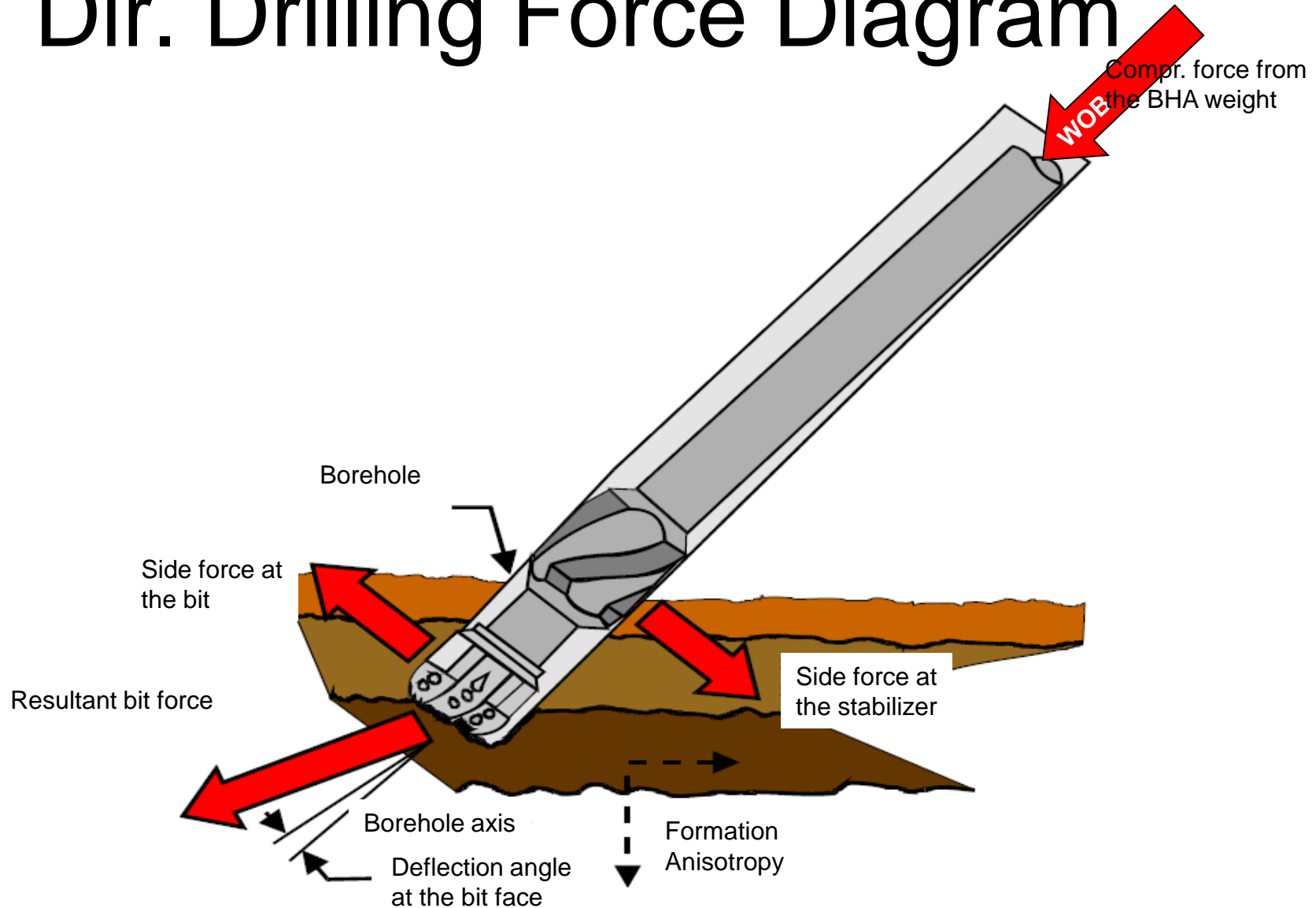


Angle of horizontally projected borehole section to geographic or magnetic North
(called: Azimuth, Bearing angle, Hole direction, etc.)

Curvatures in Directional Drilling

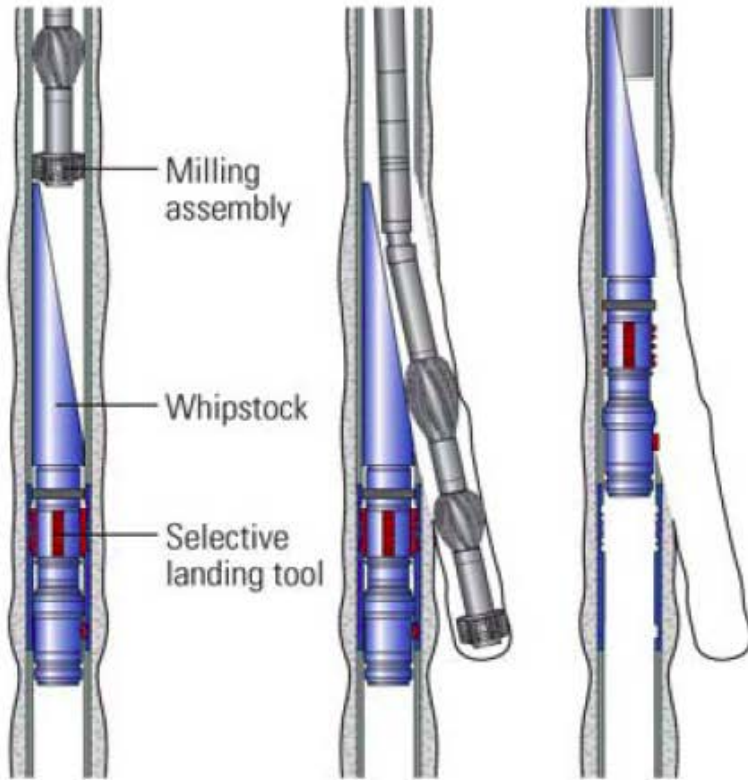


Dir. Drilling Force Diagram



Birth of Directional Drilling Casing Whipstock for Sidetracks

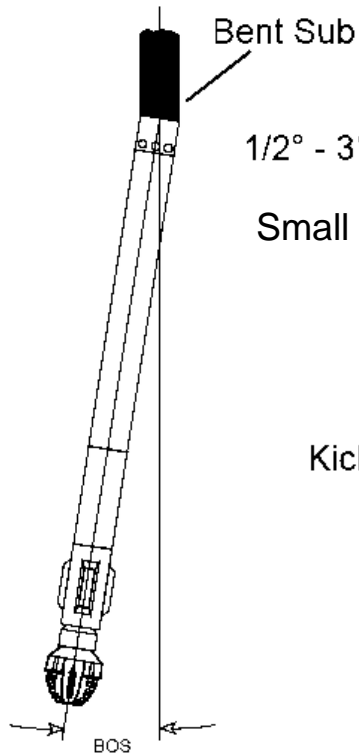
Install retrievable whipstock and mill casing exit.



Sliding kick-off motors

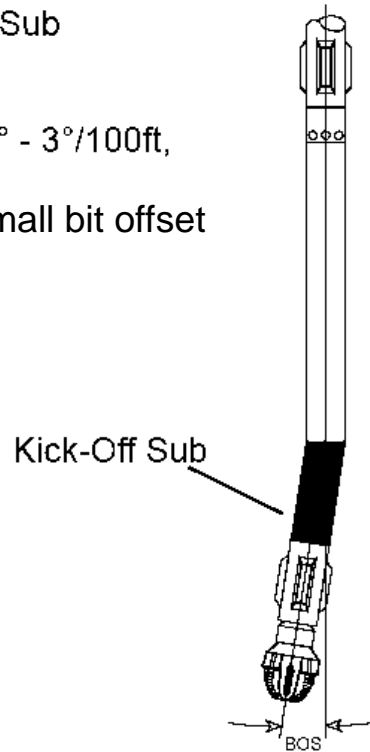
Bent Sub & Motor

$1/2^\circ - 3^\circ/100\text{ft}$
Large bit offset



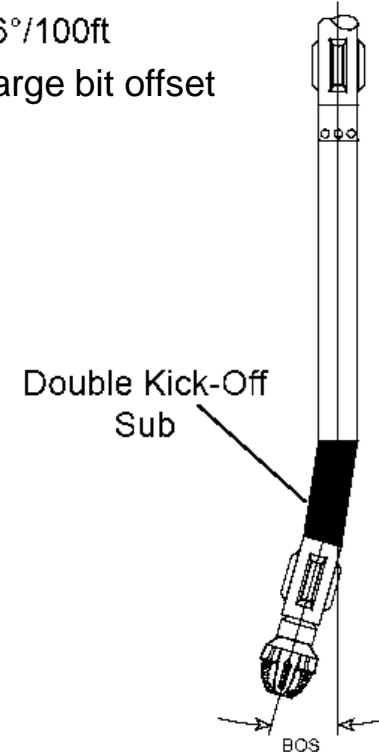
Kick Off Sub (KOS) Motor

$1/2^\circ - 3^\circ/100\text{ft}$,
Small bit offset

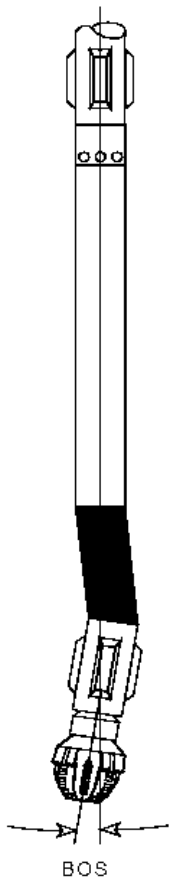


Double Kick Off (DKO) Motor

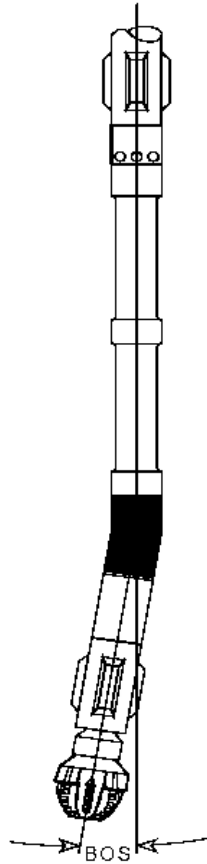
$\leq 6^\circ/100\text{ft}$
Large bit offset



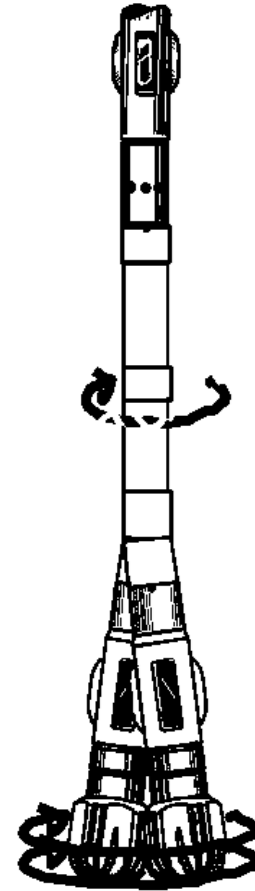
Steerable Systems



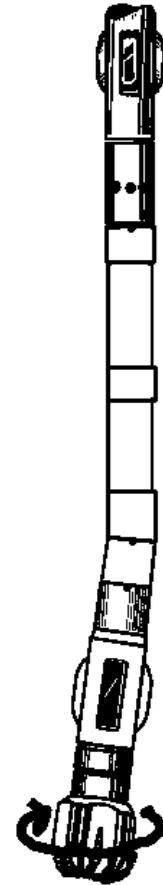
Double Tilt Universal
(DTU) Motor



Adjustable Kick Off
(AKO) Motor

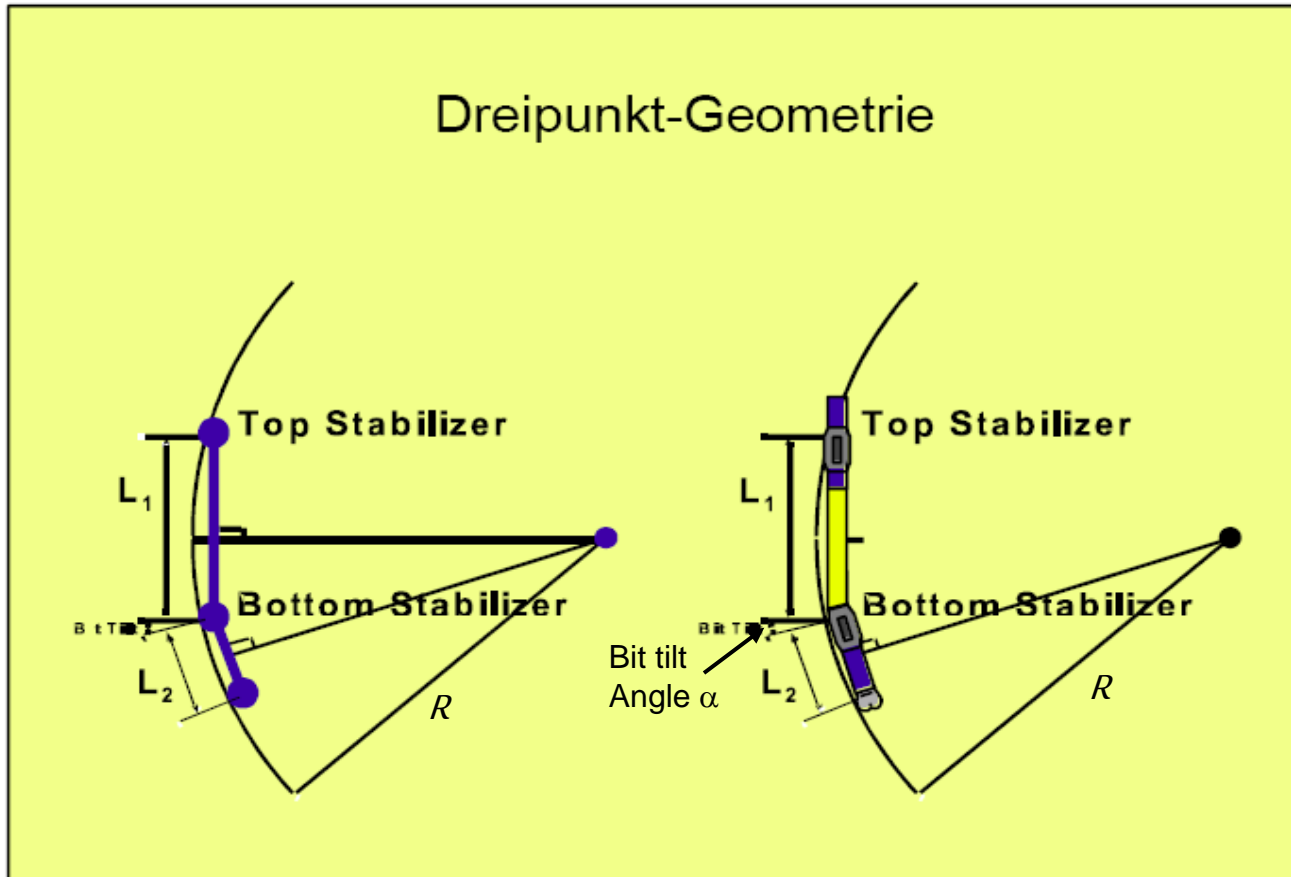


Rotary Tangent
drilling



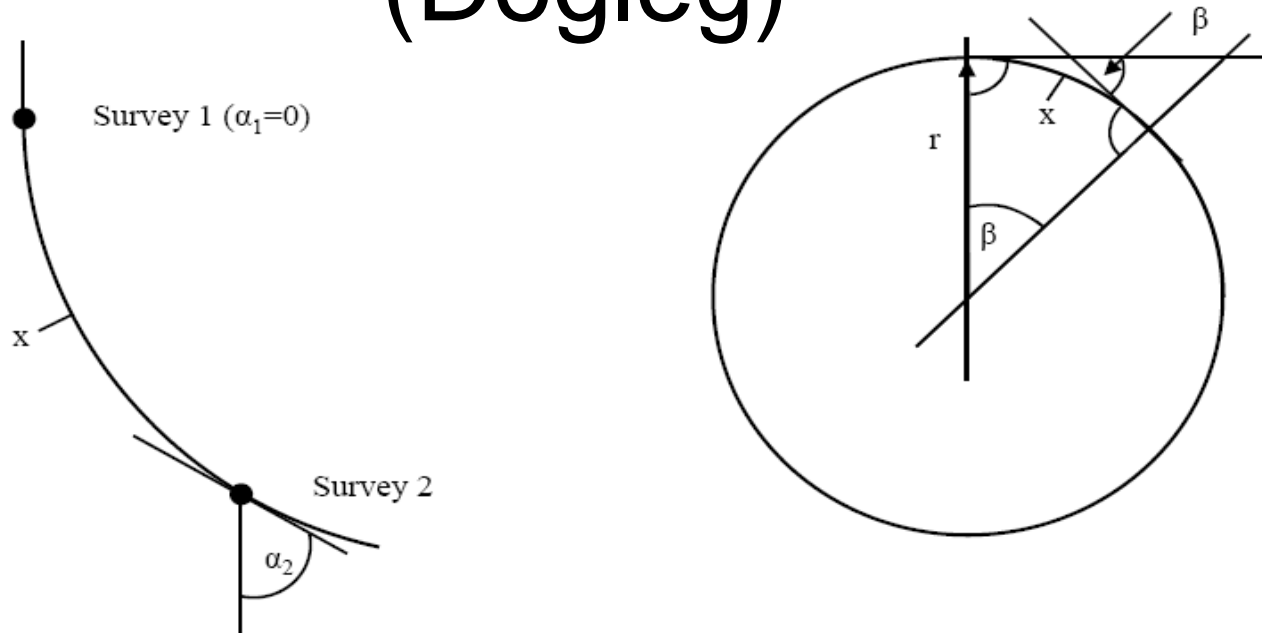
Oriented kick-off :
drilling

3-Point Geometry



$$R = \frac{L_1 + L_2}{2 \cdot \sin \alpha}$$

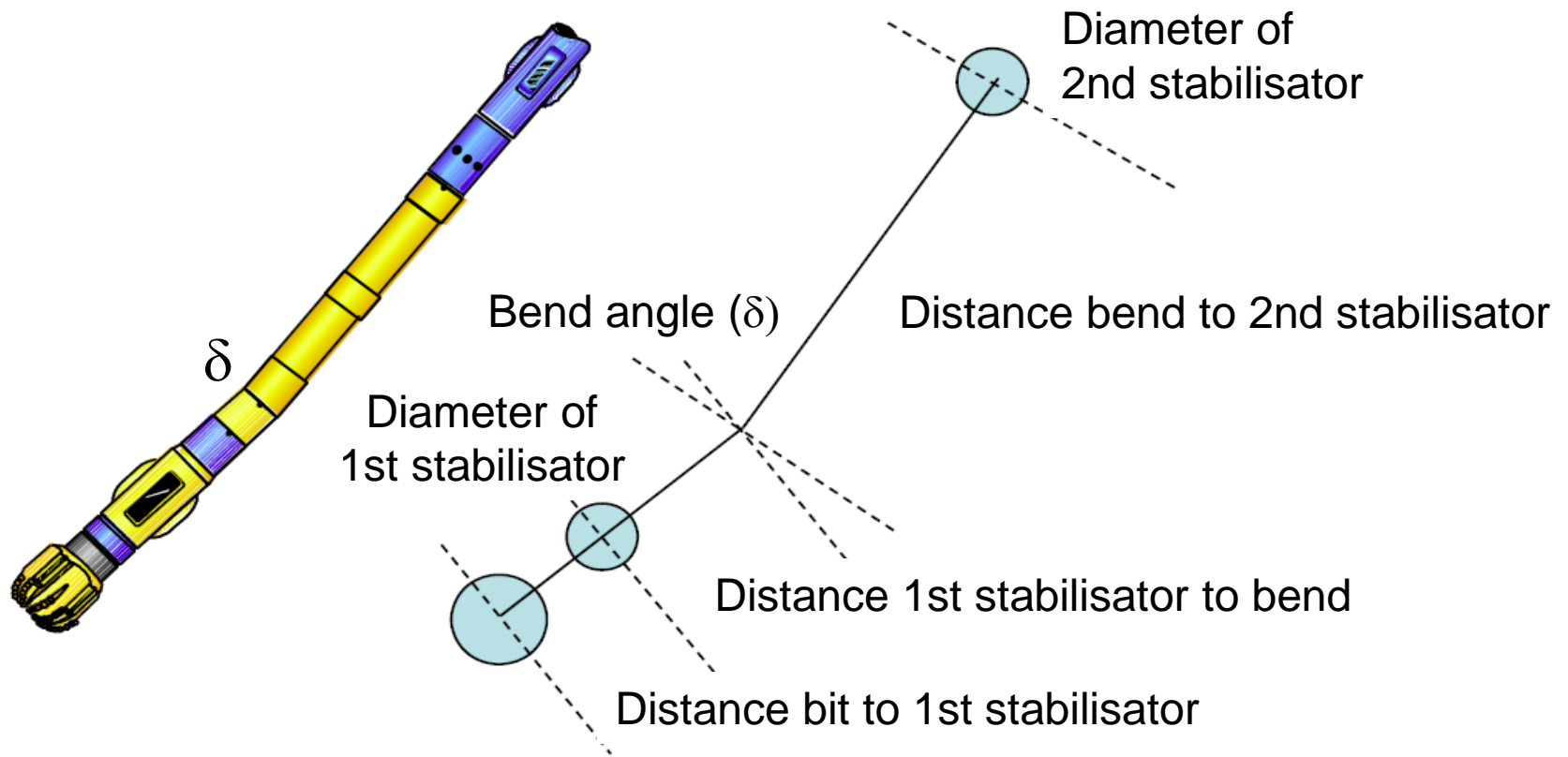
Planning the Hole Curvature (Dogleg)



$$BUR \left[\frac{^\circ}{100 \text{ ft}} \right] = \frac{\text{Section between 2 surveys (x = 100 ft)}}{\text{Inclination difference } (\beta = \alpha_1 - \alpha_2)} \quad (\text{Dogleg})$$

$$BUR \left[\frac{^\circ}{\text{ft}} \right] = \frac{360^\circ}{2\pi \cdot r} = \frac{360^\circ \cdot 0,3048 \text{ m}}{2\pi \cdot r[\text{m}] \cdot 1 \text{ ft}}$$

Simulation of the Dir.Drilling System



Directional coordinate calculation

$$\Delta TVD_1 = CL \cdot \cos I_{avq}$$

$$\Delta Lat = CL \cdot \sin I_{avq} \cdot \cos B_{avq}$$

$$\Delta Dep = CL \cdot \sin I_{avq} \cdot \sin B_{avq}$$

$$I_{avq} = \frac{I_2 + I_1}{2}$$

$$B_{avq} = \frac{B_2 + B_1}{2}$$

where:

TVD ... true vertical depth

Lat ... latitude (North-South)

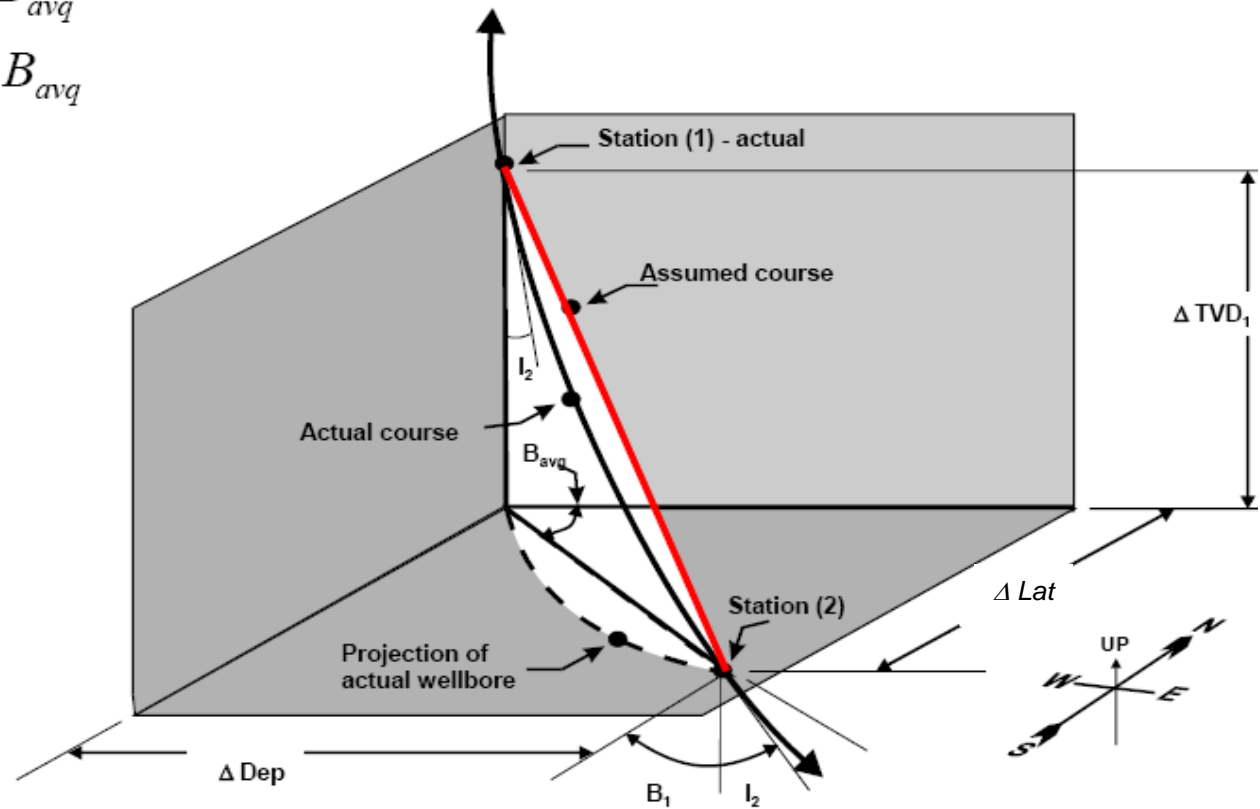
Dep ... departure (East-West)

CL ... course length

I ... inclination angle

B ... bearing angle

● Average Angle



Datenübertragung im Bohrloch

Data telemetry in the borehole

Typische Messungen:

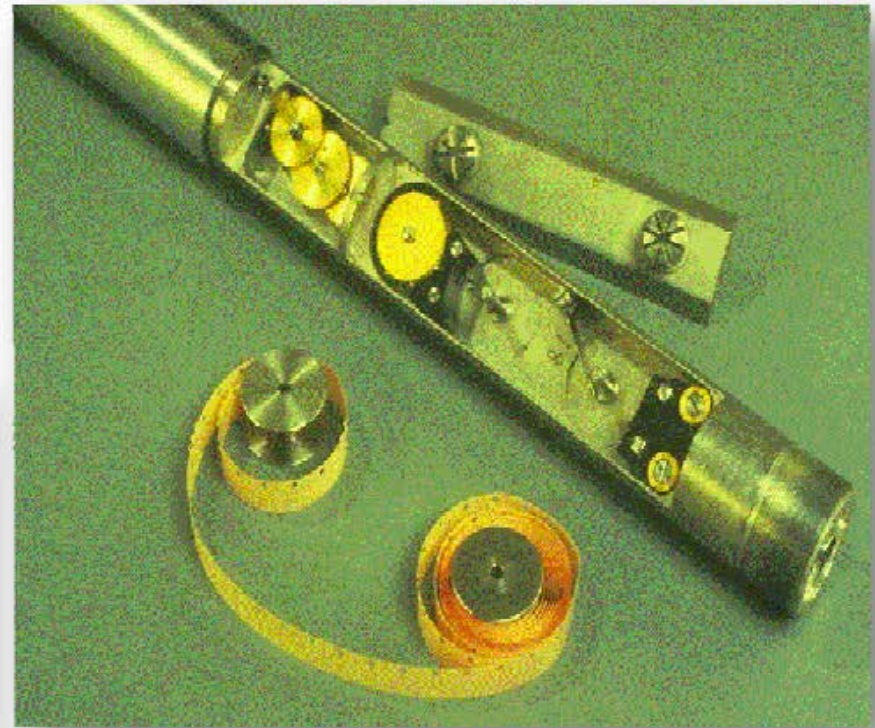
Directional	Inclination, Direction, Toolface
Druck	Annulus, DP internal, Delta-p at the bit
Dynamics	WOB, TOB, Vibration, Stick Slip, Bit Whirl
Gamma	Natural, Spectral, Azimuthal
Resistivity	Multi-Frequency, Azimuthal, Focused
Neutron Porosity	Compensated, Near/Far
Formation Density	Rho, azimuthal
Ultrasonic Caliper	Borehole diameter, logging tool excentricity
Acoustic	Rock mechanical properties
Seismic while drilling	Advanced “look ahead” seismic
NMR (nuclear magnetic resonance)	Pore volume, mobile and immobile reservoir fluids

Beginning of downhole Directional Data Recording – Photo Tools

Magnetic single shot



Magnetic multi shot



Electronic Recording & Steering Tools

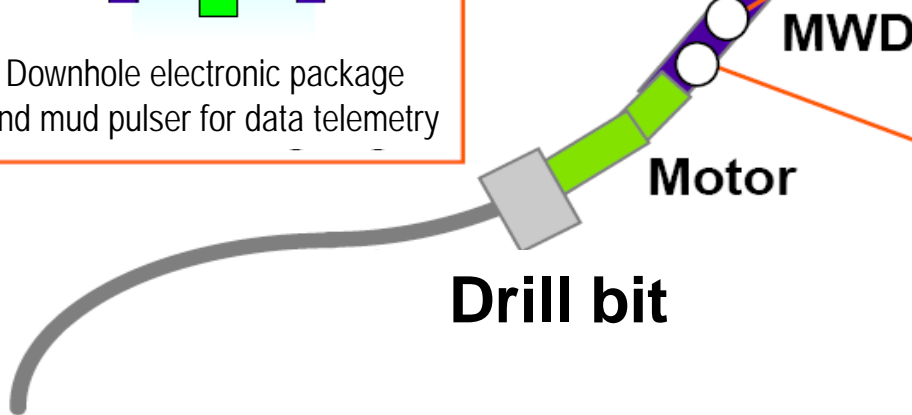
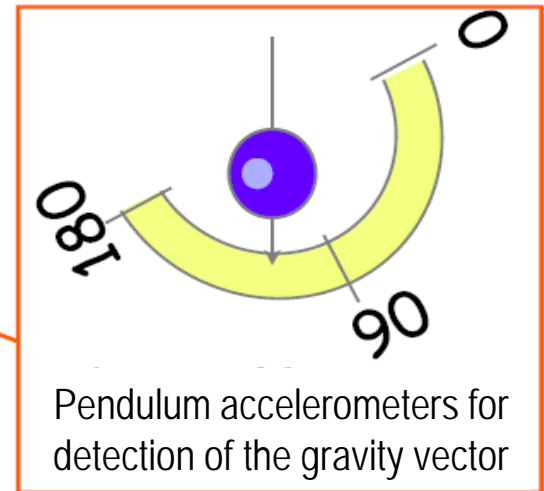
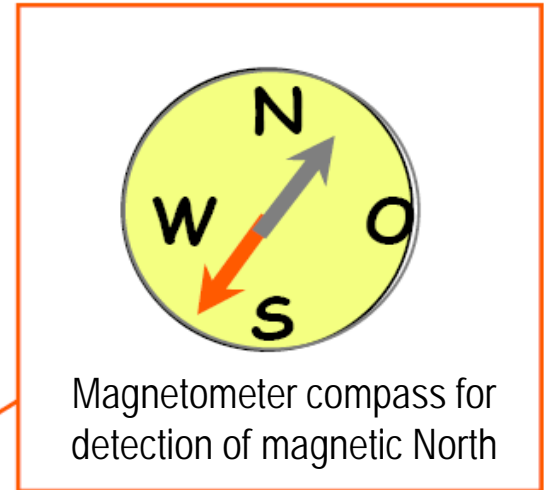
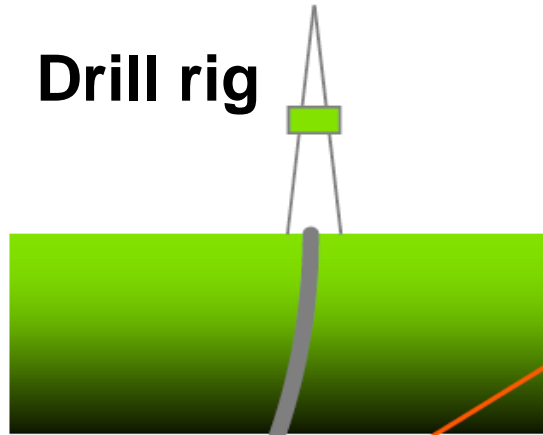
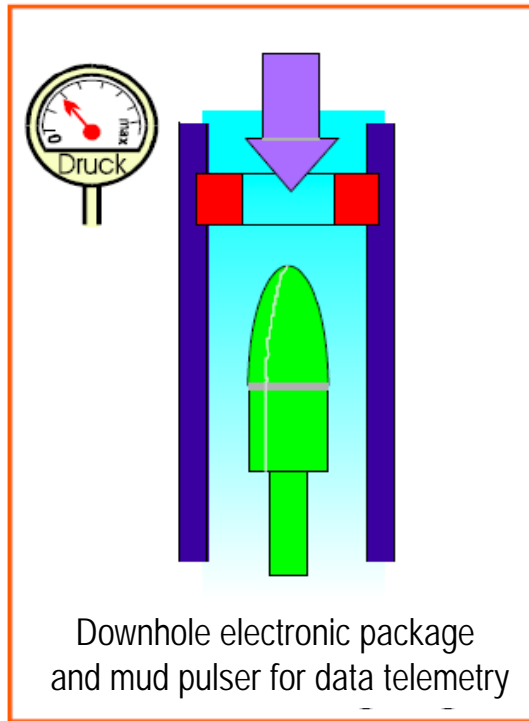
Wireline steering tool



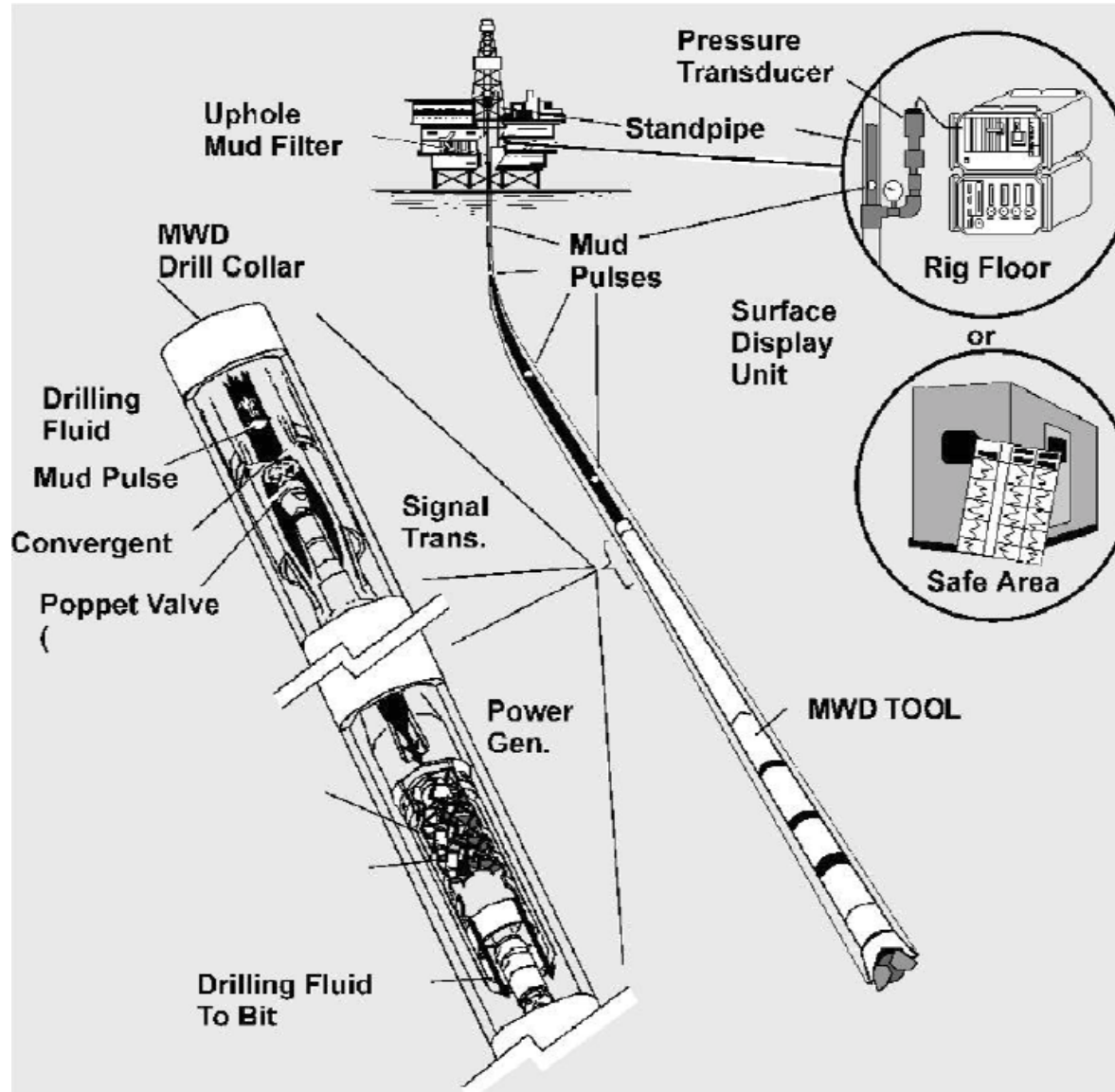
Electronic multi shot



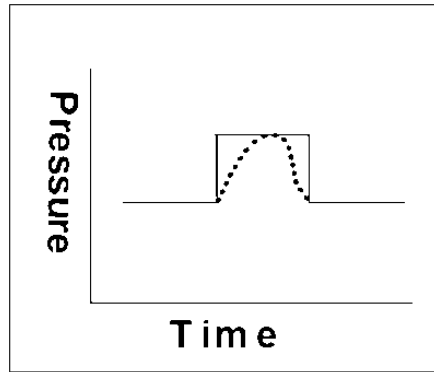
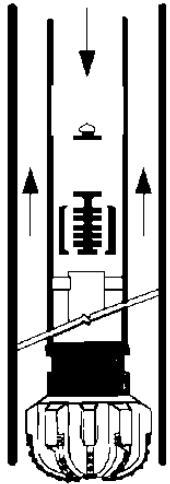
Measurement-while-drilling - today's downhole directional packages (MWD)



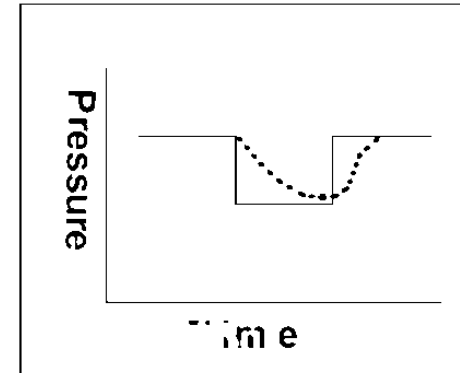
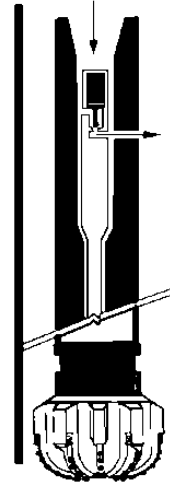
Data Telemetry Hardware



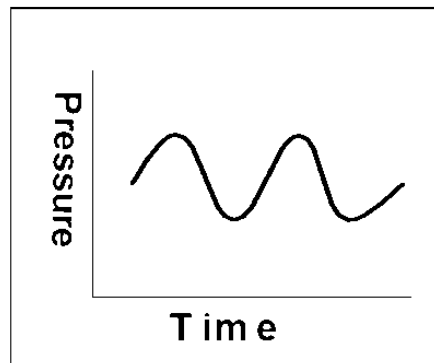
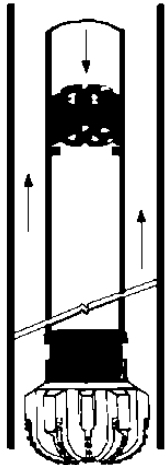
Mud pulse data telemetry systems



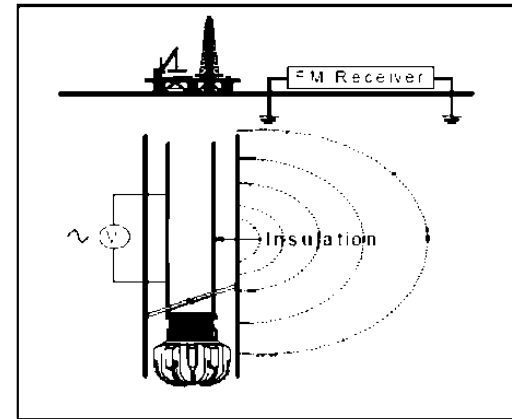
Positive Pulse



Negative Pulse



Frequency telemetry method



Electromagnetic telemetry method

Generation of Mud Pulses

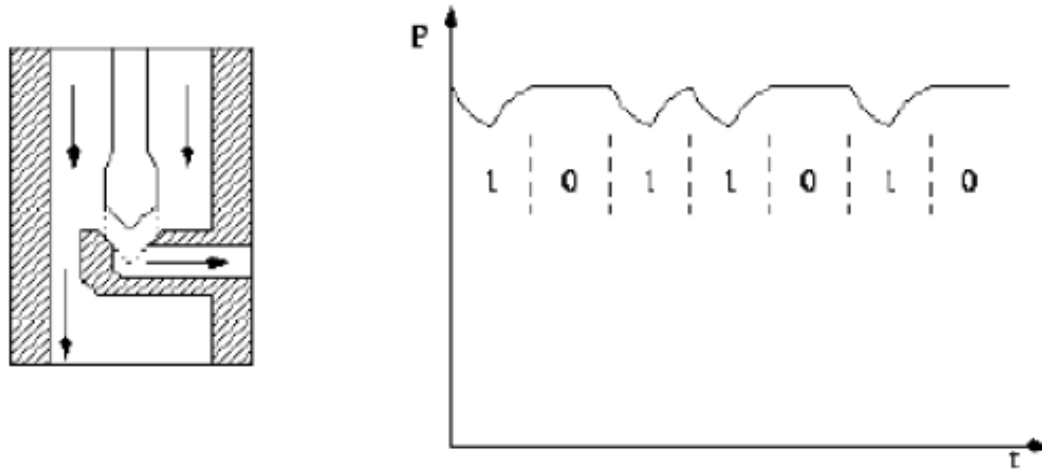


Fig. 1 – Negative pulse signal generation

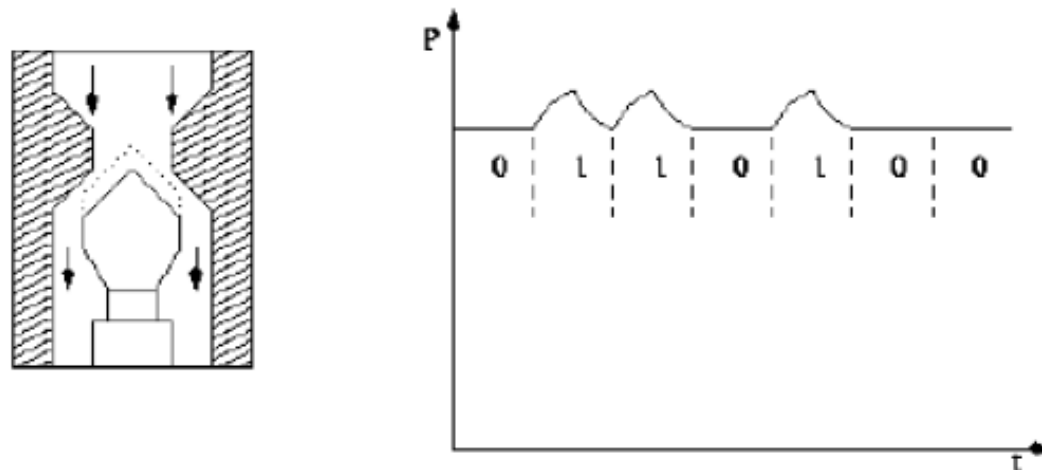
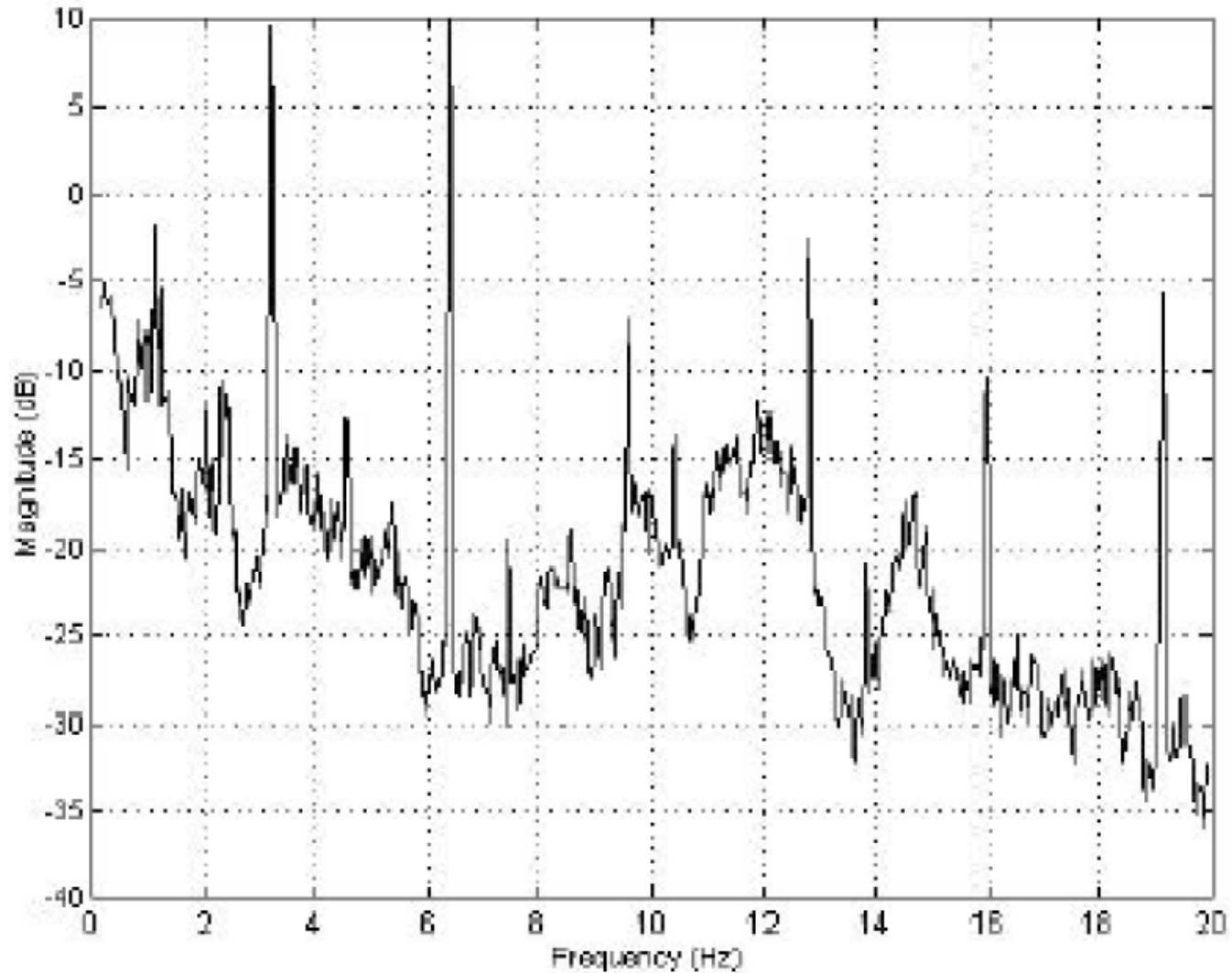


Fig. 2 – Positive pulse signal generation

Pump Pressure Spectrum



Power spectrum showing mud pump noise

Drilling Noise superimposed Data

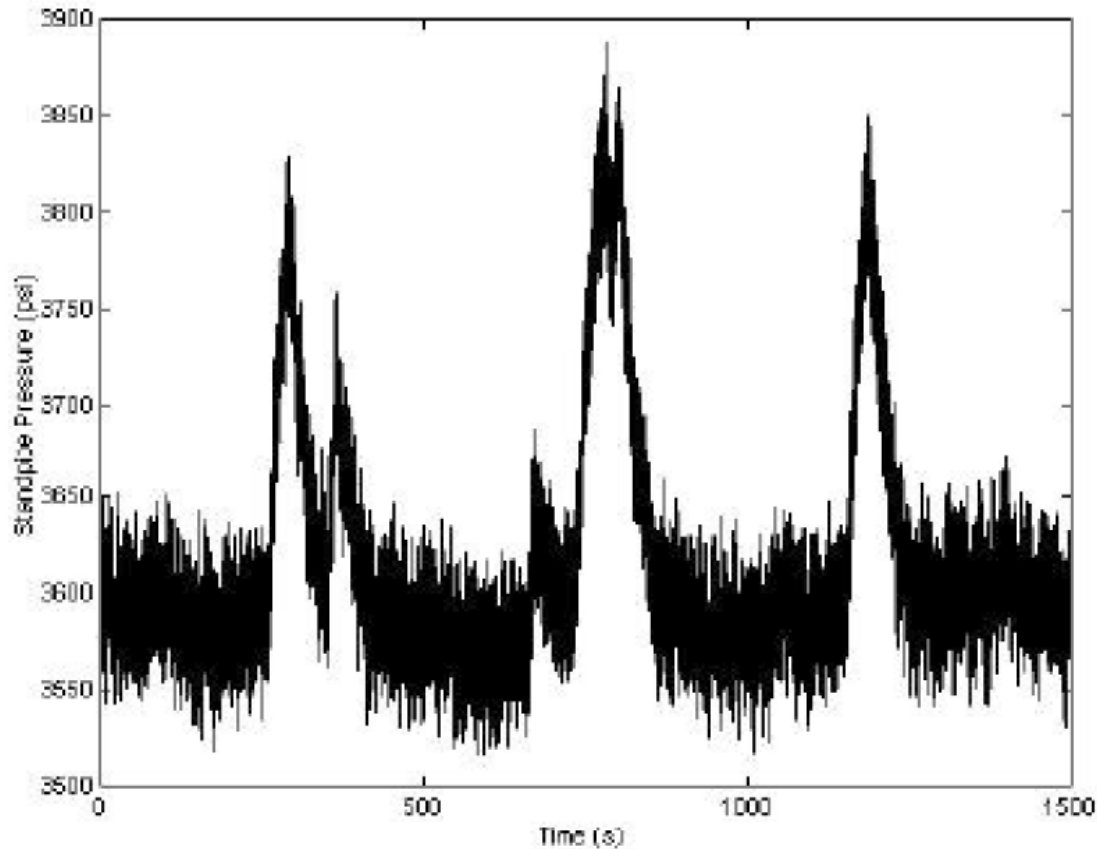
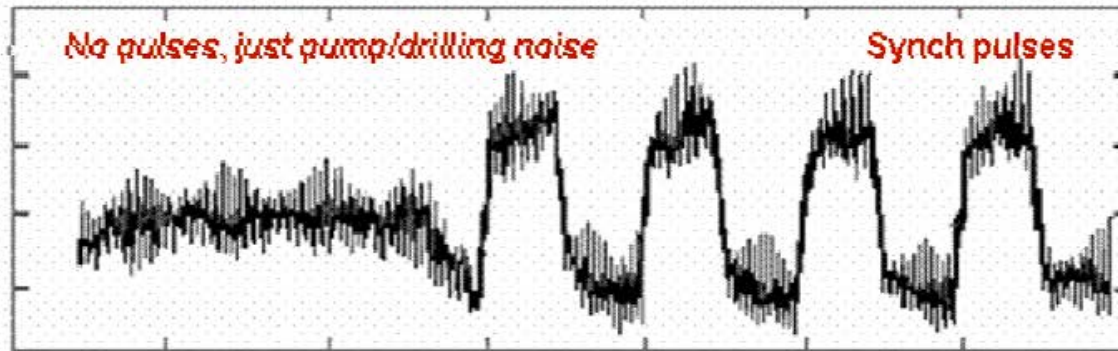
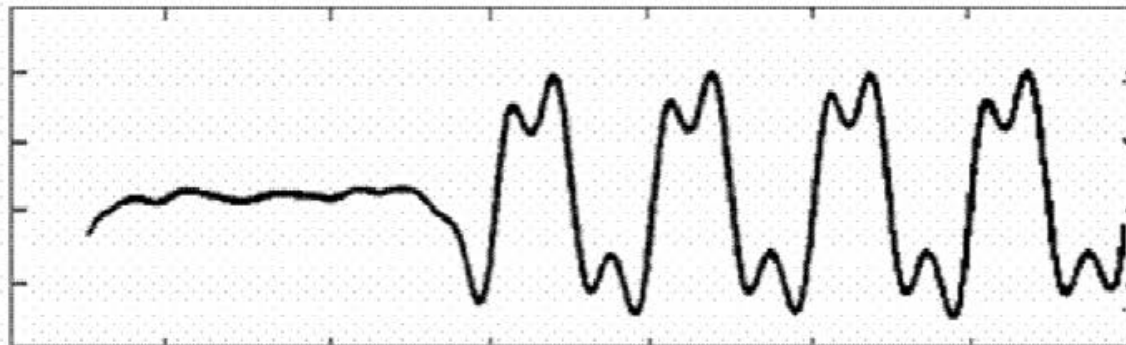


Fig.6 – Plot of standpipe pressure versus time showing pressure variations caused by stalling the downhole mud motor.

Signal Quality Improvement

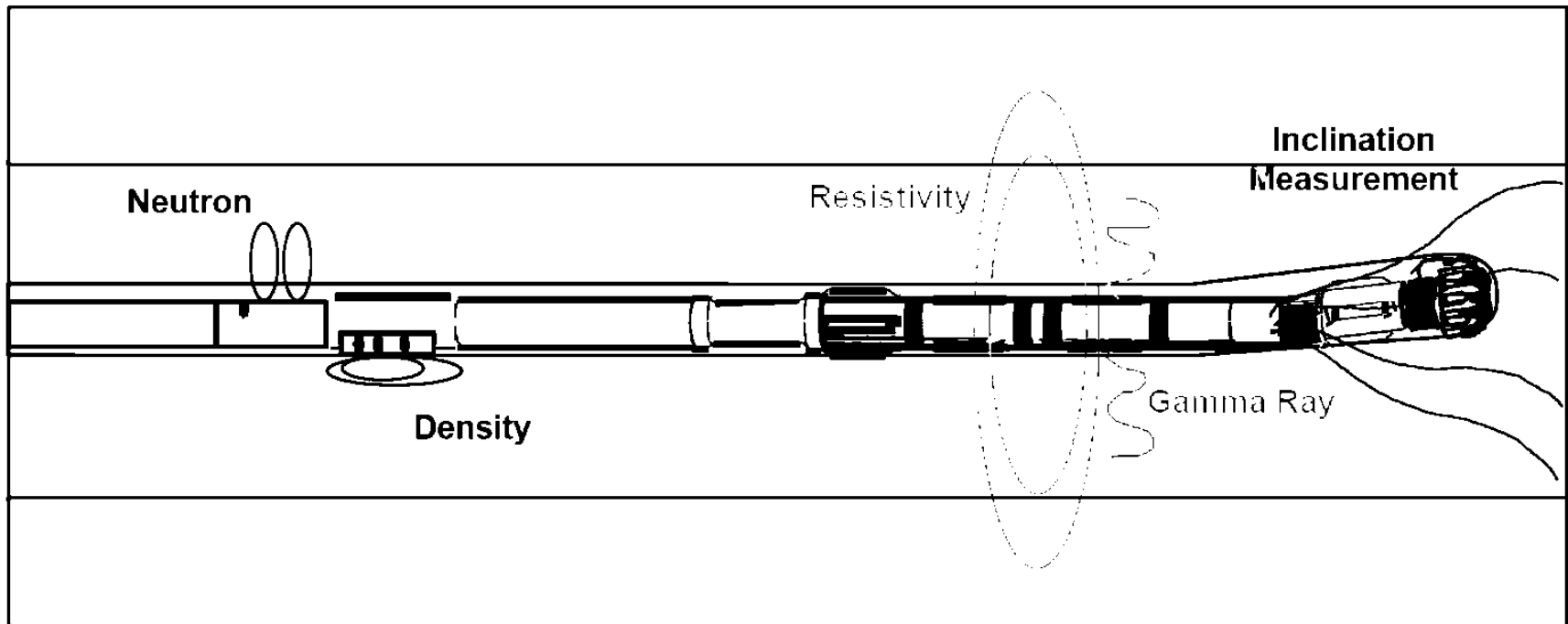


Unfiltered downhole signal



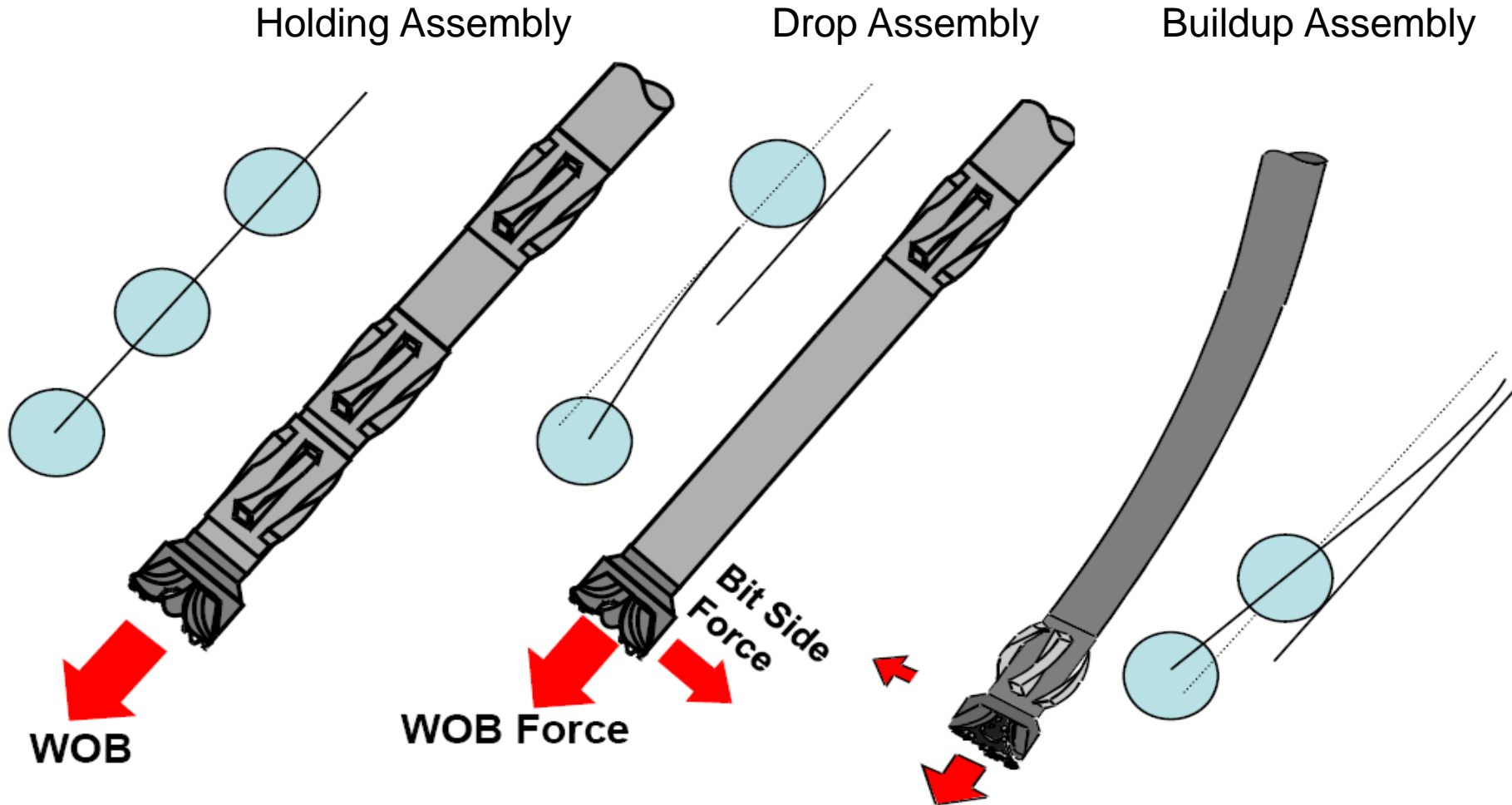
Filtered downhole signal

Logging-while-Drilling (LWD) geophysical wireline equiv. logging

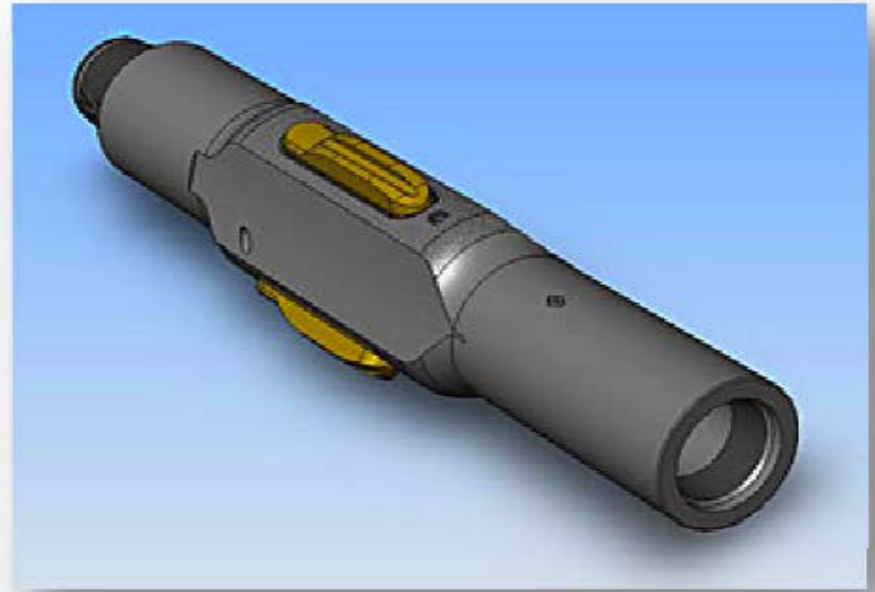
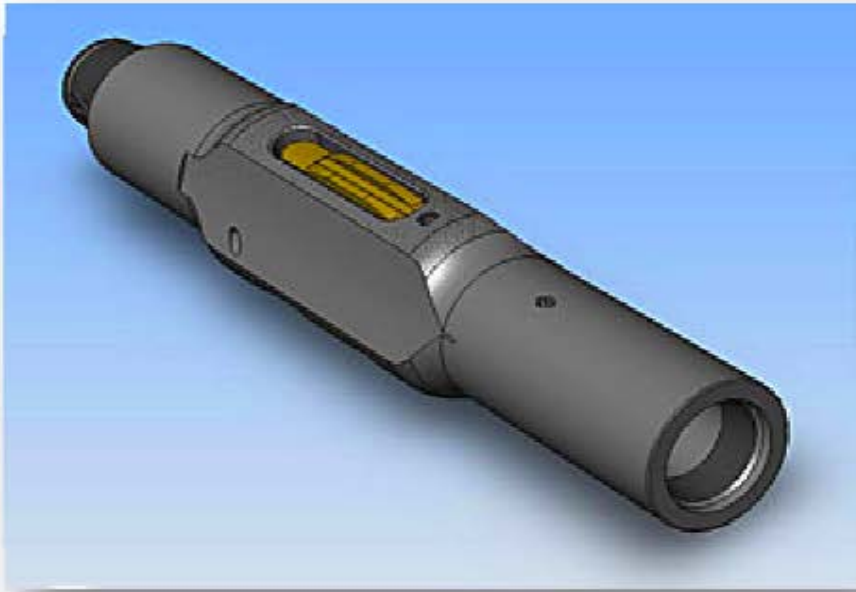


Rotary Steering Systems

BHA behaviour by stabilization

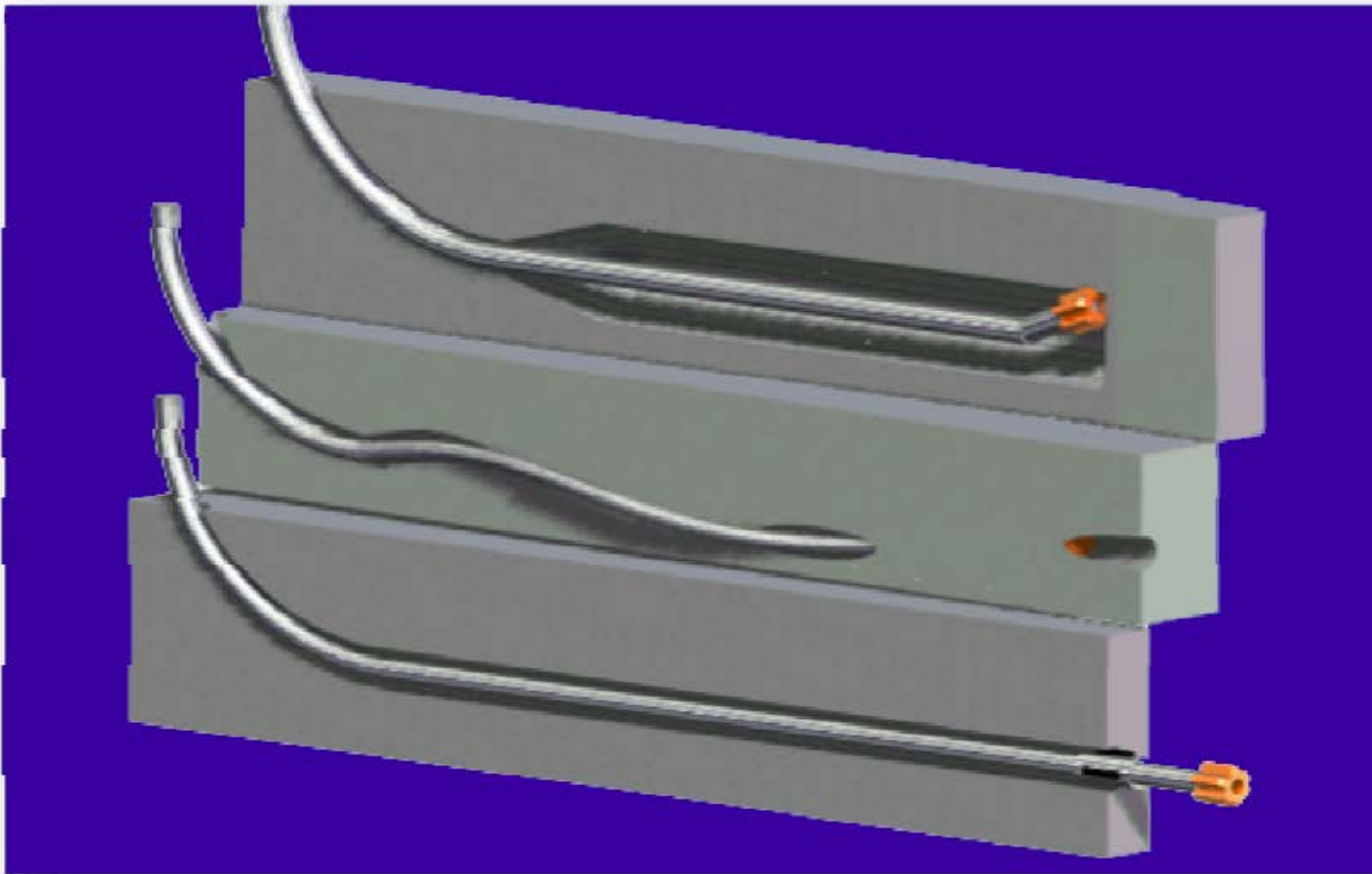


Variable gauge 2nd stabilizers



- 2 or 3 setting options for:
- Building angle
 - Holding angle
 - Dropping angle

Comparison of drilling performance

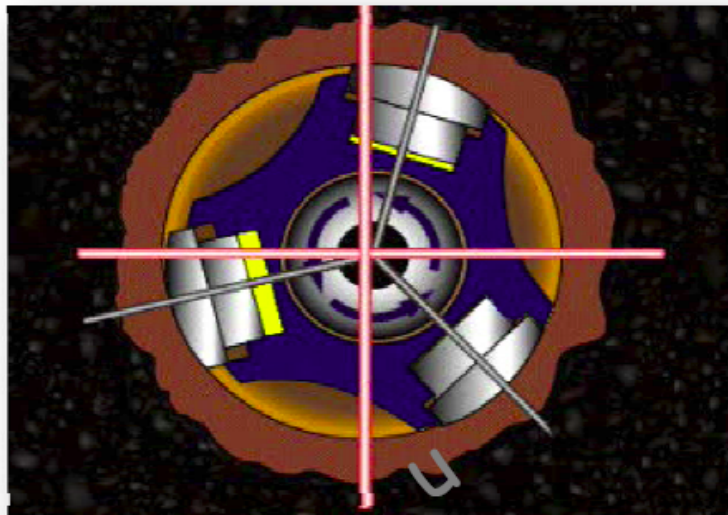
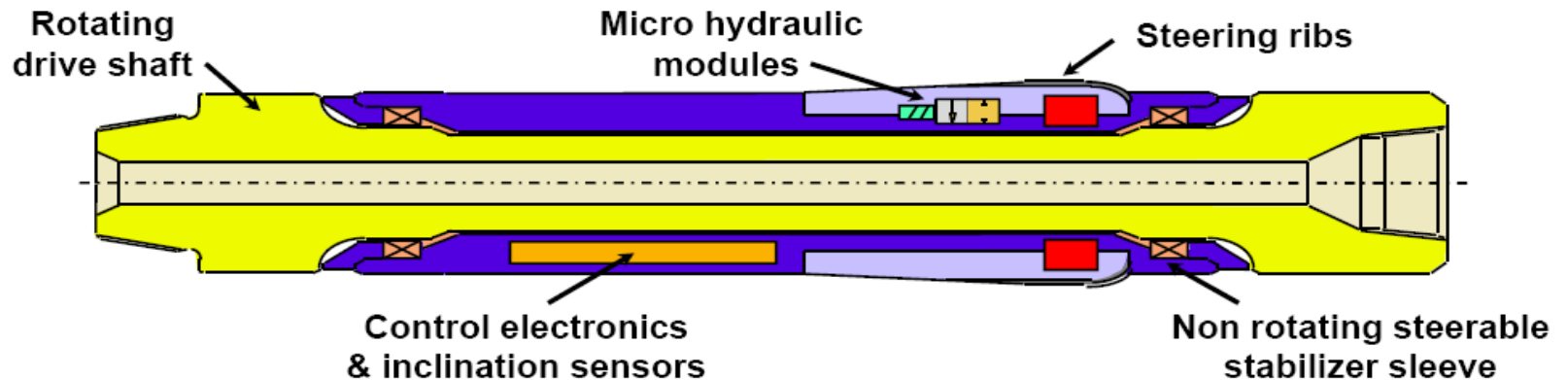


Steerable motor
in R-mode

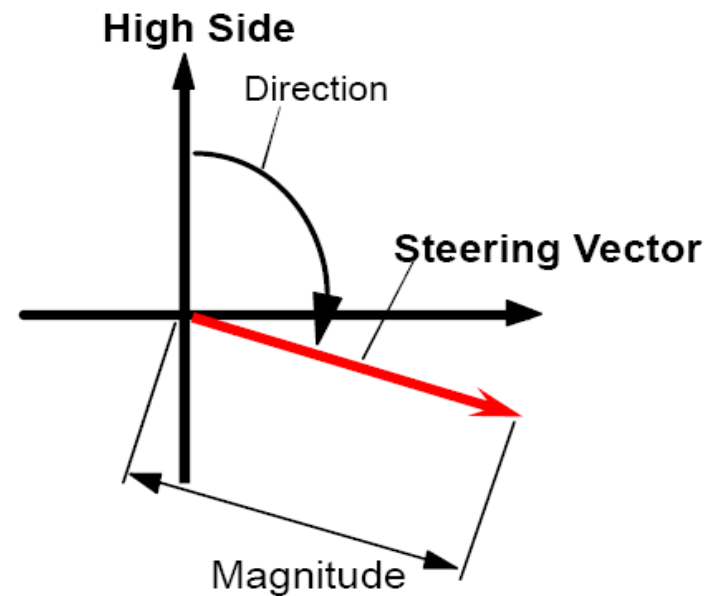
Steerable motor
in O-mode

Rotary steering
system

Haker Hughes INTEQ - Autotrak



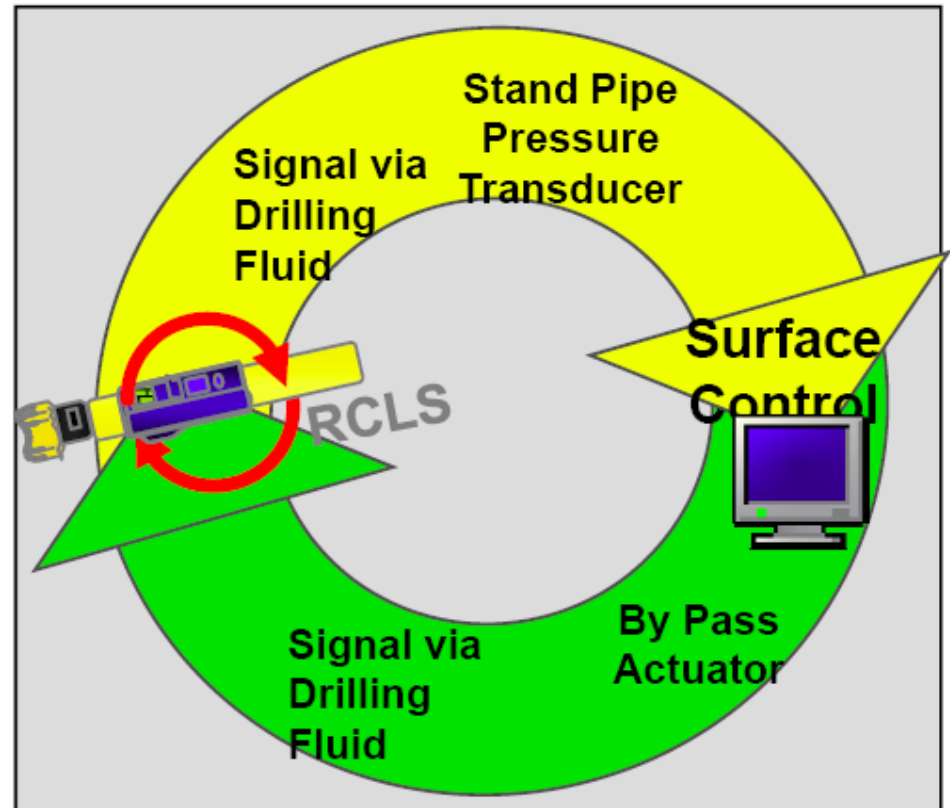
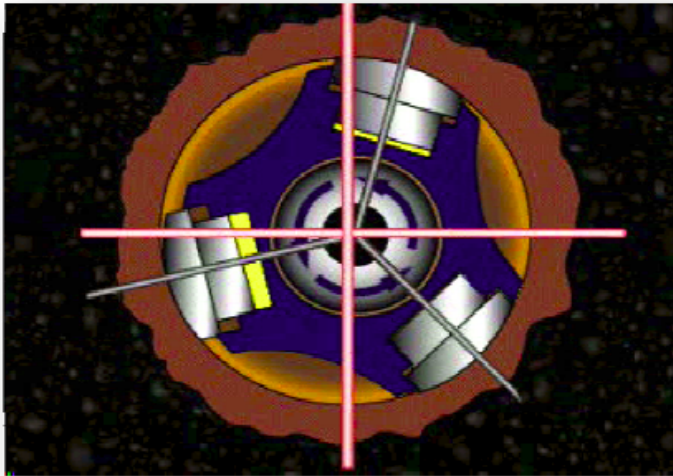
Rippendruck: Ölhydraulik



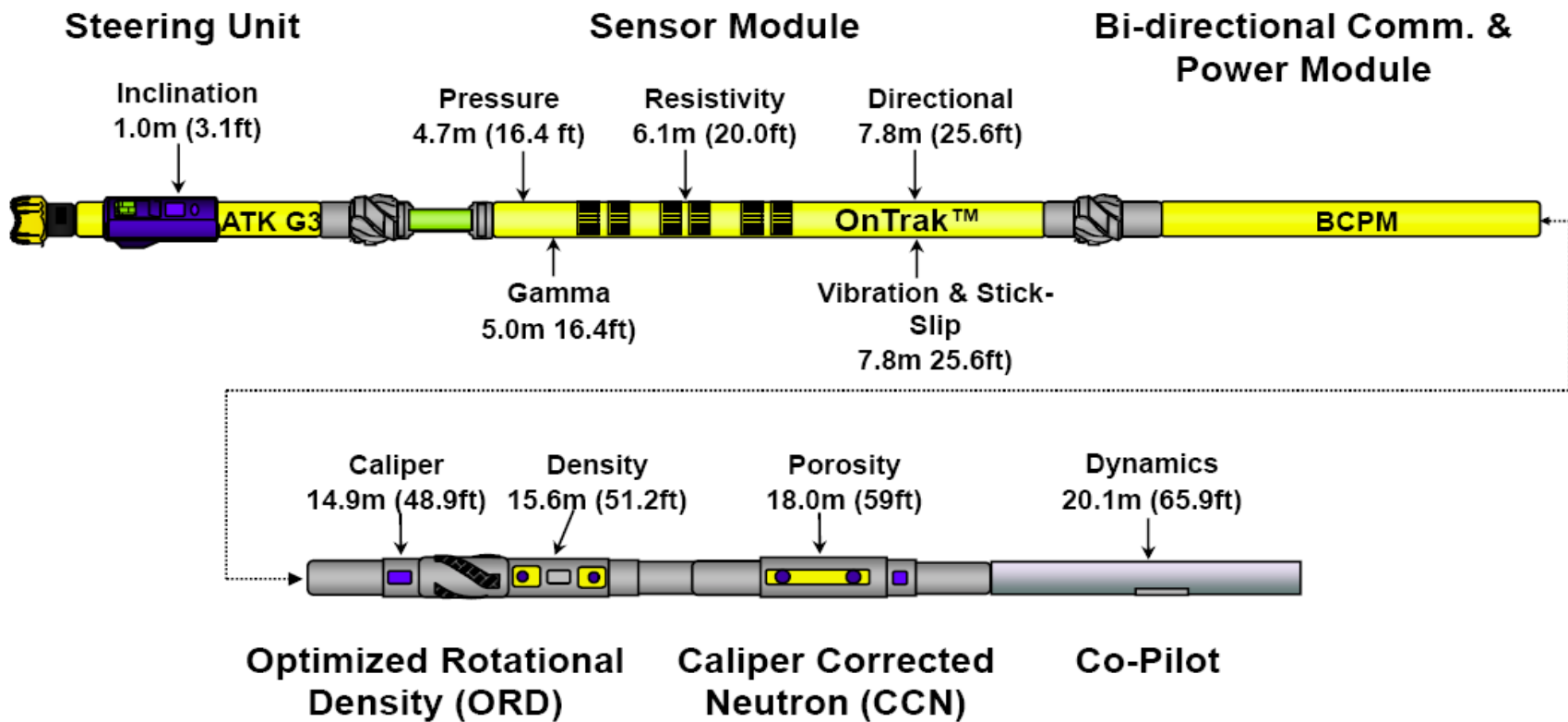
Haker Hughes INTEQ - Autotrak

RCLS - Rotary closed loop system

Rotary Steering Systems with communication from downhole to the surface without interruption of the drilling process

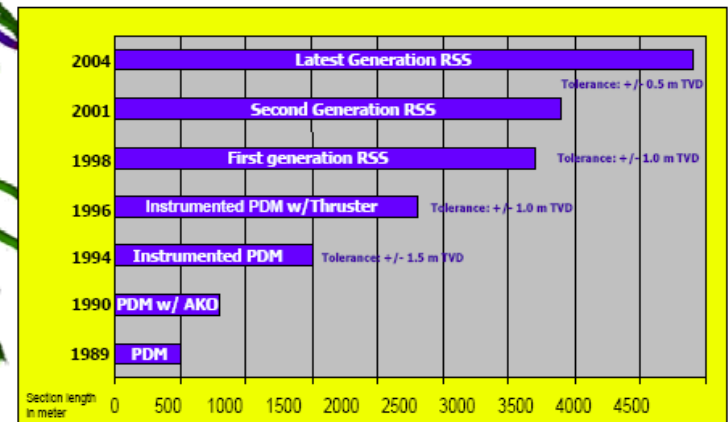
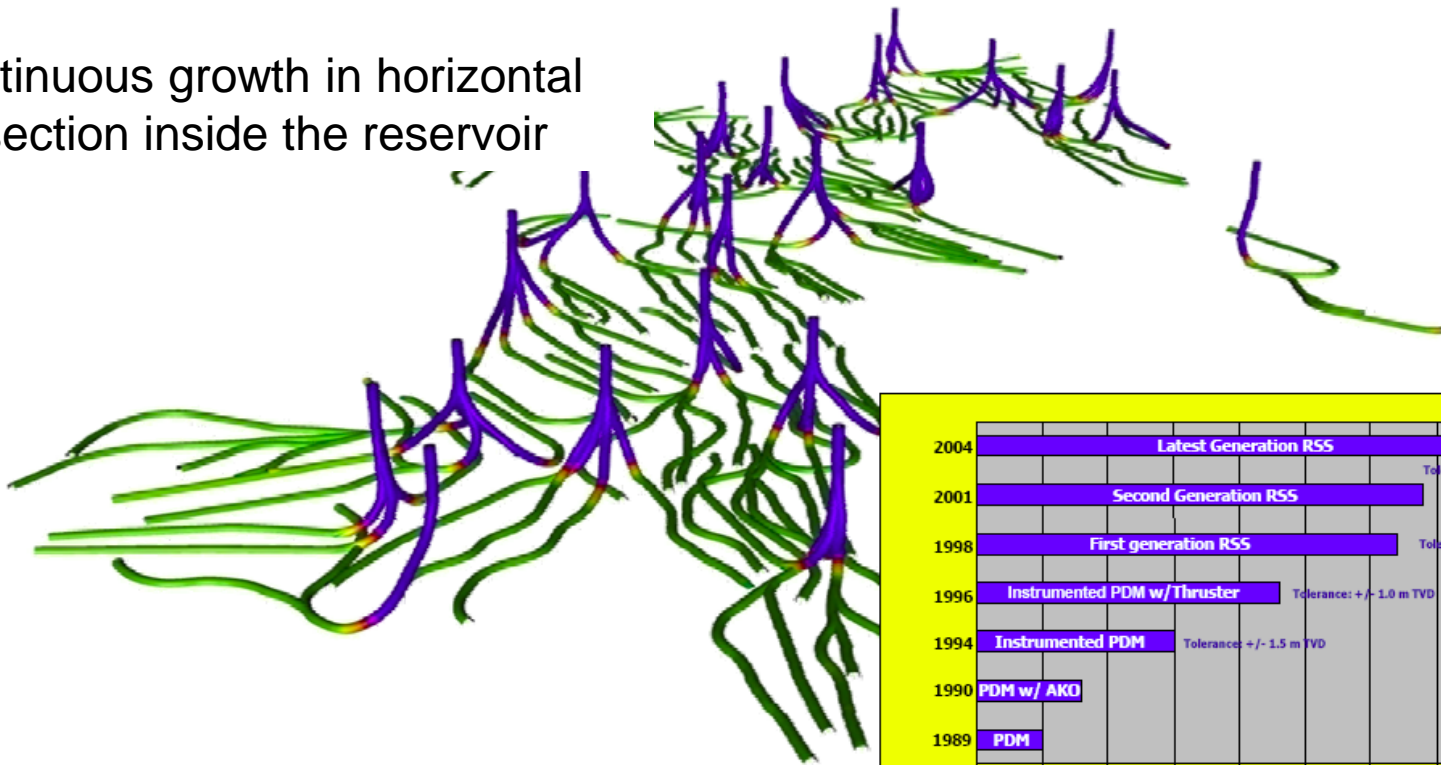


Haker Hughes INTEQ - Autotrak

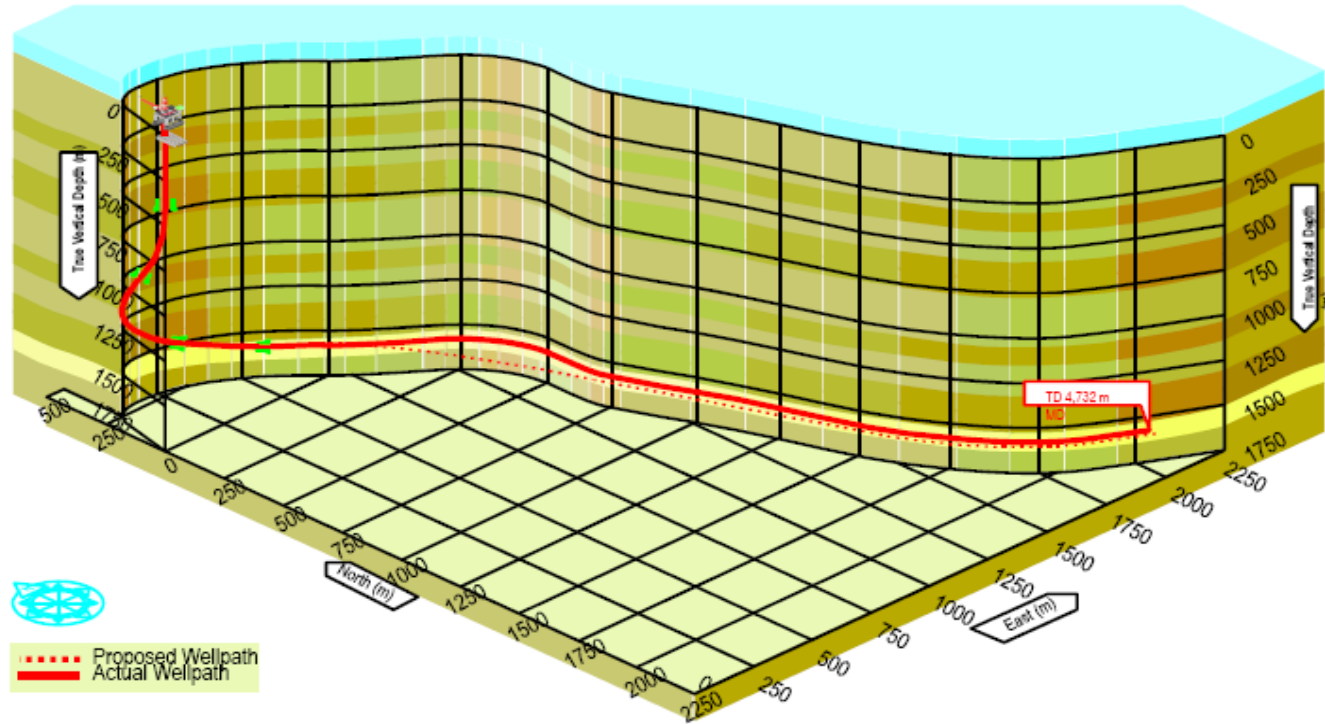


Value creation by RSS – Troll/N

- Placement of branched horizontal wells in thin production layers
- Continuous growth in horizontal well section inside the reservoir



Extreme steerability and flexibility



PDC bit improvement by RSS

>100 Design-Schritte



2001
Durchschnitt
504 m/BHA
95% open hole
sidetrack
Erfolgsrate



Record Bit Run
787 m

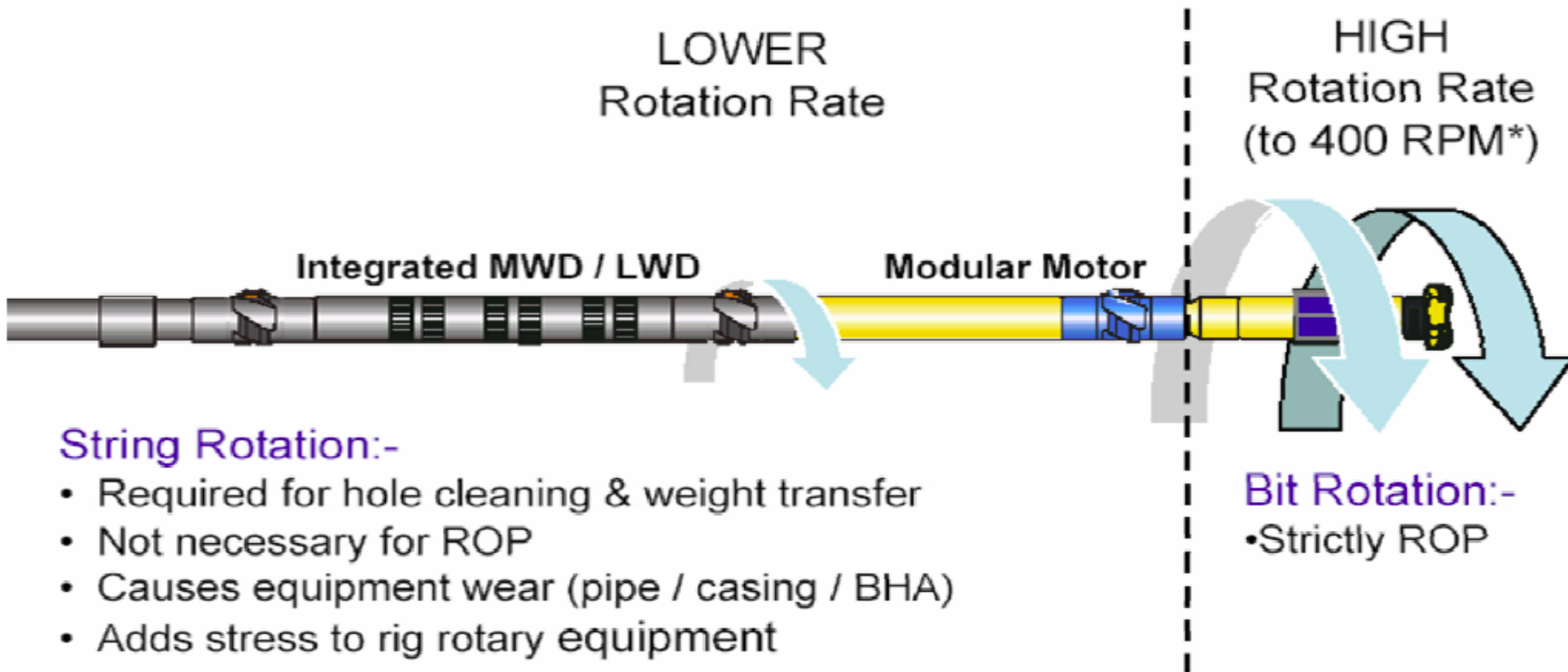
2005
Durchschnitt
851 m/BHA
100% open hole
sidetrack
Erfolgsrate



Record Bit Run
4096 m



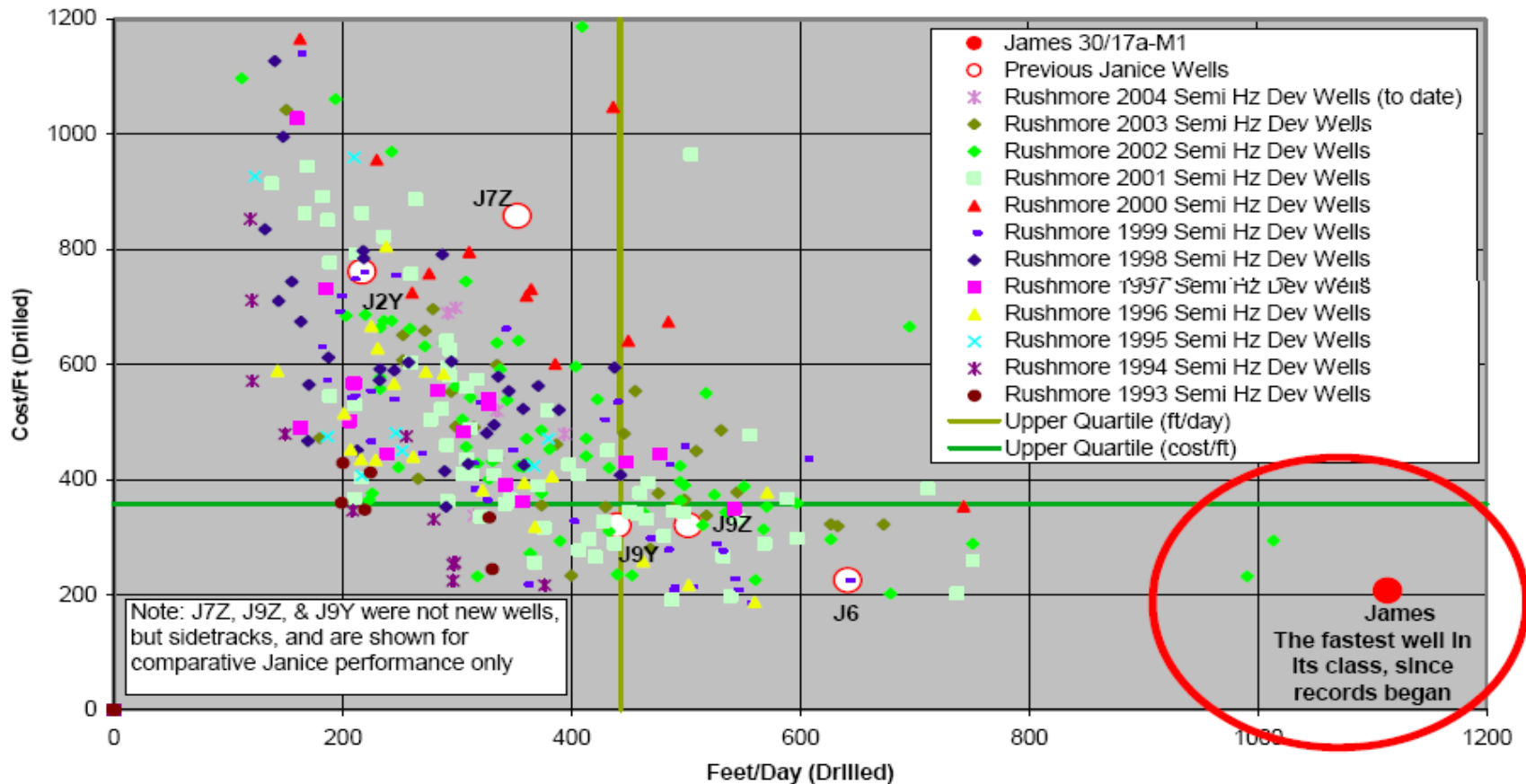
Motor assisted RSS for high drilling performance



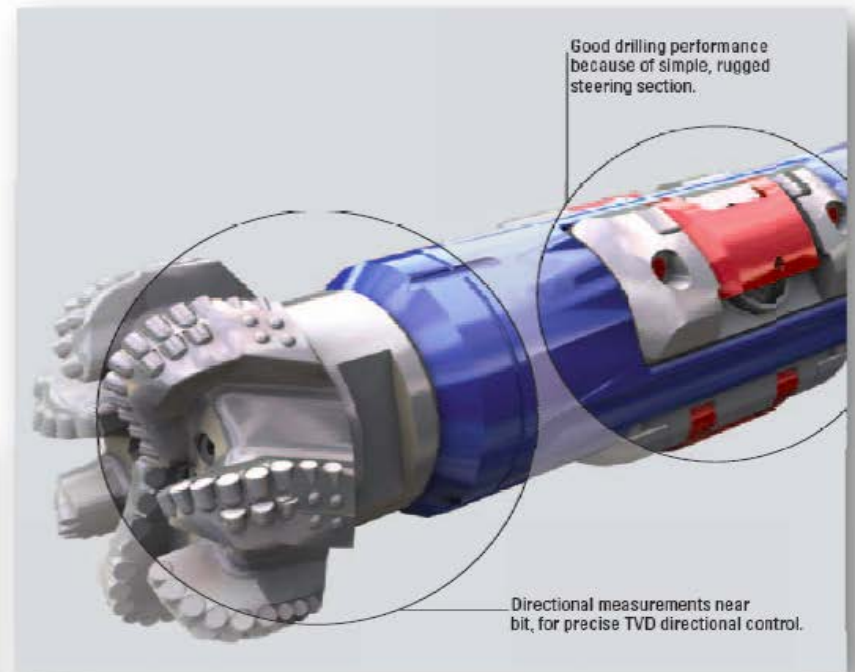
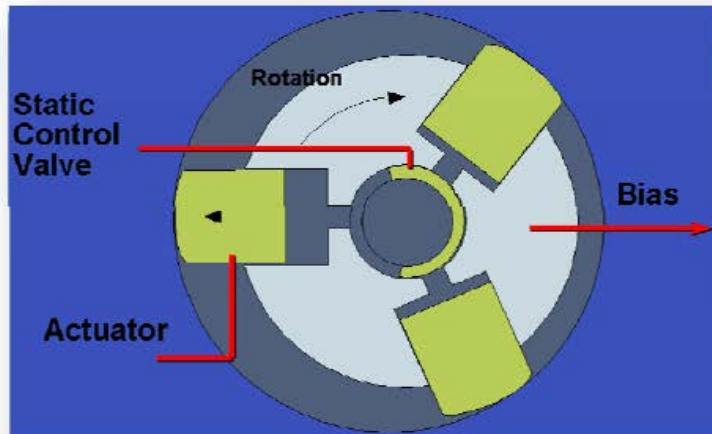
RSS exceptional drilling performance in 8 1/2" hole

INDUSTRY DRILLING PERFORMANCE

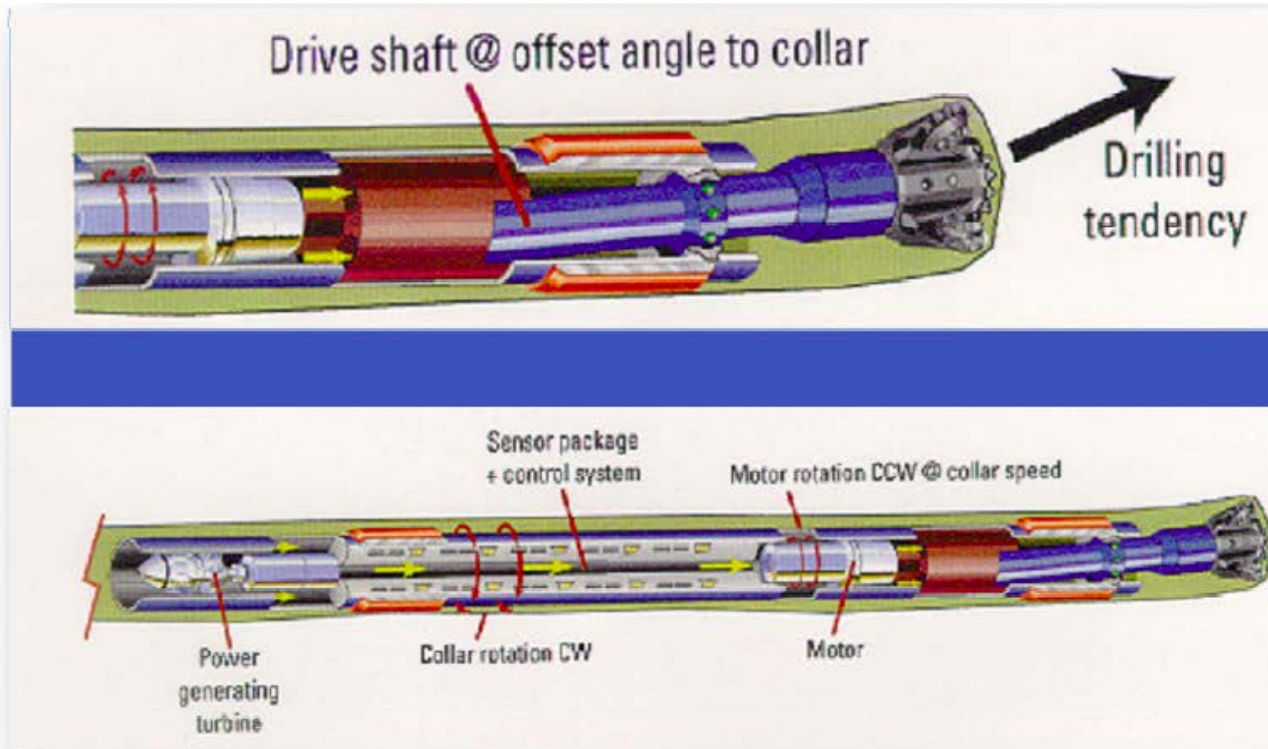
Rushmore Data - All European Semi Submersible New Horizontal Development Wells



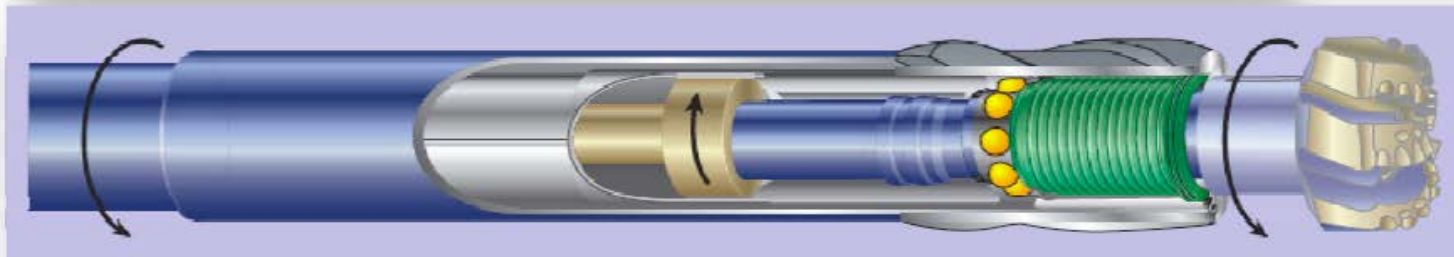
Schlumberger: PowerDrive (former CAMCO tool)



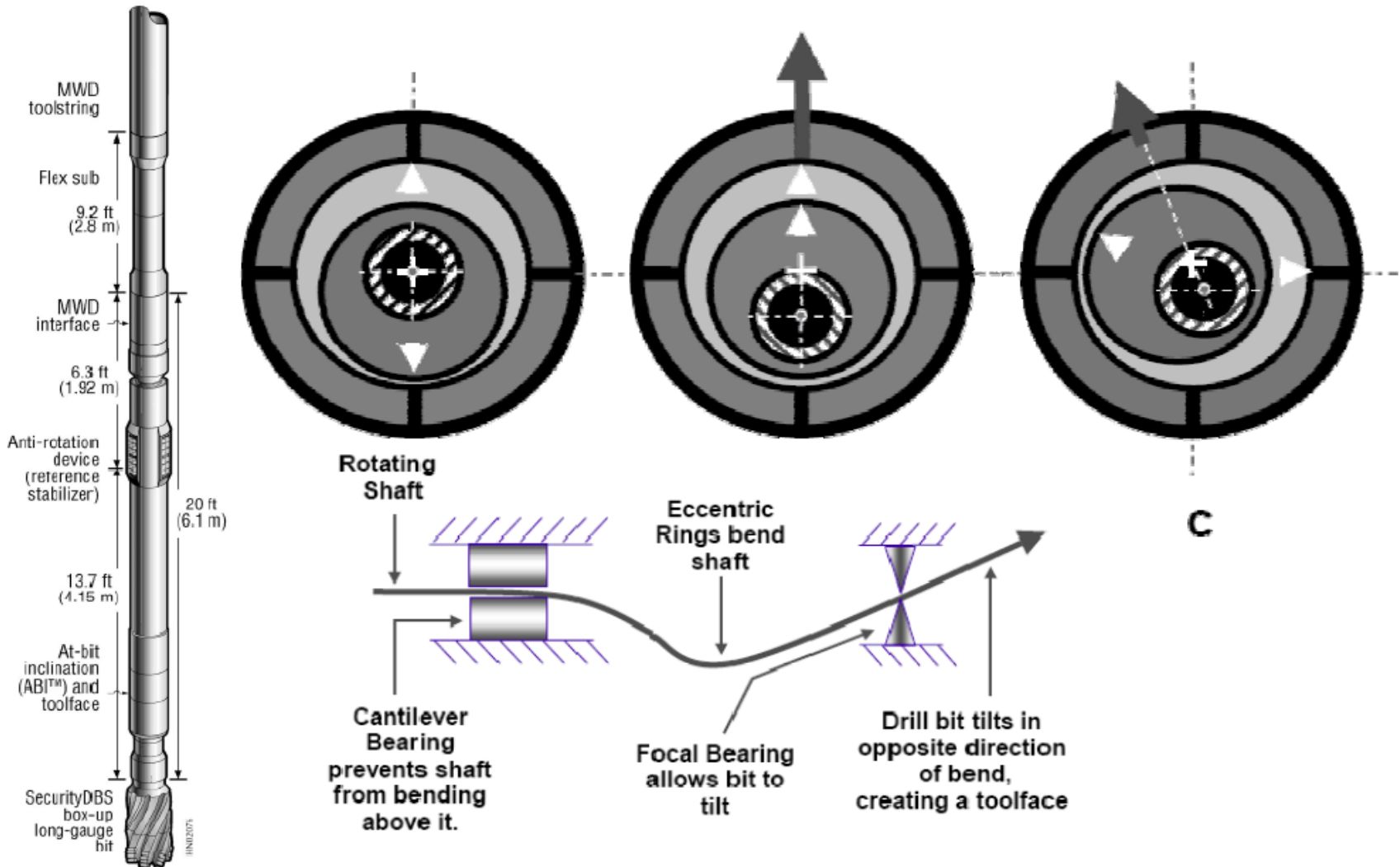
Schlumberger PowerDrive (point the bit)



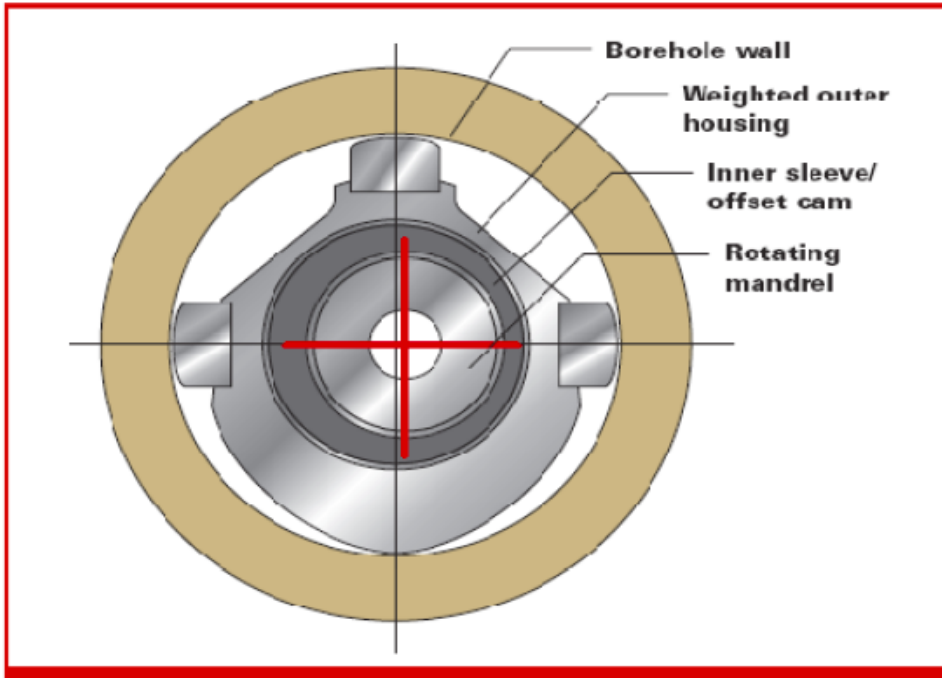
Functional Concept:
Deflection of the
Bit Drive Shaft



Halliburton GeoPilot



Halliburton (Sperry) EZ-Pilot



This cutaway shows the main components of the tool with a 90° right deflection. The EZ-Pilot™ system has fewer than 75 total components and is completely field serviceable.

- Low-cost RSS
- Sleeve orientation via gravity vector
- Orientation of the excenter sleeve by means of a battery powered electro-motor

Nobel Drilling – Well Director

4 Steering Ribs

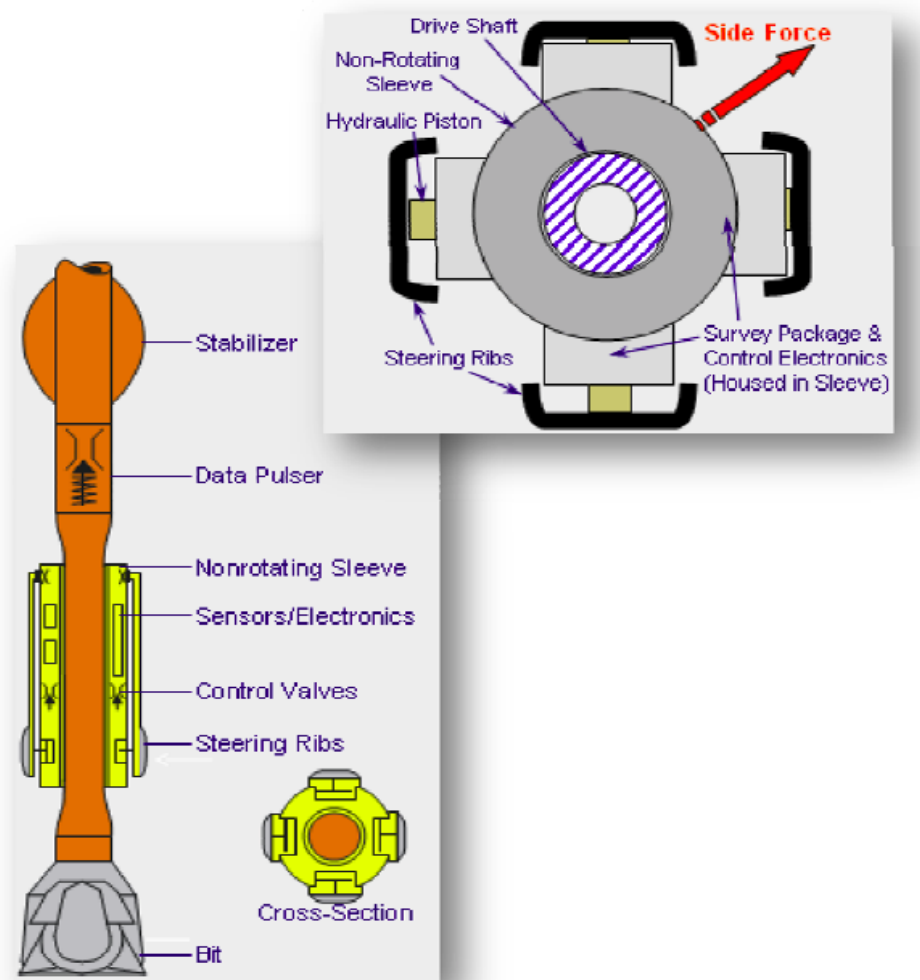
Same inventors as the one for the 1st generation AutoTrack

No rental services, only sale of tools

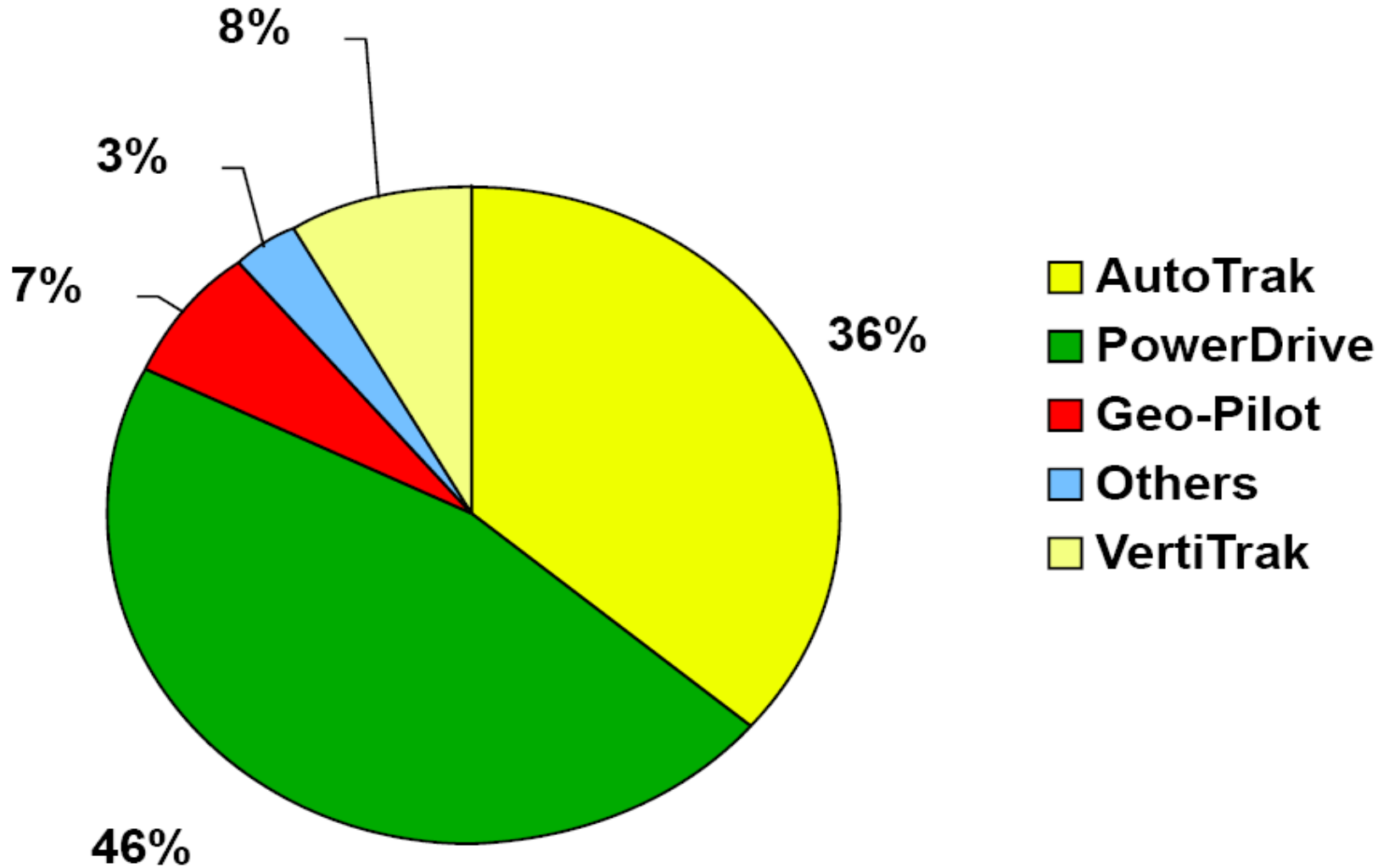
Limited success in the field (CND)

Downlink is the bypass mud flow

Rib actuation hydraulically



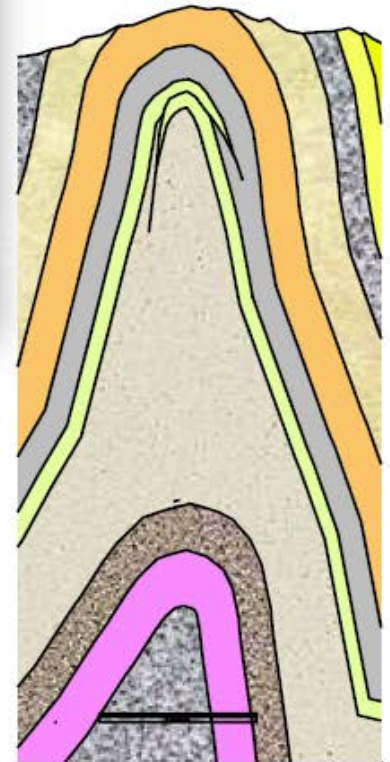
RSS: Market share 2004



Vertiklabohrsysteme

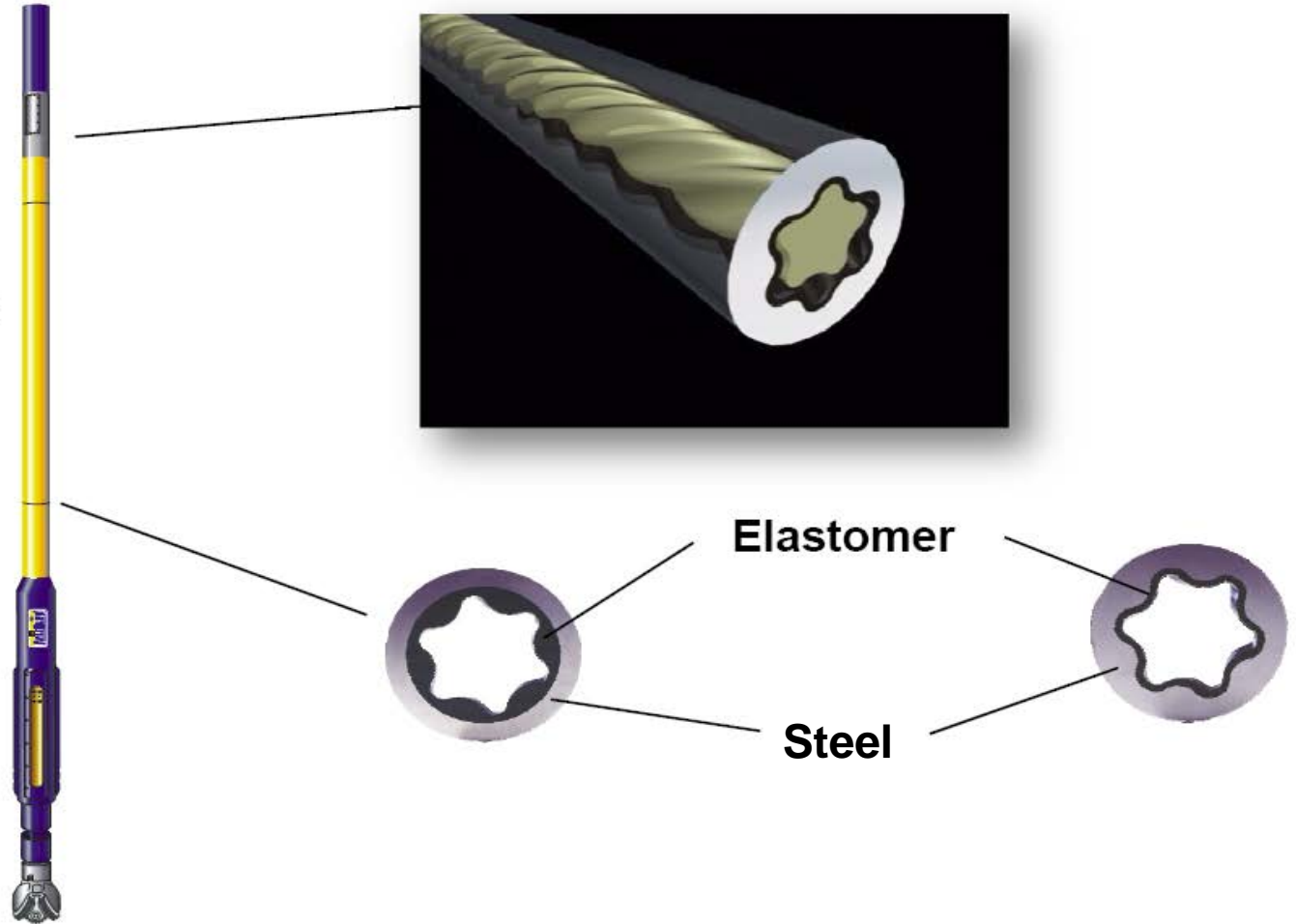
Vertical Steerable Systems (VSS)

Design Application



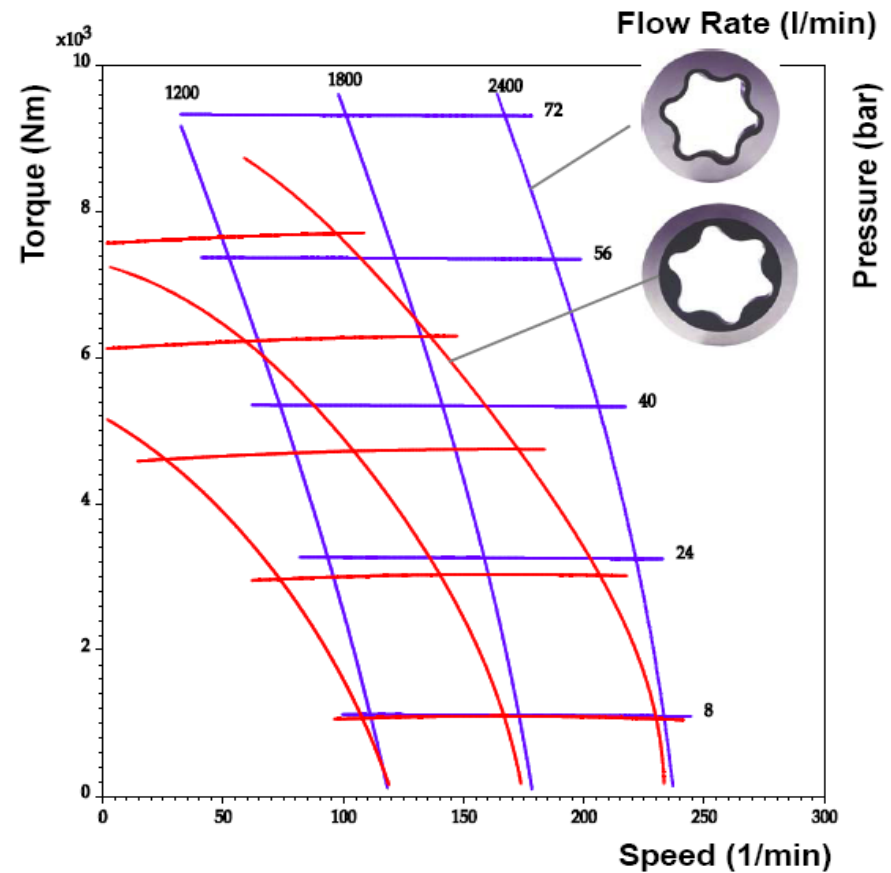
Principle design of a VSS

High Power
Motor section



Principle design of a VSS

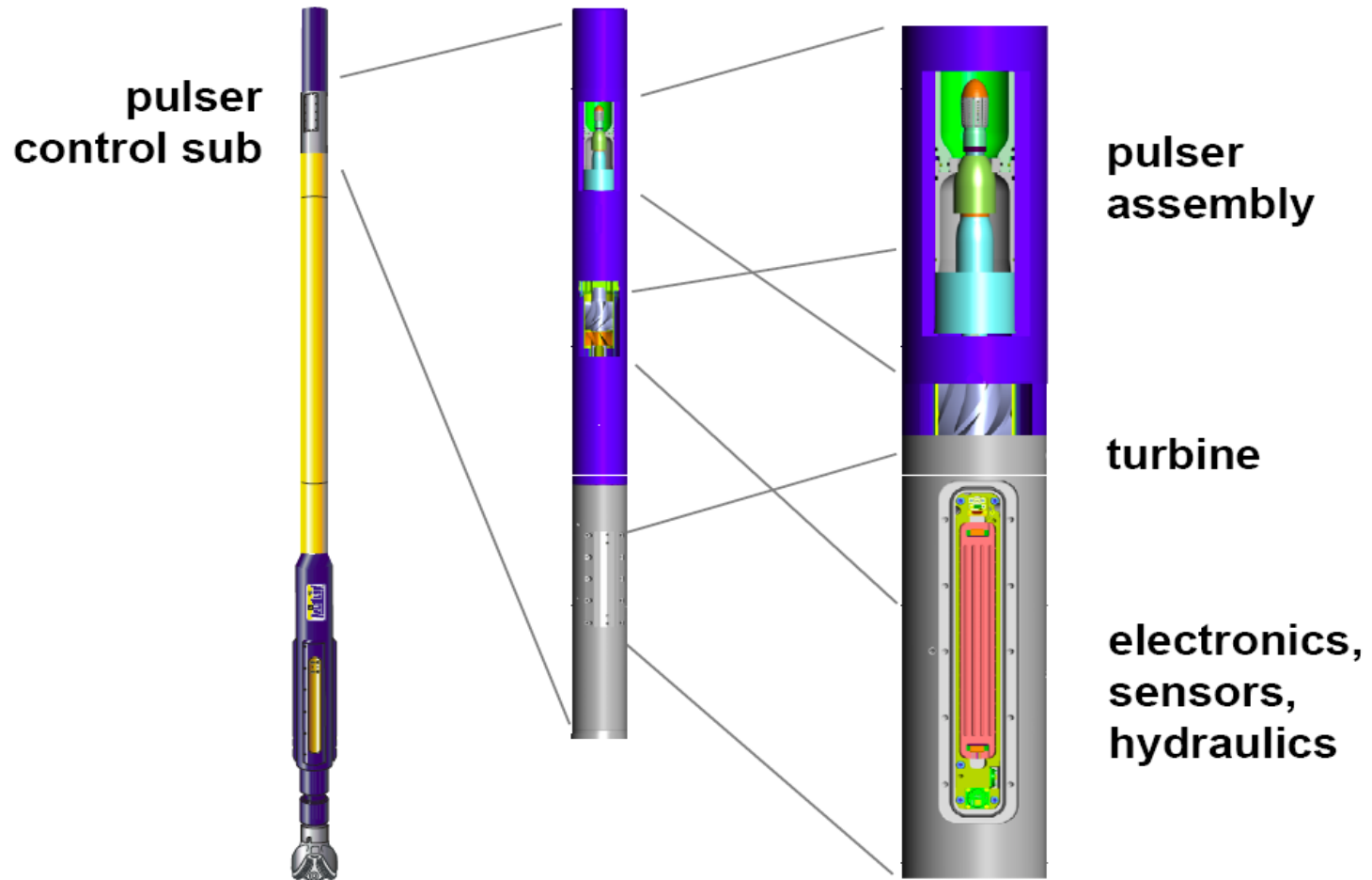
High Power
Motor section



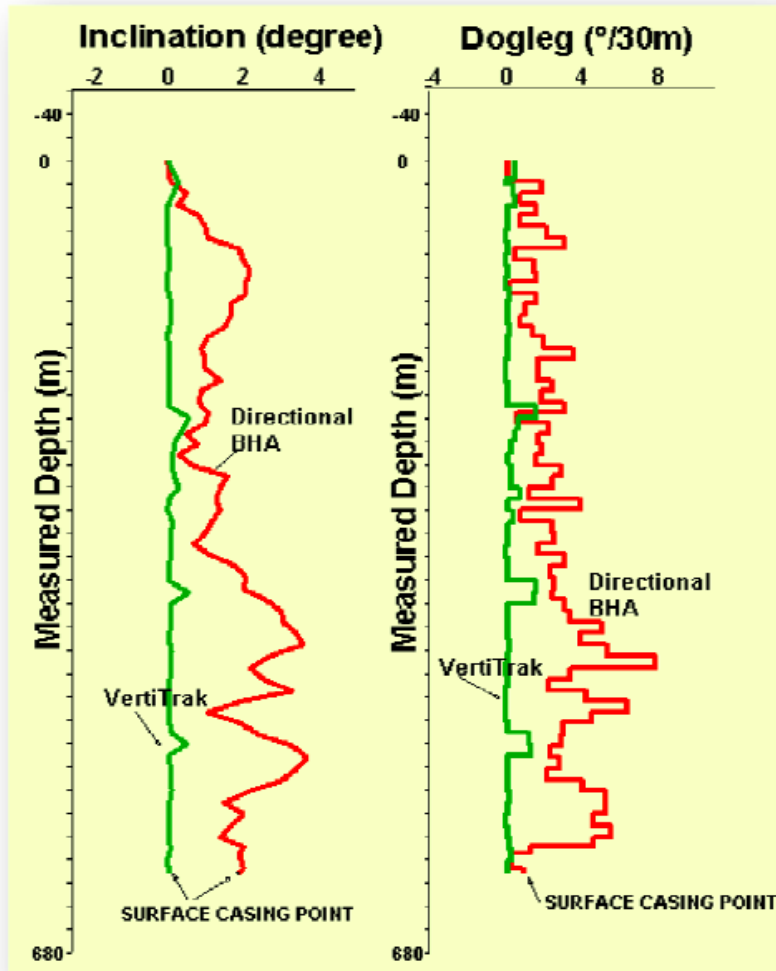
Principle design of a VSS



Principle design of a VSS



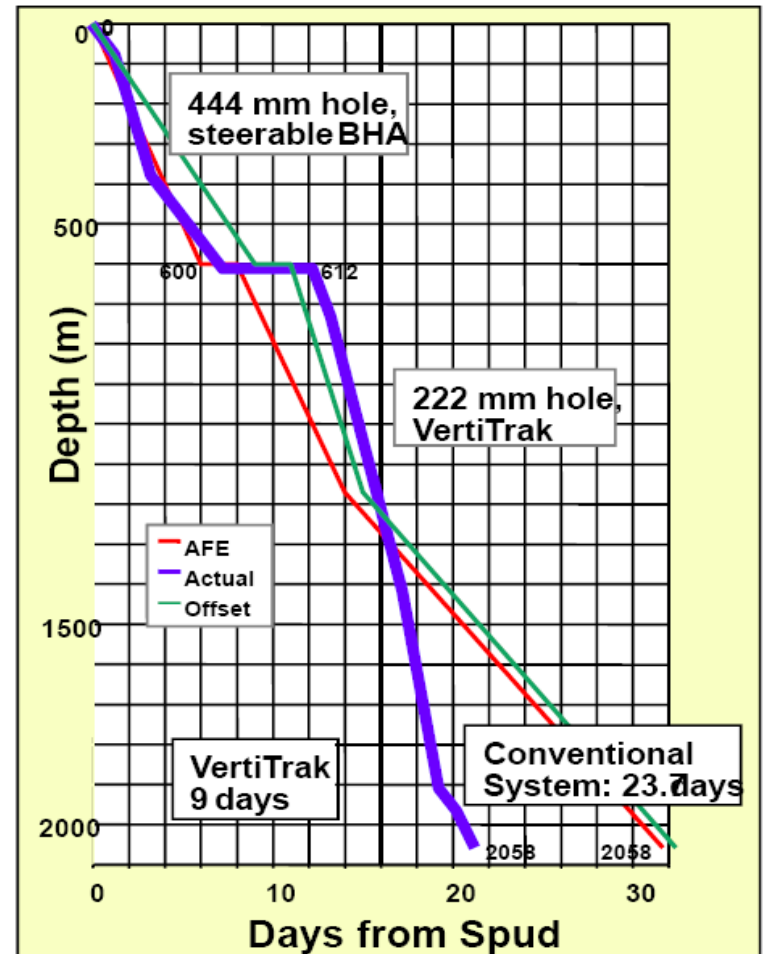
Test run – USA-Land



- Formation dip was 20° - 35°
- Typically high drag loads, especially in adjacent rotary sections
- Result:
 - the plan was for 10 drilling days, actual was 7 drilling days
 - no reaming runs required, very little drag loads
 - average dogleg was 0,11°/100ft
 - saving of 125.000 US\$ against original budget plan

Result: USA – Land

Section drilled in 9 days,
14 days faster than planned



Why VSS?

Tangible Value

High Quality Wellbore

Less Reaming

Increased Gross ROP

Reduced Torque and Drag

Less Cement

Fewer Bits / BHAs

Reduced wear on drill string

Reduced Operational Risks

Reduced wear on casing

Less fuel for mud pumps (less SPP)

Reduced Mud Bill

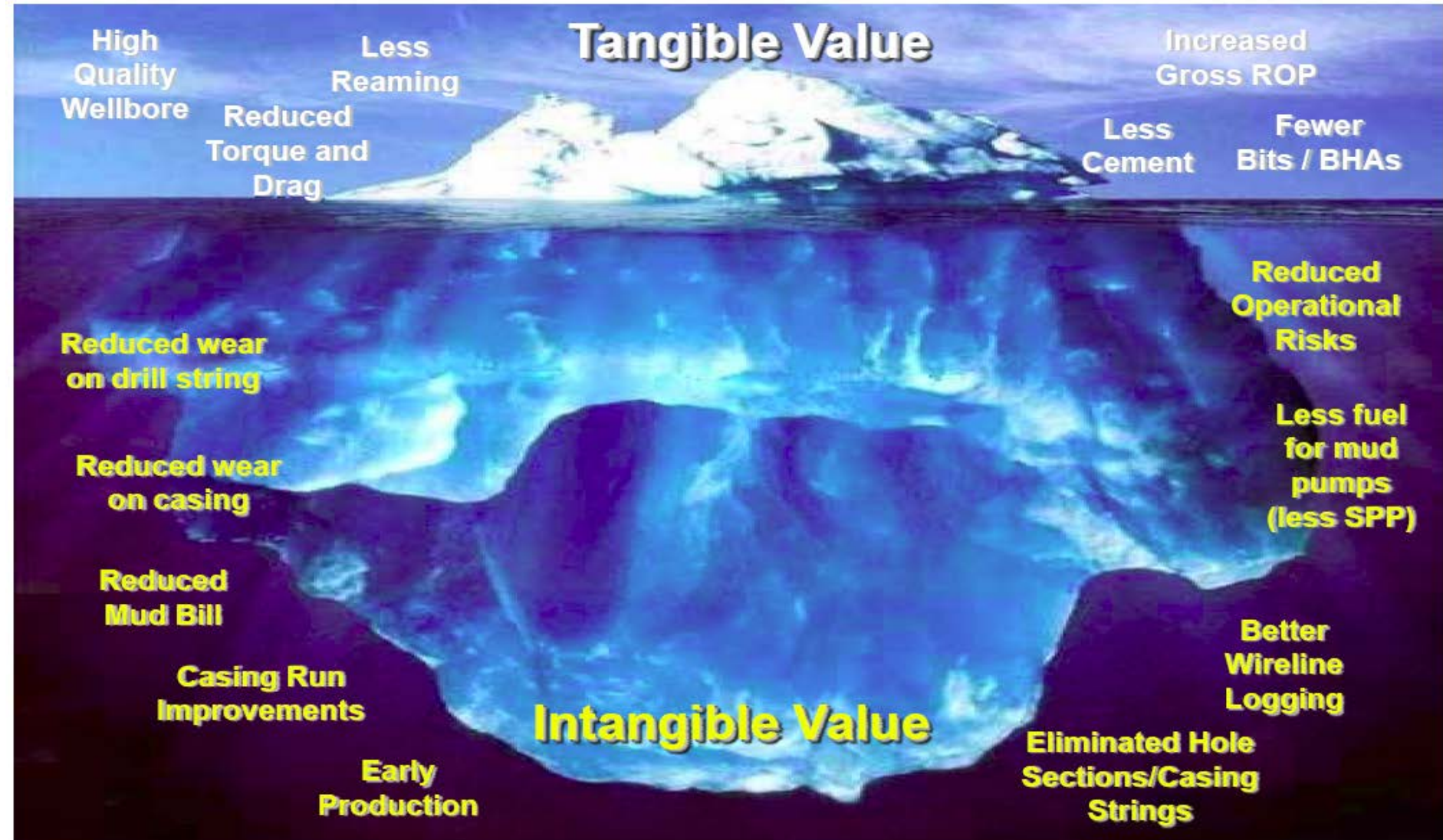
Better Wireline Logging

Casing Run Improvements

Intangible Value

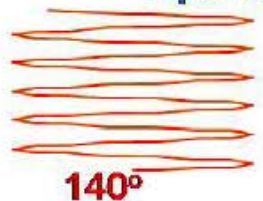
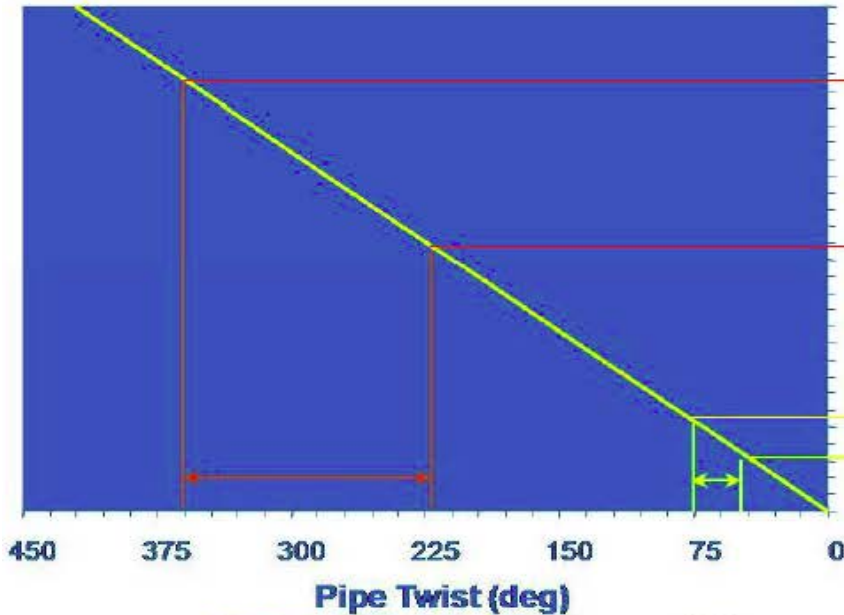
Early Production

Eliminated Hole Sections/Casing Strings



Fatigue reduction of drill pipe

Pipe Twist vs Torque
5,000 ft 5-1/2" Steel Drill Pipe

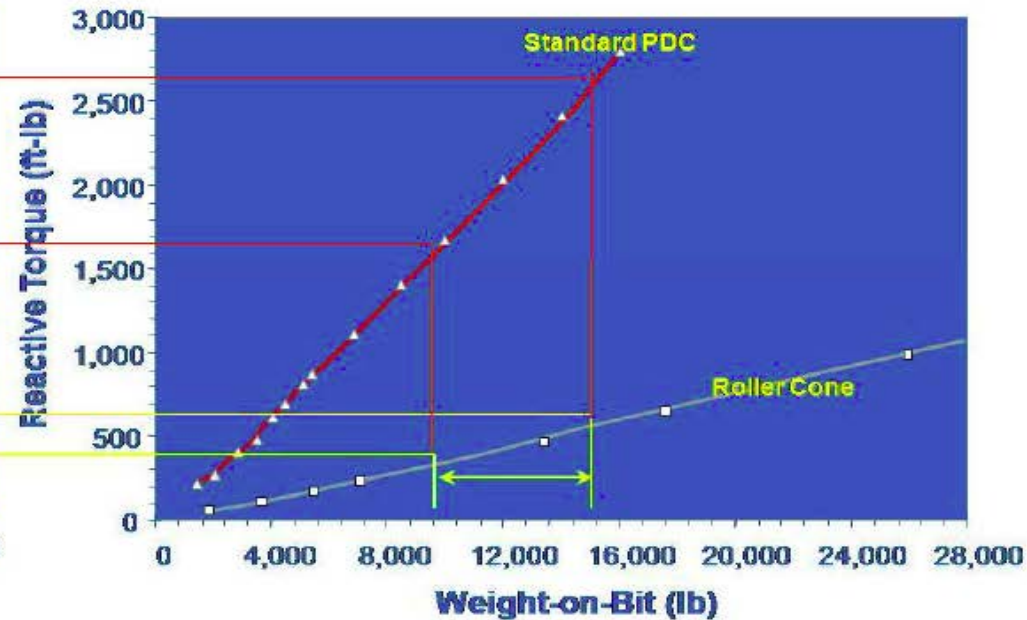


ROTARY



VSS

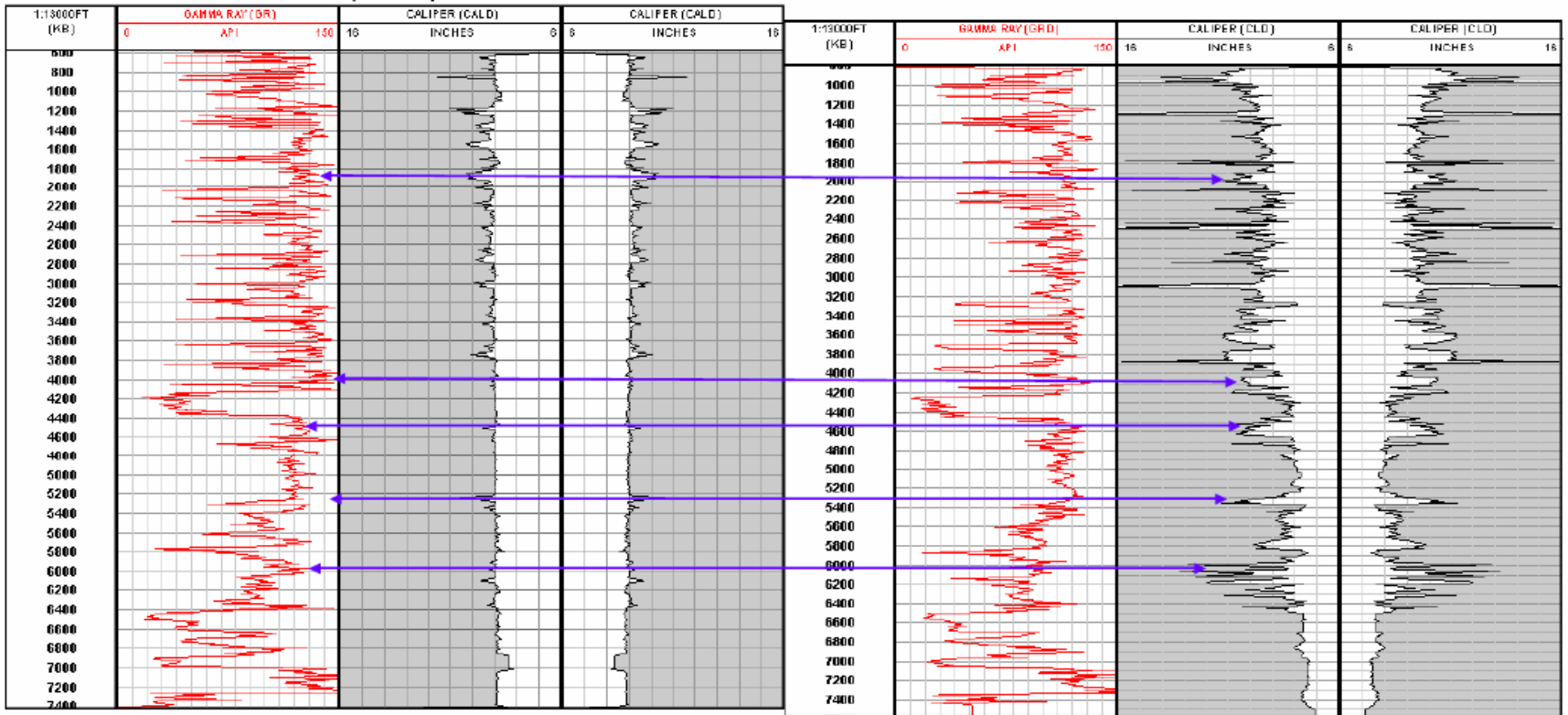
Drilling Torque vs. Weight-on-Bit
Various 8.500" Bits



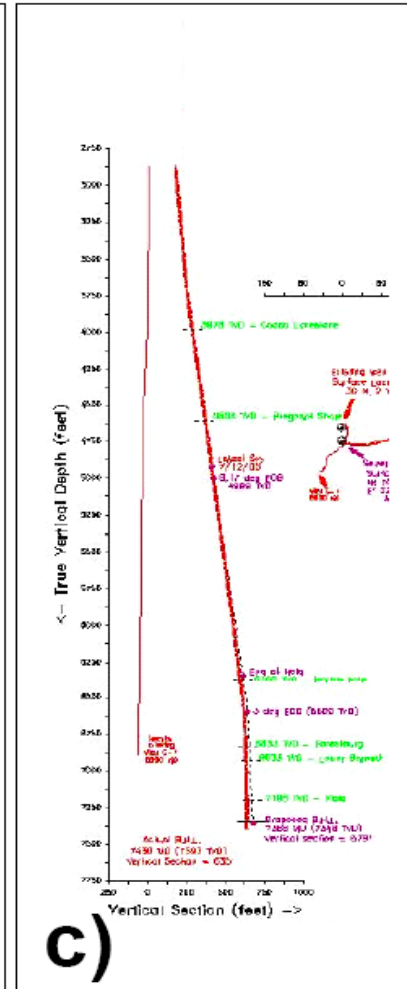
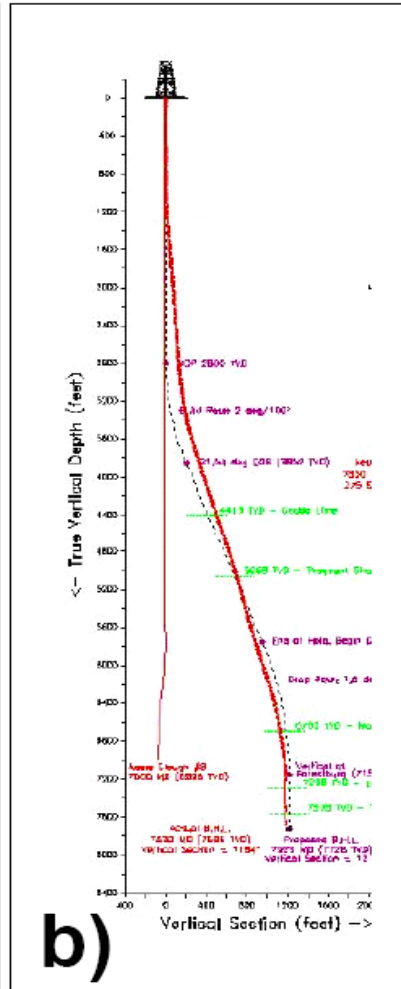
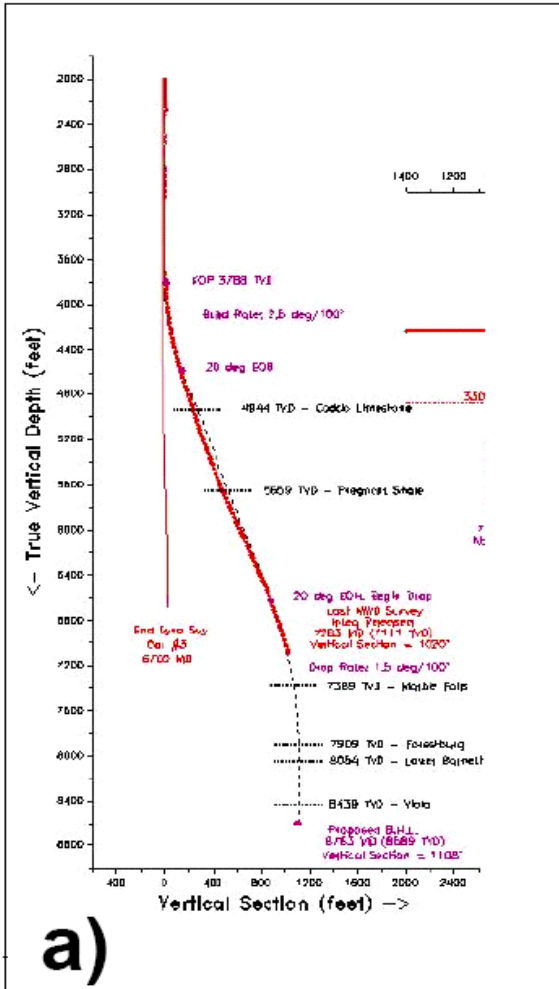
Superior borehole shape

Sewell Ranch 4D
(MCLS)

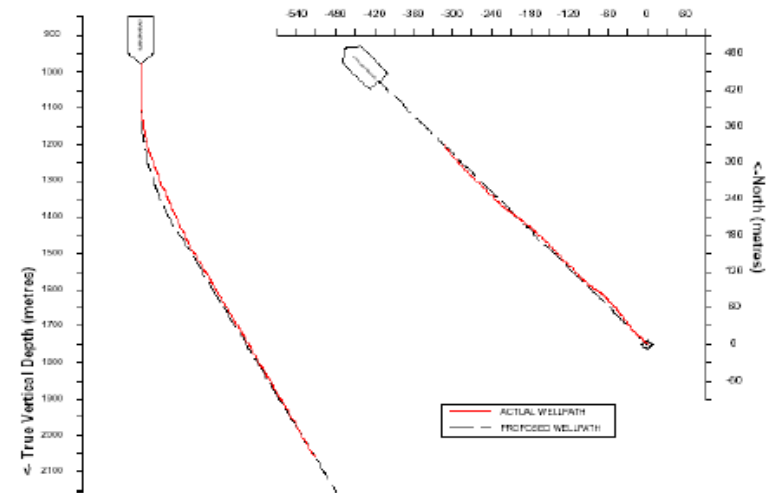
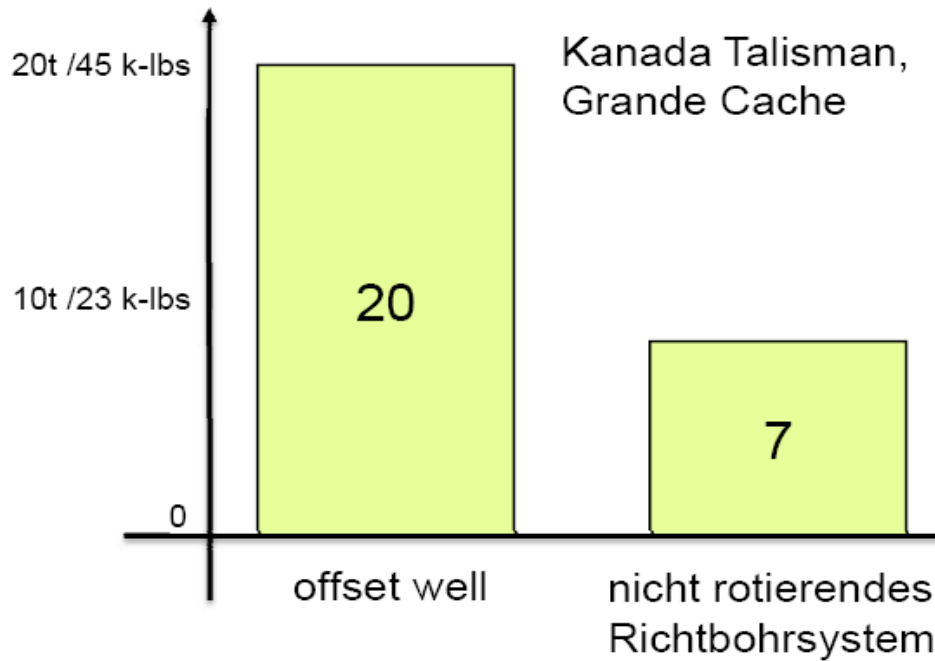
Sewell Ranch 1



Improved well planning



Reduced borehole drag forces



Thank You!

Q's please