Optimizing Drilling Efficiency by Addressing the Issue of Borehole Quality

Blaine Comeaux

SlickBore™

Drilling System

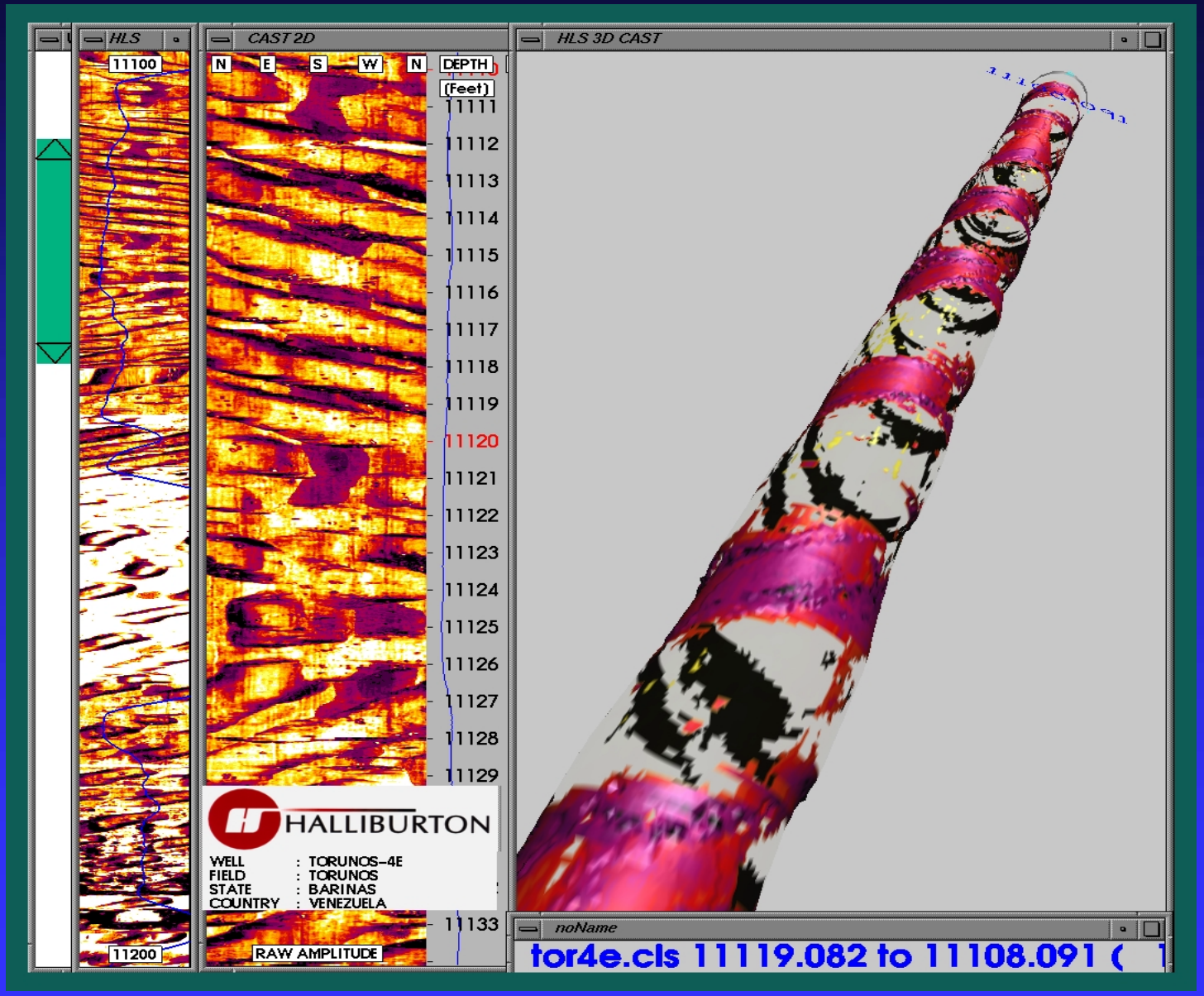
Geo-Pilot™

Rotary Steerable System

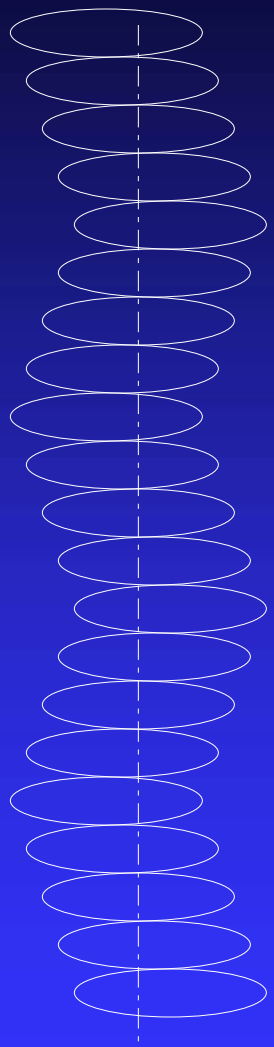
Introduction

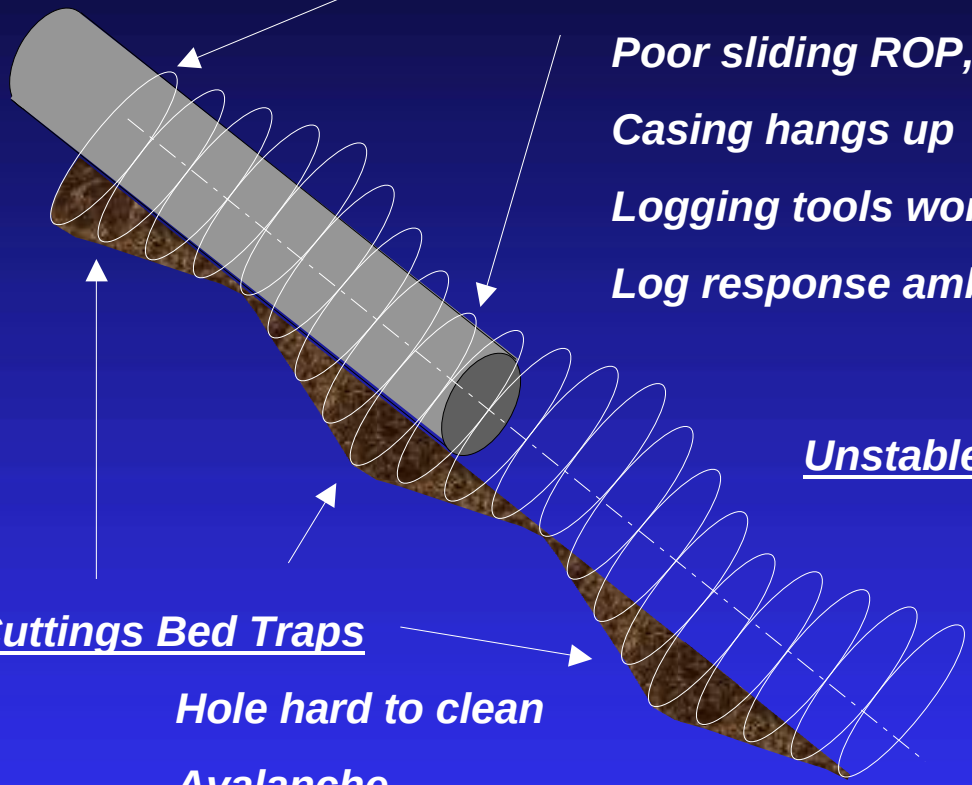
- Background: Wellbore Quality
- SlickBore System Description
- Geo-Pilot System Description
- Potential Benefits
- Case Histories
- Candidate Selection / Economic Evaluation

CAST Example of Hole Spiraling



Spiraling Results





Excess Sliding Friction

Poor sliding ROP, weight transfer

Casing hangs up

Logging tools won't go to bottom

Log response ambiguous

Unstable bit

Higher vibration

More failures

Shortened bit life

More trips

Cuttings Bed Traps

Hole hard to clean

Avalanche

Stuck Pipe

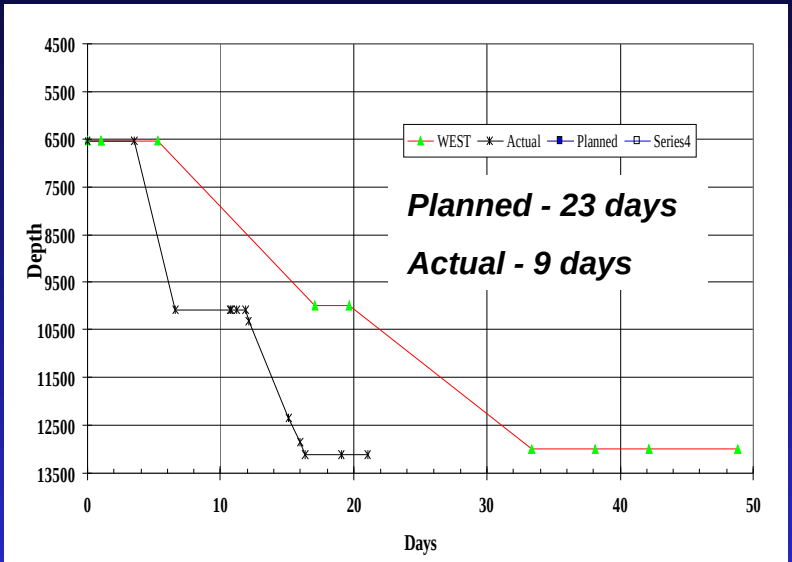
Backreaming cuts new rock

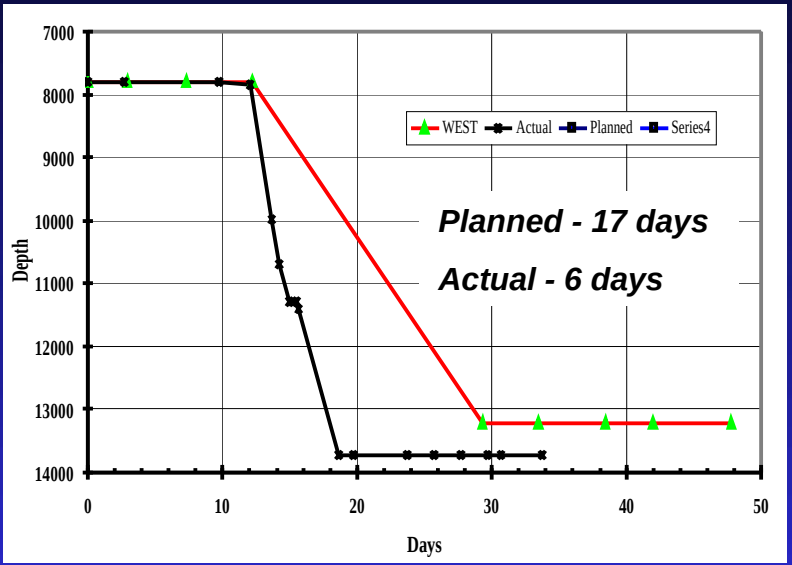
Poor Quality Cement Job

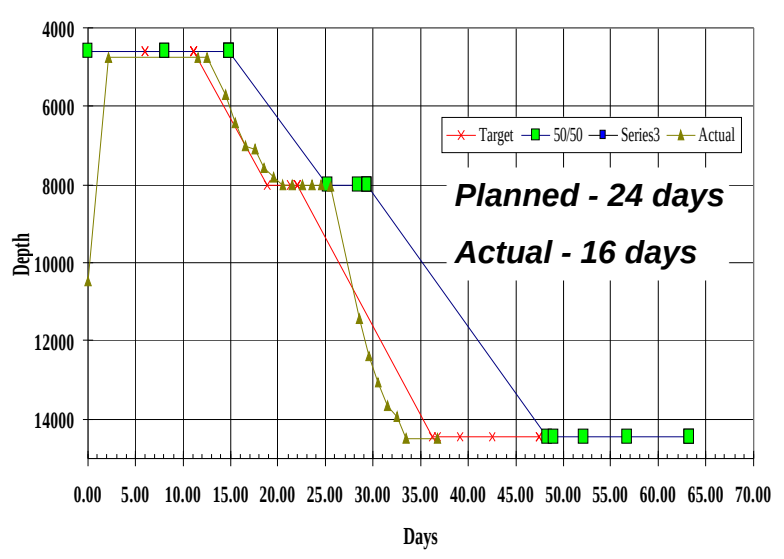
SlickBore Background

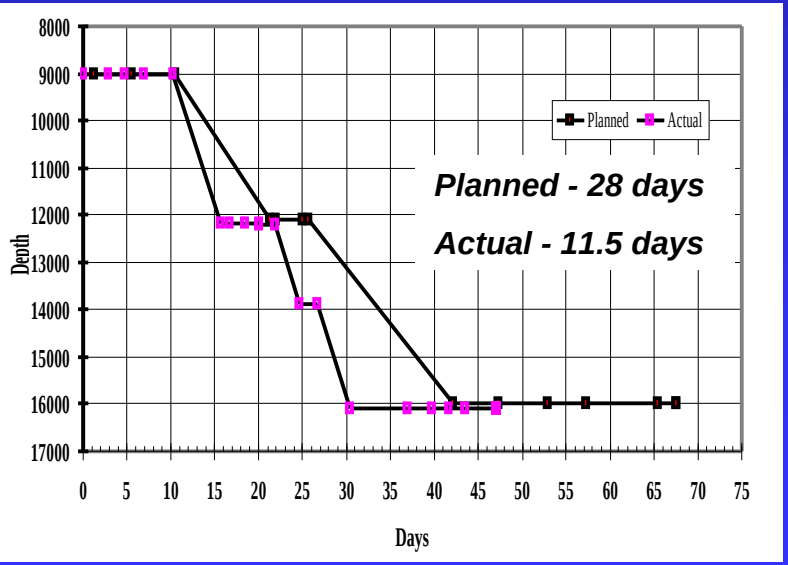
- Old North Sea field, heavily drilled, with following symptoms:
  - Poor sliding ROP relative to rotating ROP
  - Vibration-related tool failures
  - Problems getting casing to bottom
  - Excessive bit and downhole tool wear

Time/Depth Plots









*SlickBore Concept**

- **Matched Drilling System including:**

  Specially Designed PDM Motor

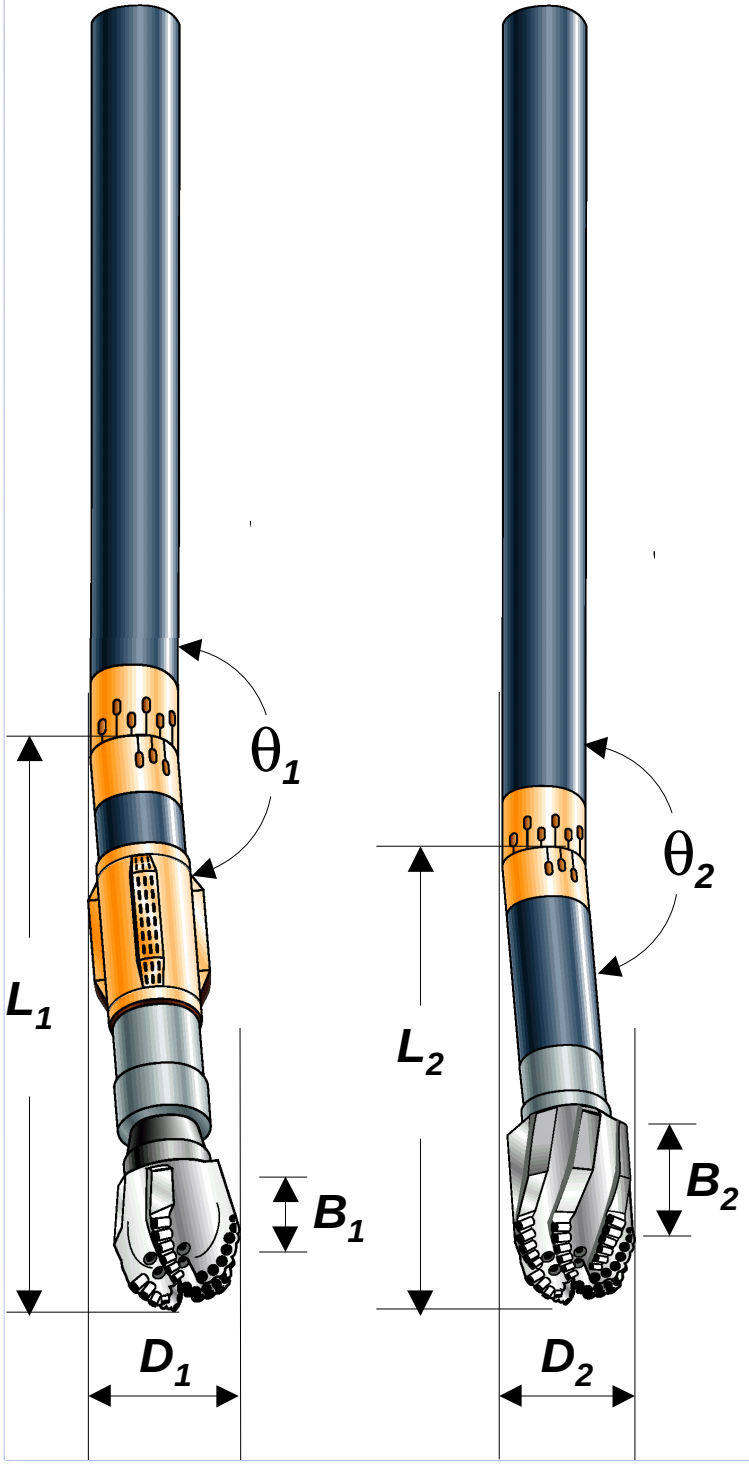
  - **Shorter Bit-to-Bend gives better steering with less bend angle on motor.**

  Long Gauge Bit

  - **Optimized cutting structure for better toolface control**

- **Incorporation of new directional drilling techniques**

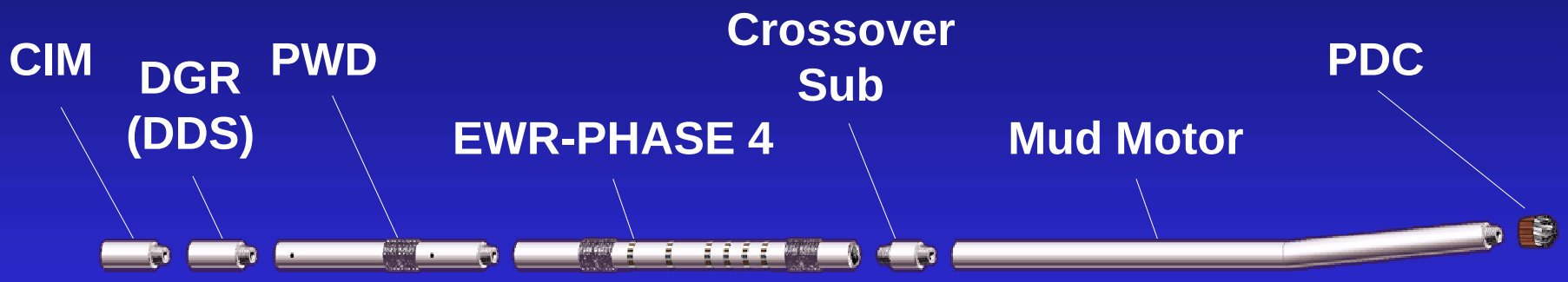
**** PATENT PENDING***



SlickBore vs. Conventional Motor

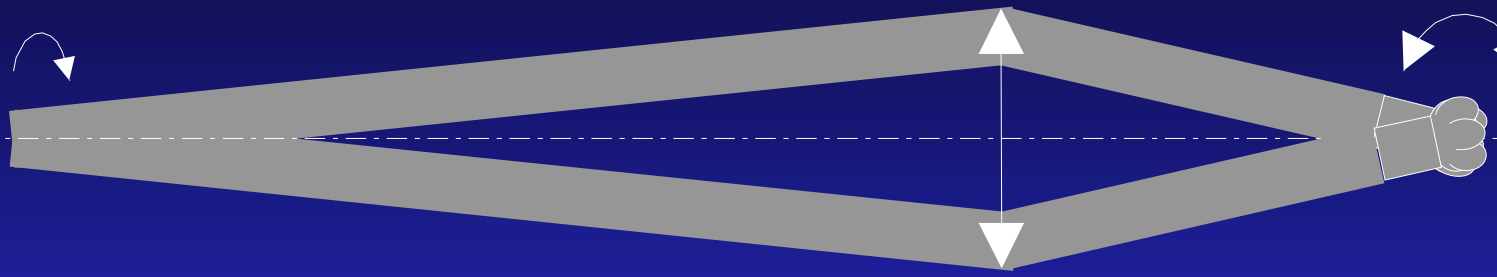
- Shortened Bit-to-Bend Length
  - Permits adding gauge length
  - Reduces the required Bent Housing angle for the same build rate
  - Reduces moment arm
  - Reduces radius of rotation

Typical SlickBore BHA

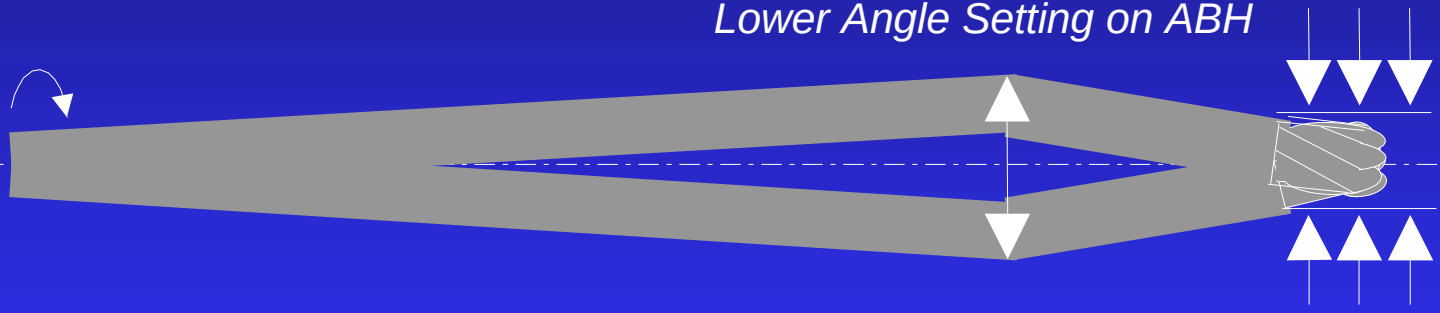


BHA Stability

Short Gauge Bit



Lower Angle Setting on ABH



SlickBore Bit

Potential SlickBore Benefits

- Straighter hole
  - Less hole tortuosity
  - Less hole spiraling

Ù Better hole cleaning, easier trips

Ù Lower torque, better weight transfer

Ù Improved log response, less cement channeling, less keyseating, better gravel pack success

- Better bit stability
  - More efficient cutting
  - Better tool face stability

Ù Increased bit life, faster drilling

Ù Higher ROP's, longer runs

Ù Higher sliding ROP's

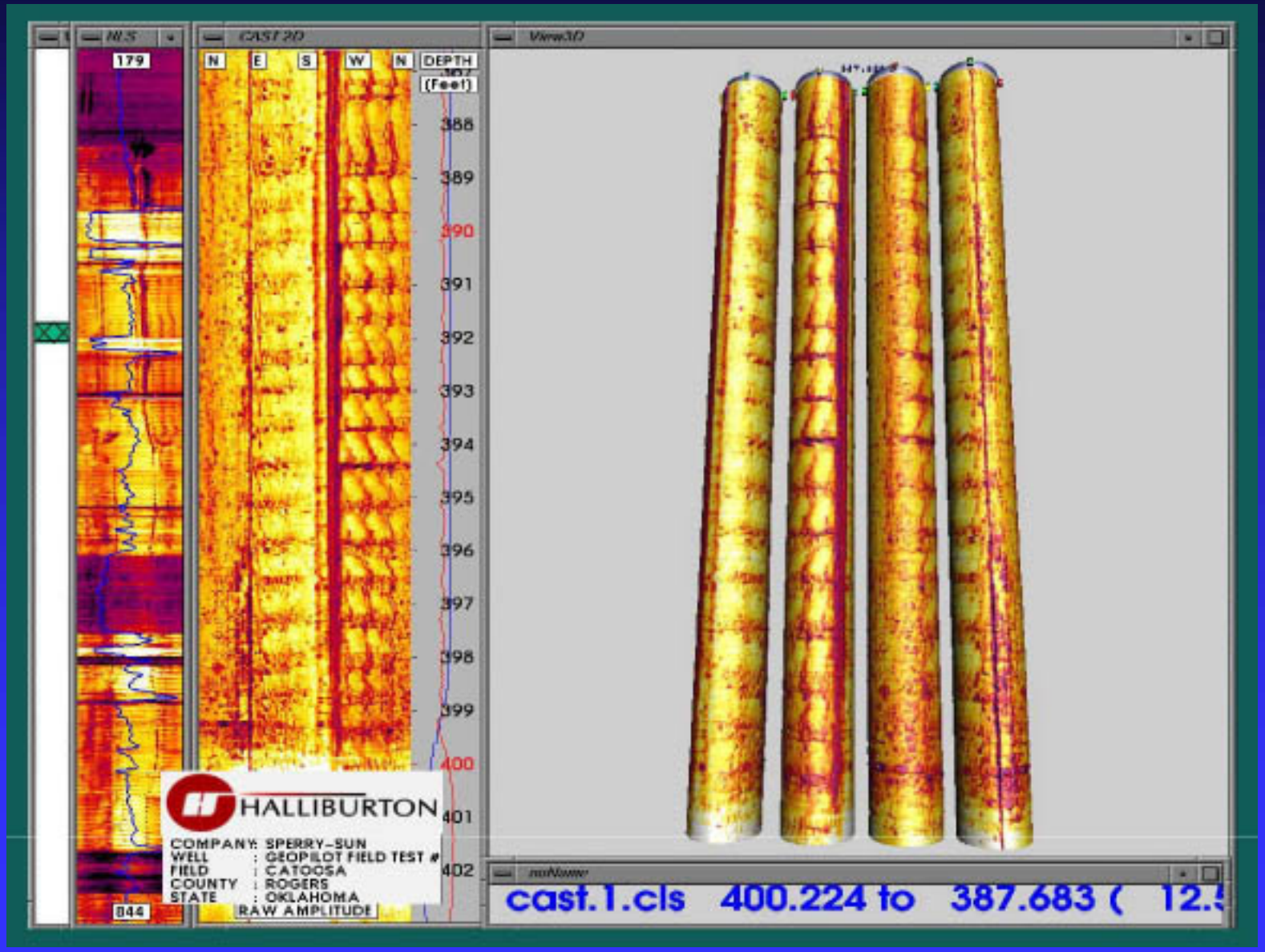
- Reduced vibration

Ù Minimize trips for failures

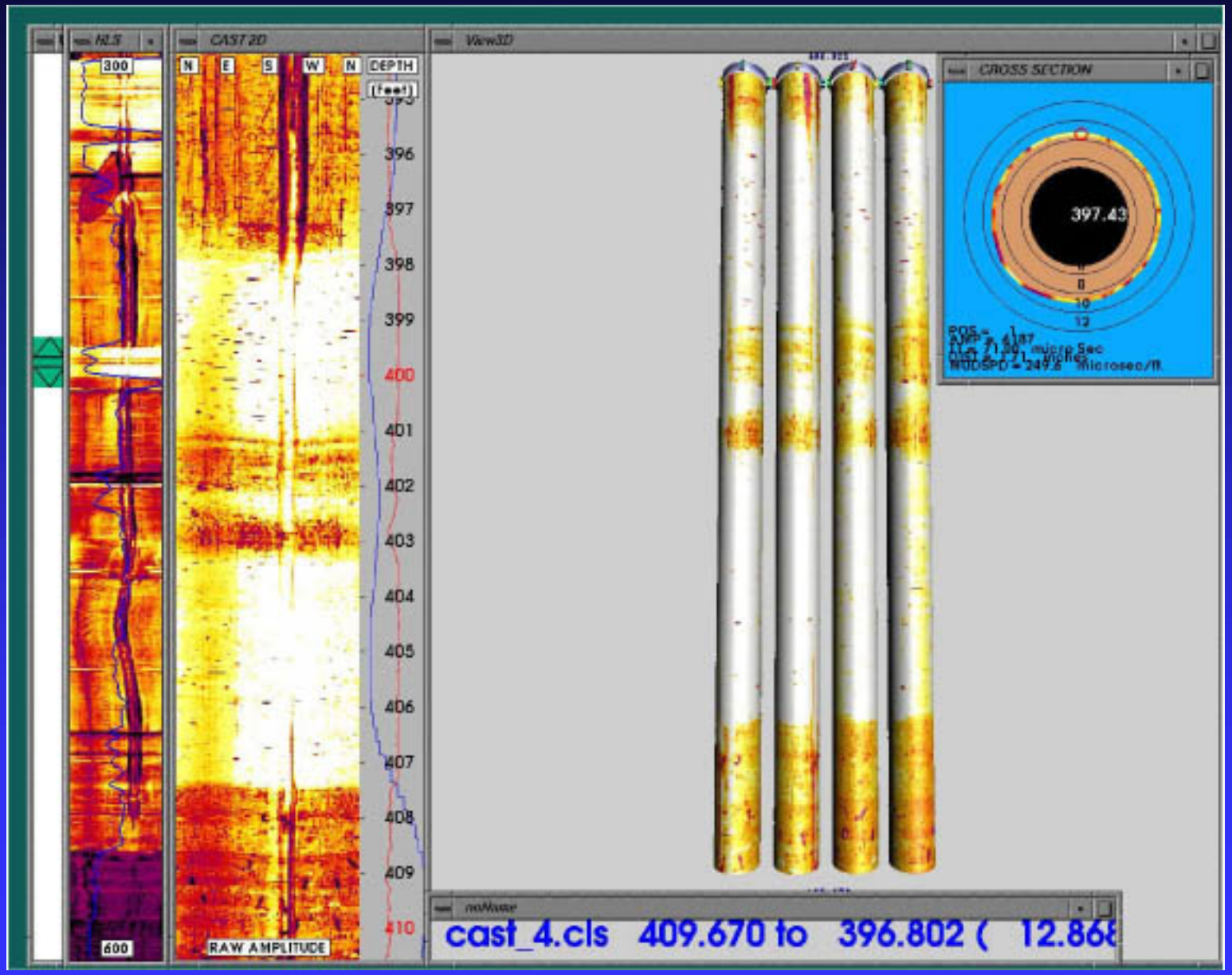
- Reduced bending stress

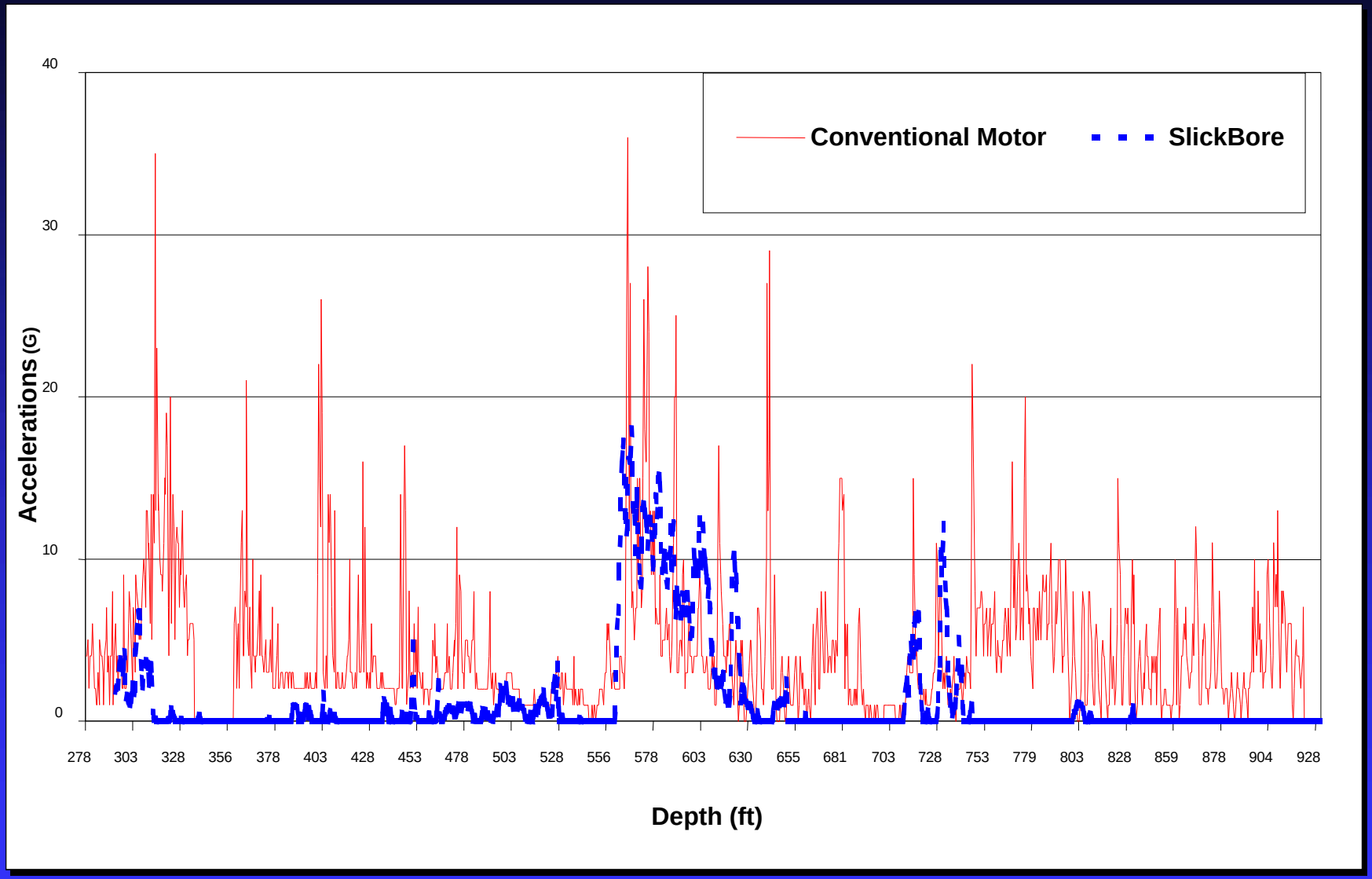
Ù Increased component life

CAST Image - Conventional Steerable Assembly



CAST Image - SlickBore




Conventional Motor
SlickBore
Accelerations (G)
40
30
20
10
0
278 303 328 356 378 403 428 453 478 503 528 556 578 603 630 655 681 703 728 753 779 803 828 859 878 904 928
Depth (ft)

Catoosa Test Results

BHA No.	Bit Gauge Length (in.)	Motor Configuration	High Side Tool Face Sliding			Low Side Tool Face Sliding			Rotary Drilling[3]		
			Inc. (deg.)	Predicted DLS (deg/100')	Measured DLS (deg/100')	Inc. (deg.)	Predicted DLS (deg/100')	Measured DLS (deg/100')	Inc. (deg.)	Predicted DLS (deg/100')	Measure DLS (deg/100
1	10	1.15 deg bend	10	9.3	10.1	--	--	N/A	21	2.5	0.2
2	10	1.5 deg bend	39	16.2	15.4	--	--	N/A	50	3.2	-0.8
3[1]	10	1.5 deg bend with 1stab at motor and 1 at BHA	54	10.8	11.6	--	--	N/A	--	--	N/A
4	10	1.15 deg bend and ABI bearing pack	10	8.9	8.2	--	--	N/A	18	2.5	0.1
5	18	1.15 deg bend	35	12.1	12.7	53	-6.1	-6.9	53	3.6	0.2

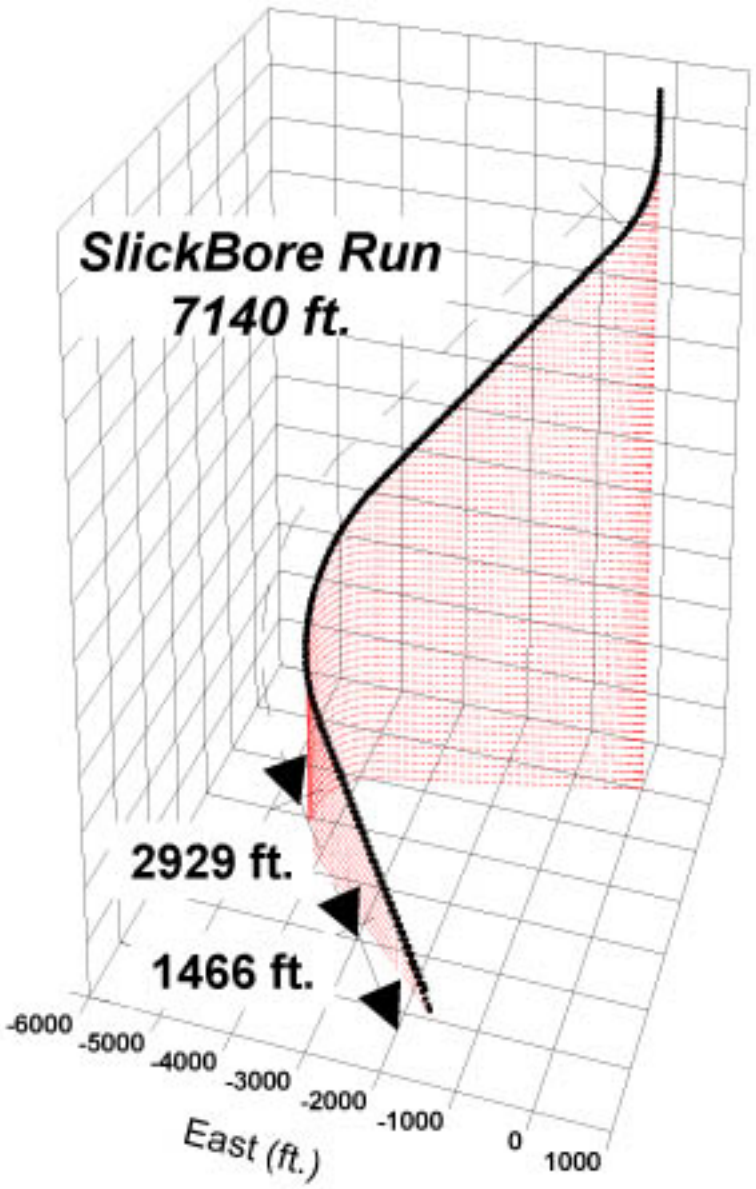
18” Gauge Bit after Bit Runs

Catoosa Test Results

- Determined Bit-to-Bend length is critical
- Appears that long gauge bit acts as stabilizer
- Confirmed vibration reduction
- CAST image demonstrated high wellbore quality
- Proved 10” and 18” gauge bits can build

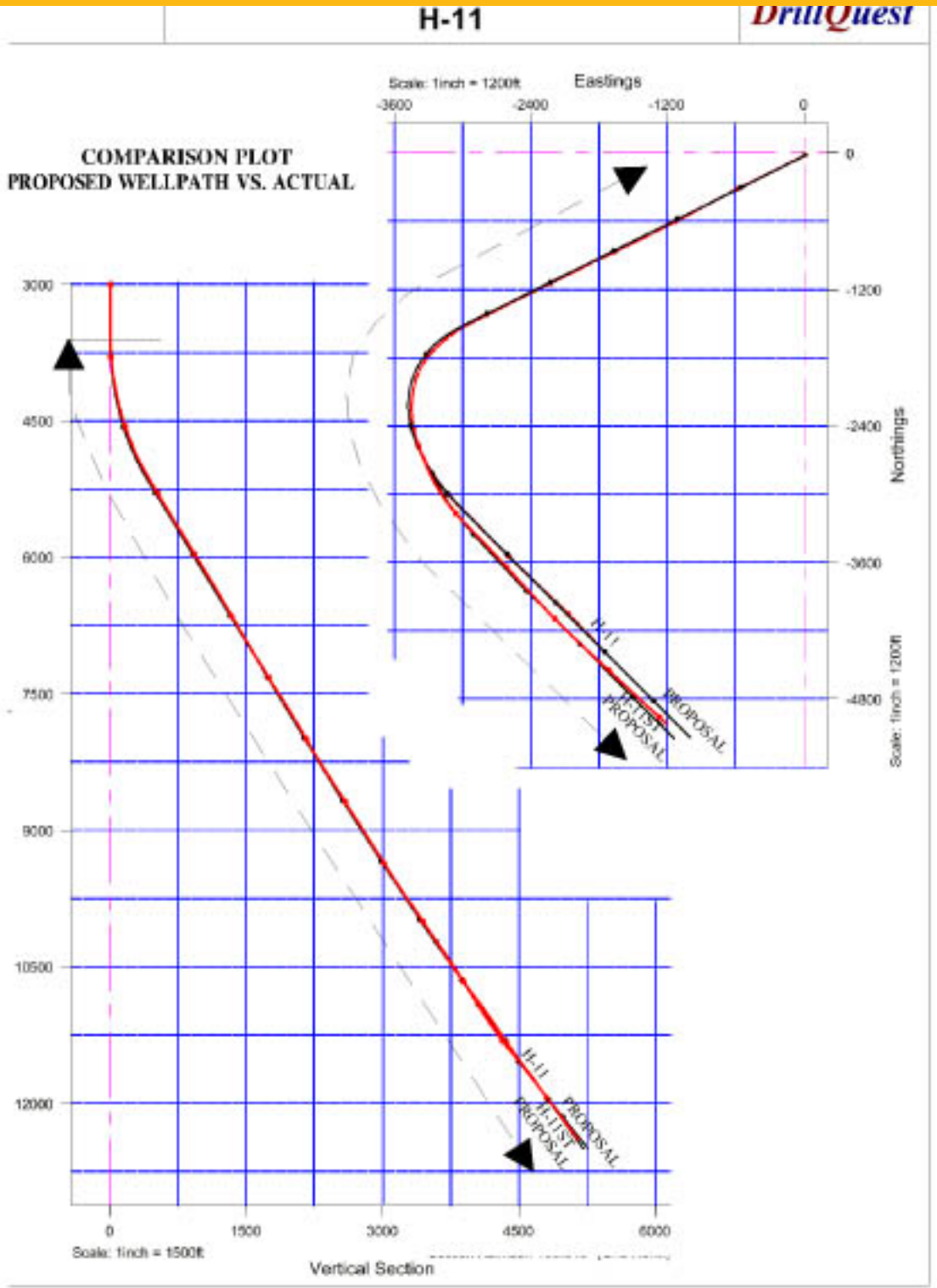
SlickBore Results

- Over 130 runs completed or in progress
  - Time: 69% drilling, 8% circulating, 23% other
- Used in North Sea, Far East, GOM, US Land, and Offshore Canada (Sable Island & Terra Nova)
- AFE days reduced 15-50%
- Less weight-on-bit required to drill
- Fewer MWD and mud motor failures
- Decreased bit wear
- DDS™ sensor data supports vibration reduction
- Casing ran to bottom very easily



Ship Shoal H-8

- 12-1/4” hole, Synthetic mud
- 3,505’ - 10,645’ (7,140’) SlickBore
- 85 hours drilling
- 60.5 hour circulating/reaming
- Average ROP: 84 ft/hr
- Sliding ROP: 54 ft/hr
- Rotating ROP: 93 ft/hr (77% of ftg.)
- 11, 535’ total open hole with 121° azimuth change at 35° - 53° inclination
- Torque and drag significantly lower than predicted by model



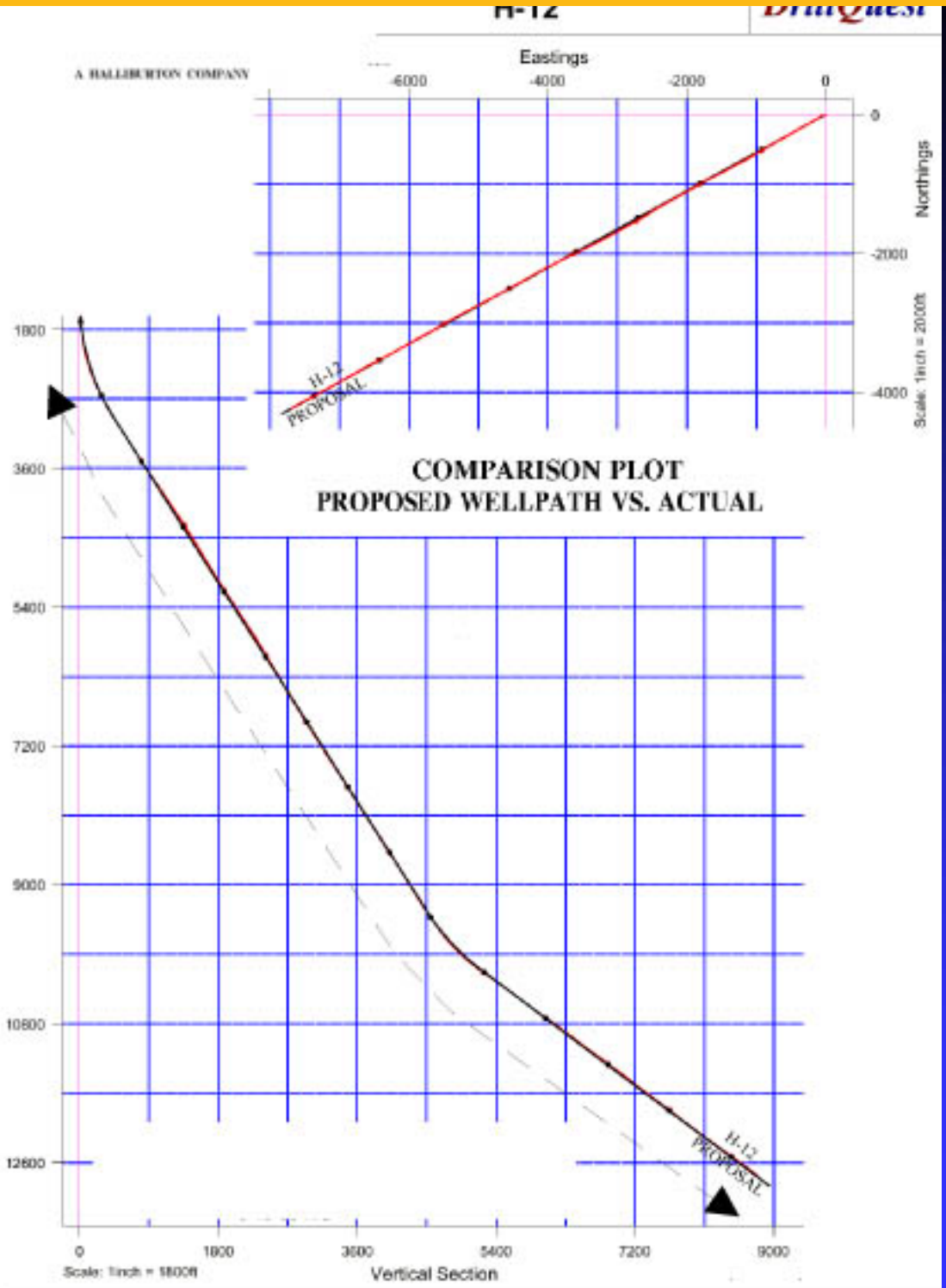
Ship Shoal H-11

- 8-1/2” Hole
- 3,500’ - 14,627’ (11,127’)
- 84.5 hrs drilling
- 10.0 hrs circulating
- Average ROP: 132 ft/hr
- Sliding ROP: 79 ft/hr
- Rotating ROP: 143 ft/hr (83% of footage)

WELL H-11 TORQUE ANALYSIS

DEPTH (FT)	ACTUAL TORQUE (FT-LBS)	PREDICTED TORQUE (FT-LBS)	EQUIVALENT FRICTION FACTOR
3510	3000	770	0.1
4140	3175	976	0.01
4998	3650	1734	0.06
5762	4775	2985	0.14
6430	6893	4121	0.255
7192	7063	5206	0.193
7954	7688	6357	0.178
8717	7500	7519	0.137
9477	7750	8694	0.121
10239	9063	9913	0.136
11383	10563	11750	0.136
12145	10781	13877	0.122
12907	11313	15205	0.121
13662	13938	16553	0.15
14325	14643	18093	0.15

AVERAGE OPEN HOLE FRICTION FACTOR: 0.146



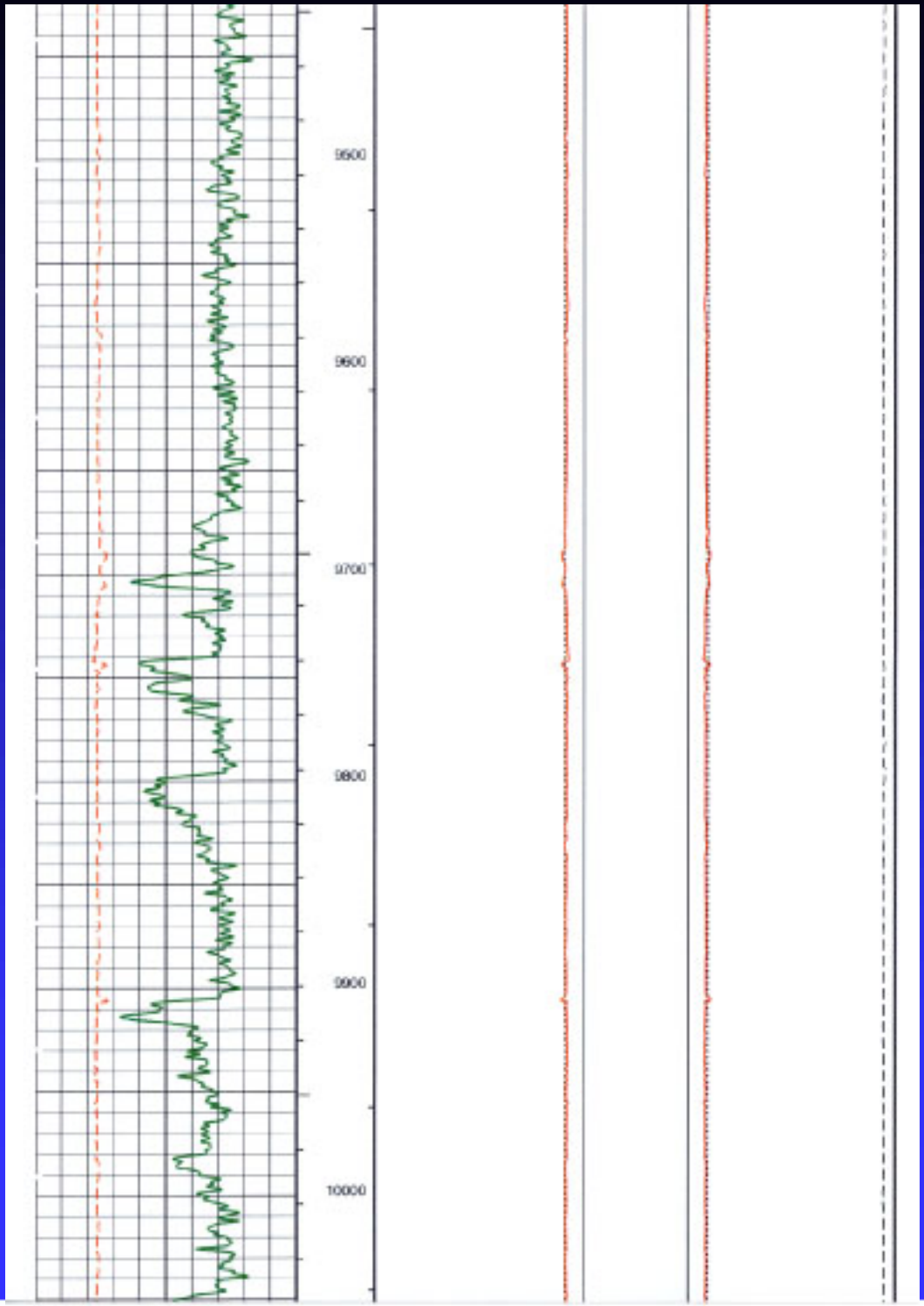
Ship Shoal H-12

- 8-1/2” Hole
- 3,263’ - 15,412’ (12,149’)
- 66.5 hours drilling
- 16.5 hours circulating
- Average ROP: 188 ft/hr
- Oriented ROP: 98 ft/hr
- Rotating ROP: 183 ft/hr
  (94% of footage)

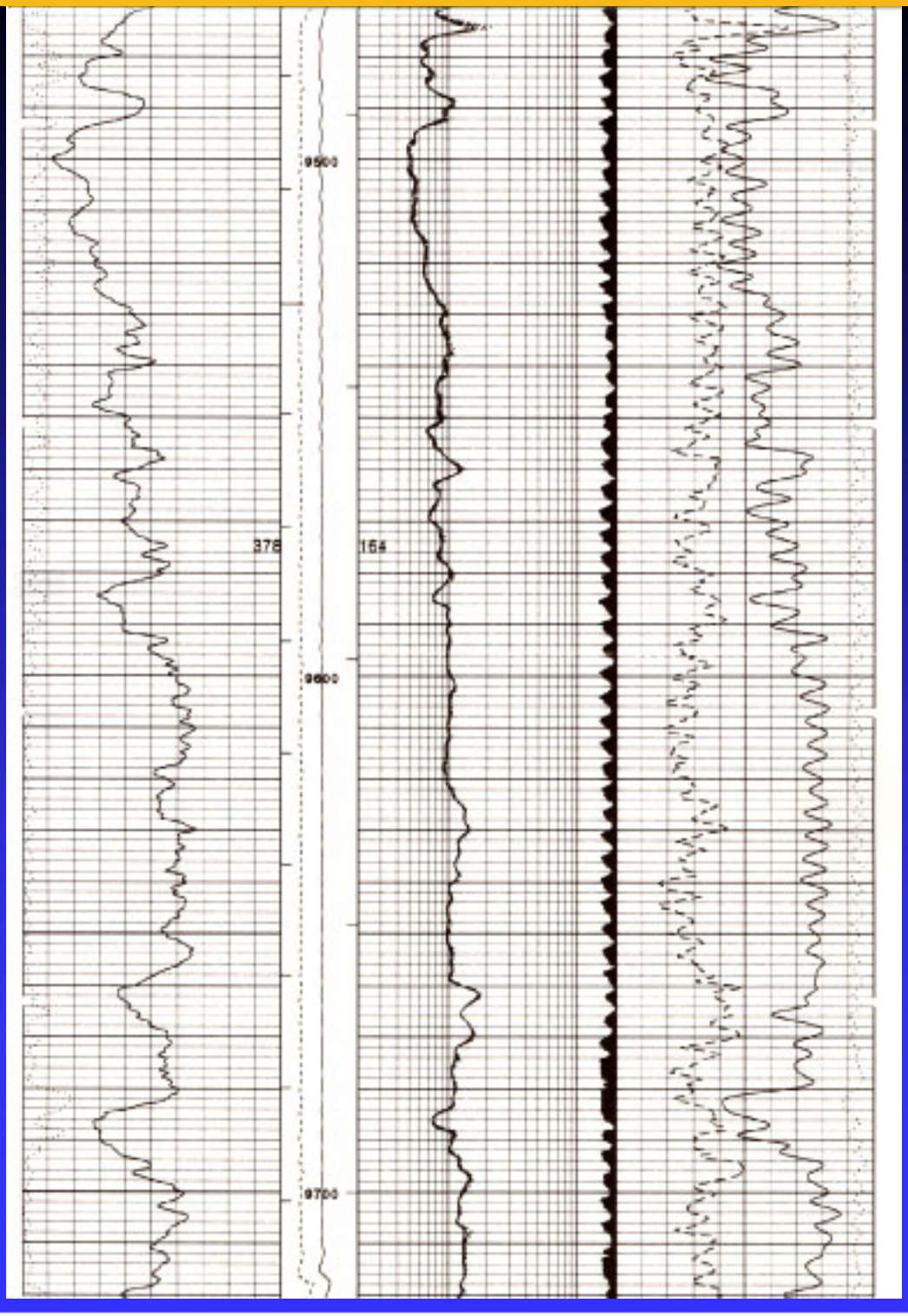
Ship Shoal Well H-12

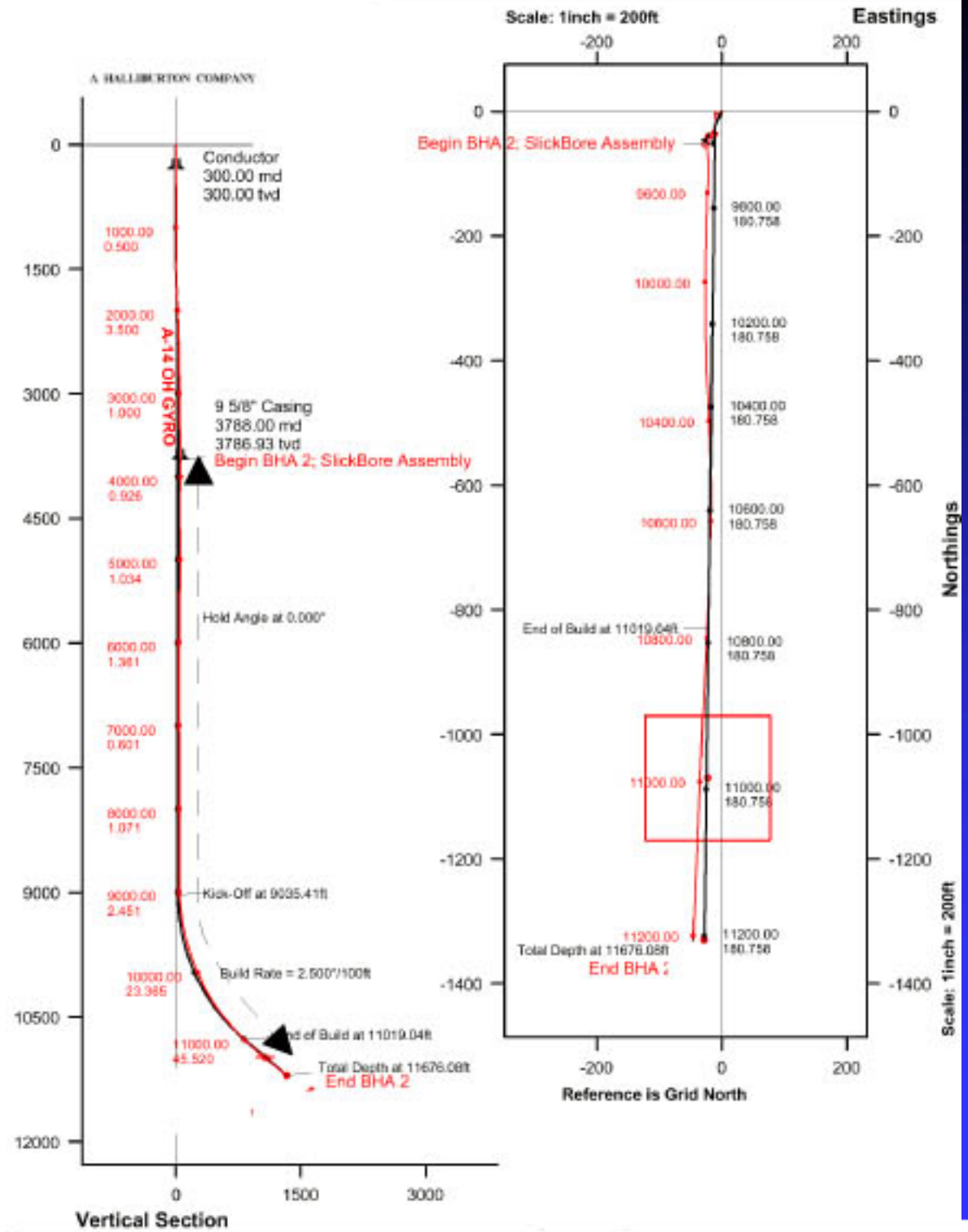
- 12,149’ drilled in 2.7 days (3,263’ - 15,412’)
  - 7,630’ drilled in 24 hours
- *This ROP is not abnormally high for this rig*
- No wiper trip was made during this entire run
- Minimal hole exposure time between drilling and casing
- Standard hole opener run indicated hole was gauge
- Caliper log proved hole was absolutely in gauge
- 7” casing went to bottom easily
- 100% success on cement jobs
  - Zero squeezes, excellent CBL/CAST-V

Ship Shoal Well H-12



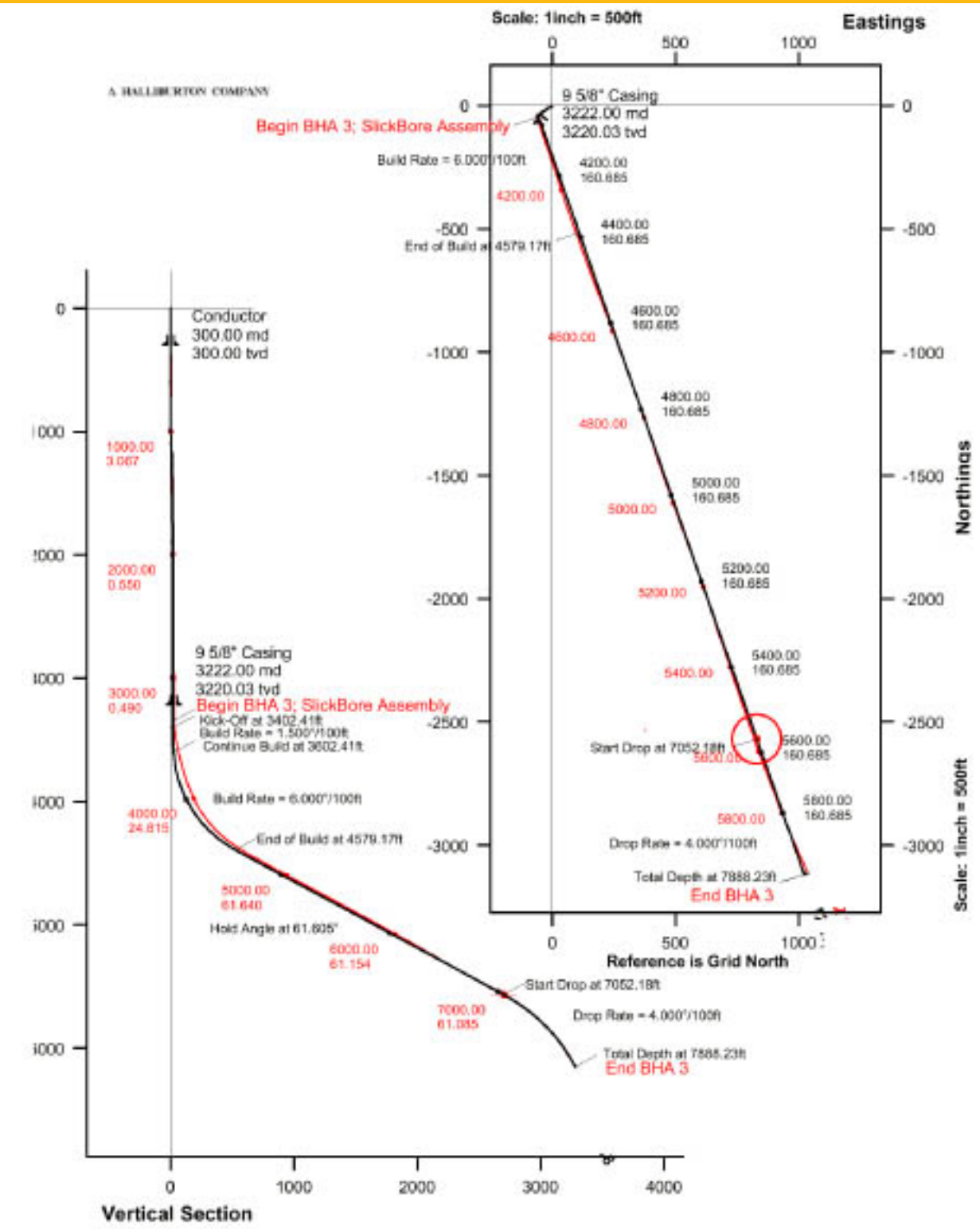
- *Louisiana Inland Waters*
- *9-7/8” Hole*
- *Oil Based Mud*
- *17-20° Inclination*
- *Profound Spiraling*





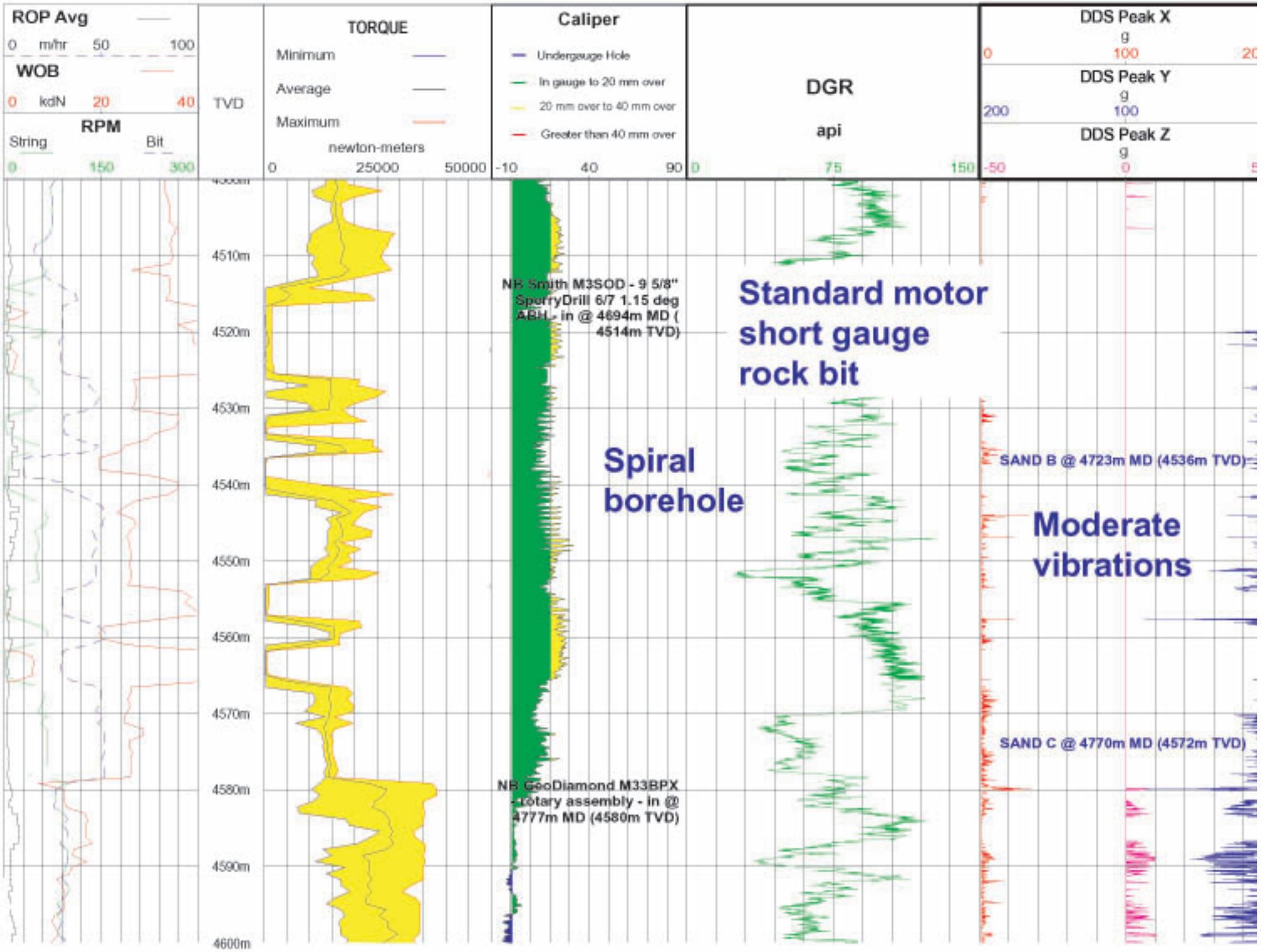
South Timbalier Example #3

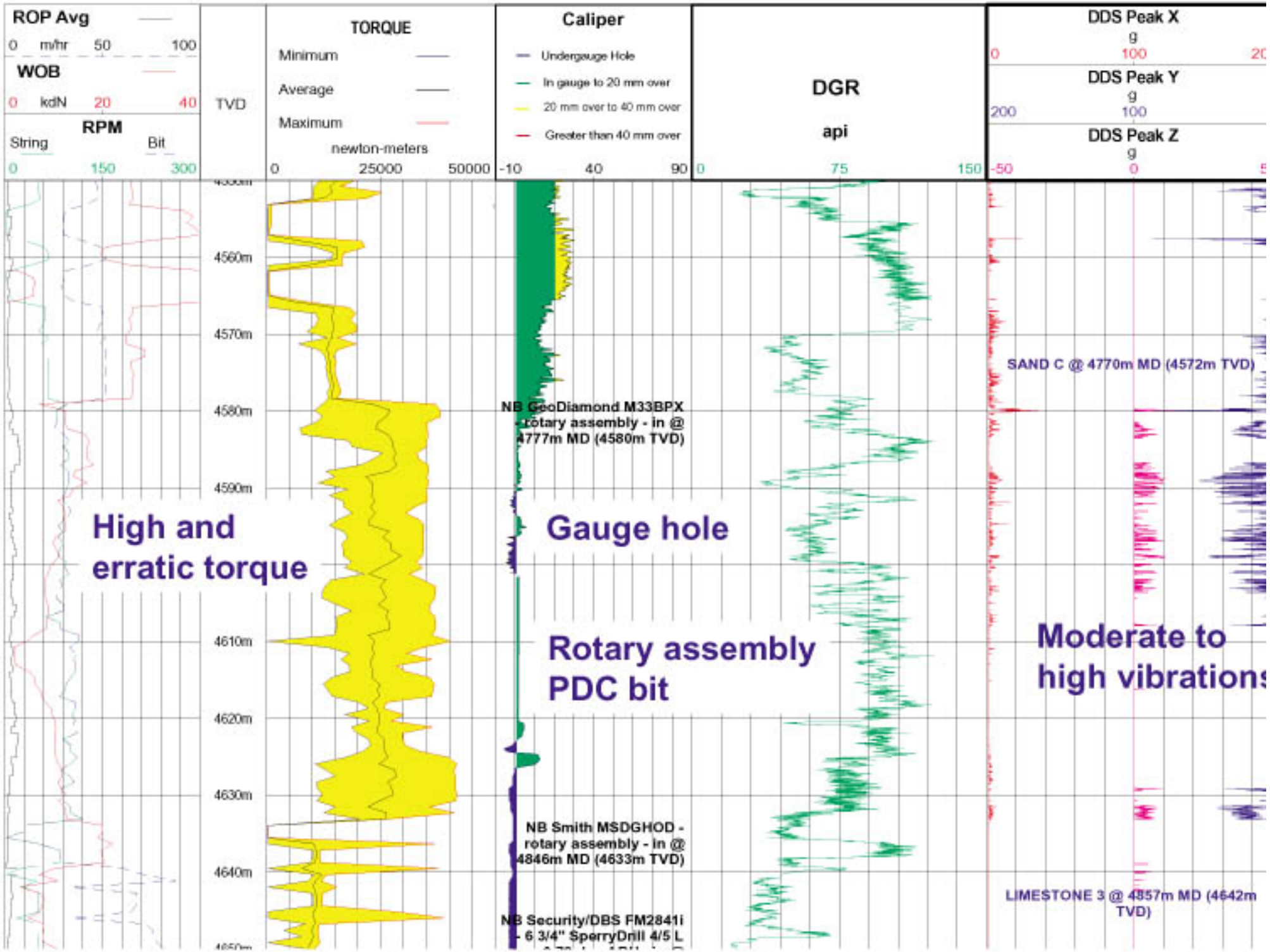
- 8-1/2” Hole
- Kicked off from vertical
- 3,800’ - 11,658’ (7,858’)
- 102 hrs drilling
- 9.25 hrs circulating
- Average ROP: 77 ft/hr (some control drilling)
- Sliding ROP: 23 ft/hr
- Rotating ROP: 86 ft/hr (86% of footage)

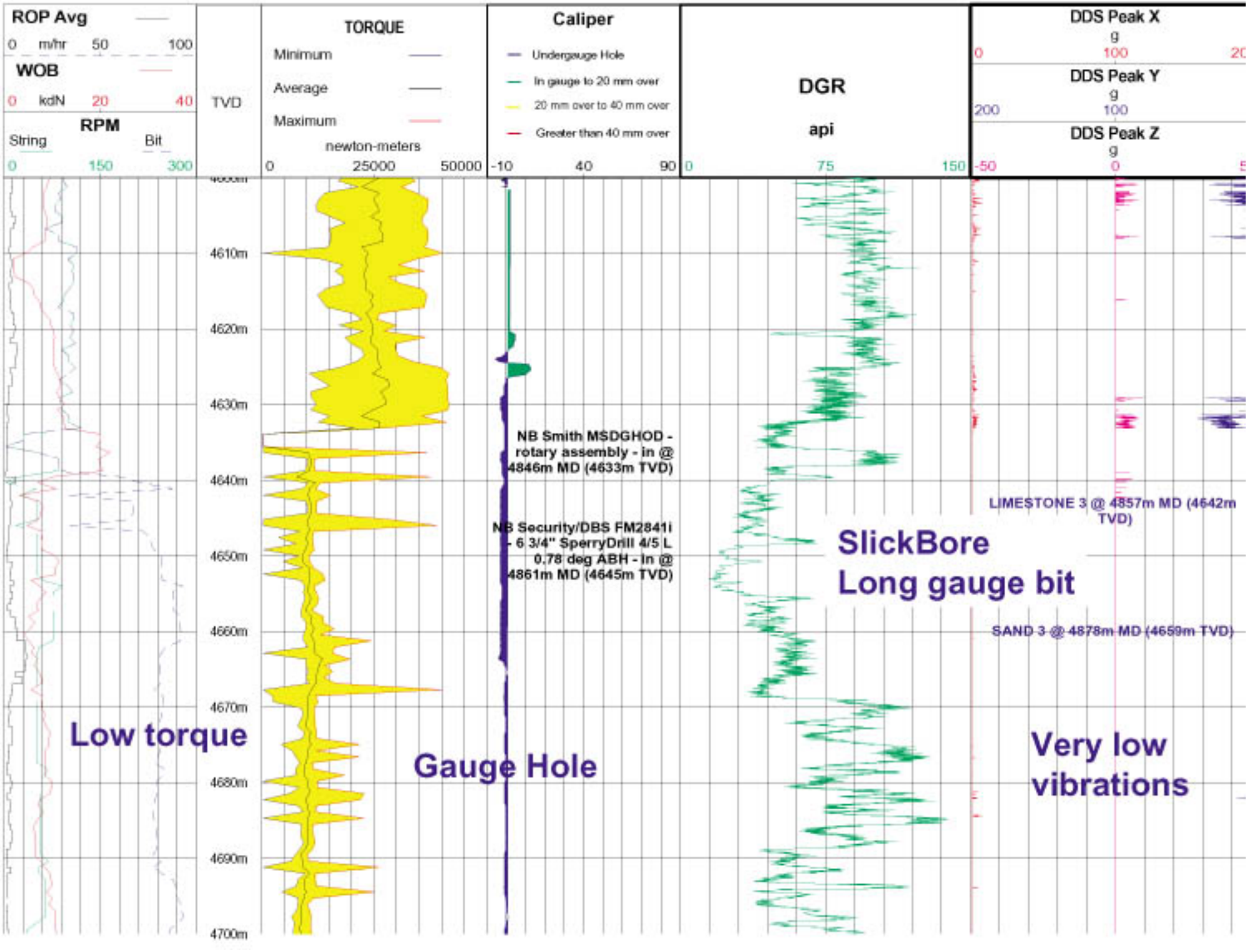


South Timbalier Example #4

- 8-1/2” Hole
- Kicked off from vertical
- 3,344’ - 7,846’ (4,502’)
- 45 hours drilling
- 12.5 hours circulating
- Average ROP: 100 ft/hr
- Sliding ROP: 97 ft/hr
- Rotating ROP: 101 ft/hr
  (75% of footage)


ROP Avg
0 m/hr 50 100
WOB
0 kdN 20 40
RPM
String Bit
0 150 300
TVD
TORQUE
Minimum
Average
Maximum
newton-meters
0 25000 50000
Caliper
Undergauge Hole
In gauge to 20 mm over
20 mm over to 40 mm over
Greater than 40 mm over
-10 40 90
DGR
api
0 75 150
DDS Peak X
g
0 100 20
DDS Peak Y
g
200 100
DDS Peak Z
g
-50 0
4510m
4520m
4530m
4540m
4550m
4560m
4570m
4580m
4590m
4600m
NB Smith M3SOD - 9 5/8" SperryDrill 6/7 1.15 deg ABH - in @ 4694m MD (4514m TVD)
NB GeoDiamond M33BPX - rotary assembly - in @ 4777m MD (4580m TVD)
Standard motor short gauge rock bit
Spiral borehole
SAND B @ 4723m MD (4536m TVD)
Moderate vibrations
SAND C @ 4770m MD (4572m TVD)


ROP Avg
0 m/hr 50 100
WOB
0 kdN 20 40
RPM
String Bit
0 150 300
TVD
TORQUE
Minimum
Average
Maximum
newton-meters
0 25000 50000
Caliper
Undergauge Hole
In gauge to 20 mm over
20 mm over to 40 mm over
Greater than 40 mm over
-10 40 90
DGR
api
0 75 150
DDS Peak X
g
0 100 20
DDS Peak Y
g
200 100
DDS Peak Z
g
-50 0
4560m
4570m
4580m
4590m
4610m
4620m
4630m
4640m
NB GeoDiamond M33BPX - rotary assembly - in @ 4777m MD (4580m TVD)
NB Smith MSDGHOD - rotary assembly - in @ 4846m MD (4633m TVD)
NB Security/DBS FM2841i - 6 3/4" SperryDrill 4/5 L
SAND C @ 4770m MD (4572m TVD)
LIMESTONE 3 @ 4857m MD (4642m TVD)
High and erratic torque
Gauge hole
Rotary assembly PDC bit
Moderate to high vibrations


ROP Avg
0 m/hr 50 100
WOB
0 kdN 20 40
RPM
String Bit
0 150 300
TVD
TORQUE
Minimum
Average
Maximum
newton-meters
0 25000 50000
Caliper
Undergauge Hole
In gauge to 20 mm over
20 mm over to 40 mm over
Greater than 40 mm over
-10 40 90
DGR
api
0 75 150
DDS Peak X
g
0 100 20
DDS Peak Y
g
200 100
DDS Peak Z
g
-50 0
4610m
4620m
4630m
4640m
4650m
4660m
4670m
4680m
4690m
4700m
NB Smith MSDGHOD - rotary assembly - in @ 4846m MD (4633m TVD)
NB Security/DBS FM2841i - 6 3/4" SperryDrill 4/5 L 0.78 deg ABH - in @ 4861m MD (4645m TVD)
LIMESTONE 3 @ 4857m MD (4642m TVD)
SAND 3 @ 4878m MD (4659m TVD)
SlickBore
Long gauge bit
Low torque
Gauge Hole
Very low vibrations

SlickBore Candidate Selection Criteria

- **Wells/Areas with known problems of:**
  - **Excessive torque/drag due to well profile**
  - **Getting casing to bottom**
  - **Spiraling effects on LWD/wireline logs**
  - **Hole cleaning**
  - **Stuck pipe**
  - **High vibration environment / High MWD failure rate**
  - **Slow sliding ROP relative to rotary ROP**

Sperry-Sun Drilling Services

Torque and Drag Summary

Customer: ExxonMobil
Well Name: H_MM3435-P4
Kizomba Drilling Project

Country: Angola
Slot: High Angle Bld/Hld
Report: 09/15/2000 11:14:06 AM

Drill String

Comp #	Description	Class	OD (in)	ID (in)	Wt (lbs/ft)	L
1	6-3/4" SperryDrill Lobe 7/8 - 6.0 stg		6.750	0.000	61.48	
2	6-3/4" MPT w/DGR + EWR + SFD + CNO + Dir		6.750	1.840	79.93	
3	Drill Collar		6.750	2.813	101.00	
4	HWDP		5.000	3.000	49.30	
5	DP(S) - NC50(XH) - 19.50#	Used - Premium	5.000	4.276	22.60	4

Hole Details

Description	ID (in)	Friction Factor	Depth (m)
Casing	8.535	0.180	4127.0
Open Hole	8.500	0.220	5362.5

Parameters

Bit Depth (m):	5362.5
Mud Weight (ppg):	10.5
Helical Buckling Criteria:	Chen/Cheatham

Operating Parameters and Results

	Pick-Up	Slack-Off	Rotating Off-Bottom	Rotary Drilling	Oriented Drilling
Weight on Bit (klbs):	------	------	------	5	8
Torque at Bit (ft-lbs):	------	------	------	8000	------
Pipe Speed (m/min):	--------	--------	--------	0.70	--------
Rotary Speed (RPM):	----	----	----	90	----
BHA Torque (ft-lbs):	------	------	0	0	------
BHA Drag (lbf):	10000	10000	-----	0	10000
Surface Tension (lbf):	**200237**	**21404**	**122230**	**117213**	**-24389**
Surface Torque (ft-lbs):	**------**	**------**	**13157**	**21174**	**------**
Safety Factors					
Pipe Stress:	**2.80**	**6.56**	**3.18**	**2.38**	**5.33**
Tool Joint Makeup:	**----------**	**----------**	**2.16**	**1.34**	**----------**

Torque and Drag Discussion

Mud Weight is an assumption.
Friction factors are best estimates for conventional Steerable BHA in Synthetic mud.

	Rotary Drilling	Oriented Drilling
	5	8
	8000	------
	0.70	--------
	90	----
	0	------
	0	10000
	117213	**-24389**
	21174	**------**
	2.38	**5.33**
	1.34	**----------**

Sperry-Sun Drilling Services

Torque and Drag Summary

Customer: ExxonMobil
Well Name: H_MM3435-P4
Kizomba Drilling Project

Country: Angola
Slot: High Angle Bld/Hld
Report: 09/15/2000 11:18:09 AM

Drill String

Comp #	Description	Class	OD (in)	ID (in)	Wt (lbs/ft)	L
1	6-3/4" SperryDrill Lobe 7/8 - 6.0 stg		6.750	0.000	61.48	
2	6-3/4" MPT w/DGR + EWR + SFD + CNO + Dir		6.750	1.840	79.93	
3	Drill Collar		6.750	2.813	101.00	
4	HWDP		5.000	3.000	49.30	
5	DP(S) - NC50(XH) - 19.50#	Used - Premium	5.000	4.276	22.60	4

Hole Details

Description	ID (in)	Friction Factor	Depth (m)
Casing	8.535	0.180	4127.0
Open Hole	8.500	0.180	5362.5

Parameters

Bit Depth (m):	5362.5
Mud Weight (ppg):	10.5
Helical Buckling Criteria:	Chen/Cheatham

Operating Parameters and Results

	Pick-Up	Slack-Off	Rotating Off-Bottom	Rotary Drilling	Oriented Drilling
Weight on Bit (klbs):	------	------	------	5	8
Torque at Bit (ft-lbs):	------	------	------	8000	------
Pipe Speed (m/min):	--------	--------	--------	0.70	--------
Rotary Speed (RPM):	----	----	----	90	----
BHA Torque (ft-lbs):	------	------	0	0	------
BHA Drag (lbf):	10000	10000	-----	0	10000
Surface Tension (lbf):	**194357**	**38762**	**122230**	**117215**	**7545**
Surface Torque (ft-lbs):	**------**	**------**	**12013**	**20030**	**------**
Safety Factors					
Pipe Stress:	**2.89**	**7.67**	**3.33**	**2.48**	**5.97**
Tool Joint Makeup:	----------	----------	**2.36**	**1.42**	----------

Torque and Drag Discussion

Mud Weight is an assumption.
Friction factors are best estimates for slickbore BHA in Synthetic mud.

	Rotary Drilling	Oriented Drilling
	5	8
	8000	------
	0.70	--------
	90	----
	0	------
	0	10000
	117215	**7545**
	20030	**------**
	2.48	**5.97**
	1.42	----------

SlickBore
Experience & Observations

- Over 210 runs completed or in progress
- On Bottom Time: 85% drilling, 11% circ, 4% other
- North Sea, Far East, GOM, US Land, and Offshore Canada (Sable Island & Terra Nova)
- AFE days reduced 15-50%
- Less weight-on-bit required to drill
- Fewer MWD and mud motor failures
- Decreased bit wear
- DDS™ sensor data supports vibration reduction
- Casing ran to bottom very easily

SlickBore

Gulf of Mexico Comparison

- One fewer trip per well (1.7 Vs. 2.7 conventional)
- 27% faster rotating ROP
- 83% faster oriented ROP
- 55% less off-bottom circulating time per 1000’
- 59% less reaming time per 1000’
- 39% less WOB
- For Identical 180 Below Rotary Hours per well
  - SlickBore 8168’ MD Conventional 4419’ MD

Performance Comparison for Ship Shoal, South Timbalier, and West Cameron Areas

TOTALS	SlickBore™ System	Performance Motors	Comparison		
Wells	9	12			
Bit Runs	15	33			
Average Interval (m)	1494	490	205%	Increase in Footage per Run	
Average Drilling Hours	60	29	107%	For 205% More Footage	
Average ROP (m/hr)	25.9	13.7	89%	Increase in Overall ROP	
Oriented ROP (m/hr)	13.4	6.7	100%	Increase	
Rotating ROP (m/hr)	27.7	14.9	86%	Increase	
Drilling Hours / 1000 m	40.3	58.2	17.9	Less Time On Bottom Drilling / 1000m	
Circulating Hours / 1000 m	11.1	20.2	9.1	Less Time Circulating / 1000m	
Tripping Hours / 1000 m	18.2	51.0	32.8	Less Time Tripping / 1000m	
Other Time / 1000 m	1.7	4.1	2.4	Less Other Time / 1000m	
Total Operating Time per 1000 m	**71.3**	**133.5**	**62.2**	**Fewer hours per 1000 m**	

SlickBore™ Drilling System

Blaine Comeaux

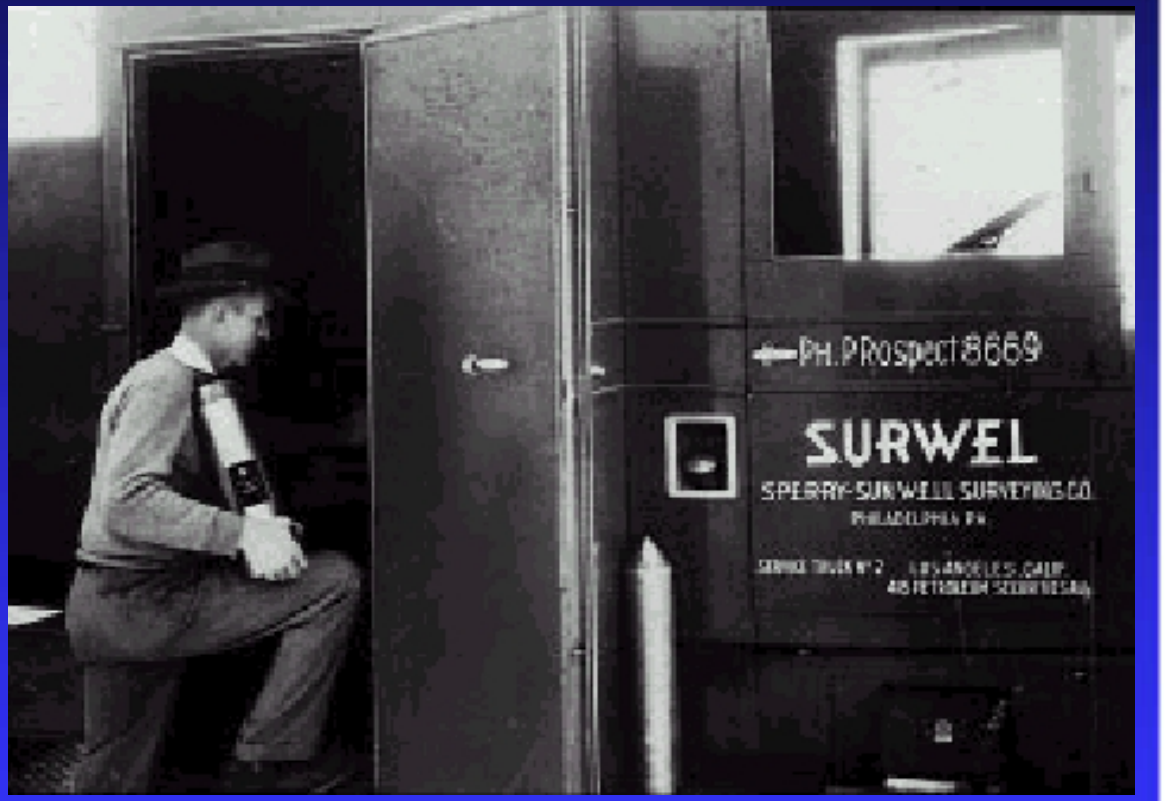
sperry-sun®
DRILLING SERVICES
A Halliburton Company

In collaboration with

JAPAN NATIONAL OIL CORPORATION (JNOC)

Elmer Sperry

- 1912 - Invented Automatic Pilot
- Allowed transoceanic flight, missile guidance and Space program



New Era of Automatic Downhole Navigation

- New Generation of Drilling Tools
  - 2nd Generation Rotary Steerable System
  - Allow drilling of smoother, more precise well paths than ever before (even other R/S's)
  - Longer reach is possible
  - Ability to place wellbore through multiple targets greatly improves recovery from single well

Rotary Steerable Concept

- Desire to rotate the drillstring 100% of the time
  - Improves weight transfer and ROP
  - Improves hole cleaning by constant agitation of cuttings
- Desire to orient the bit and drill directional well
- Goal: *DECOUPLE THE METHOD OF BIT DEFLECTION FROM DRILL STRING*

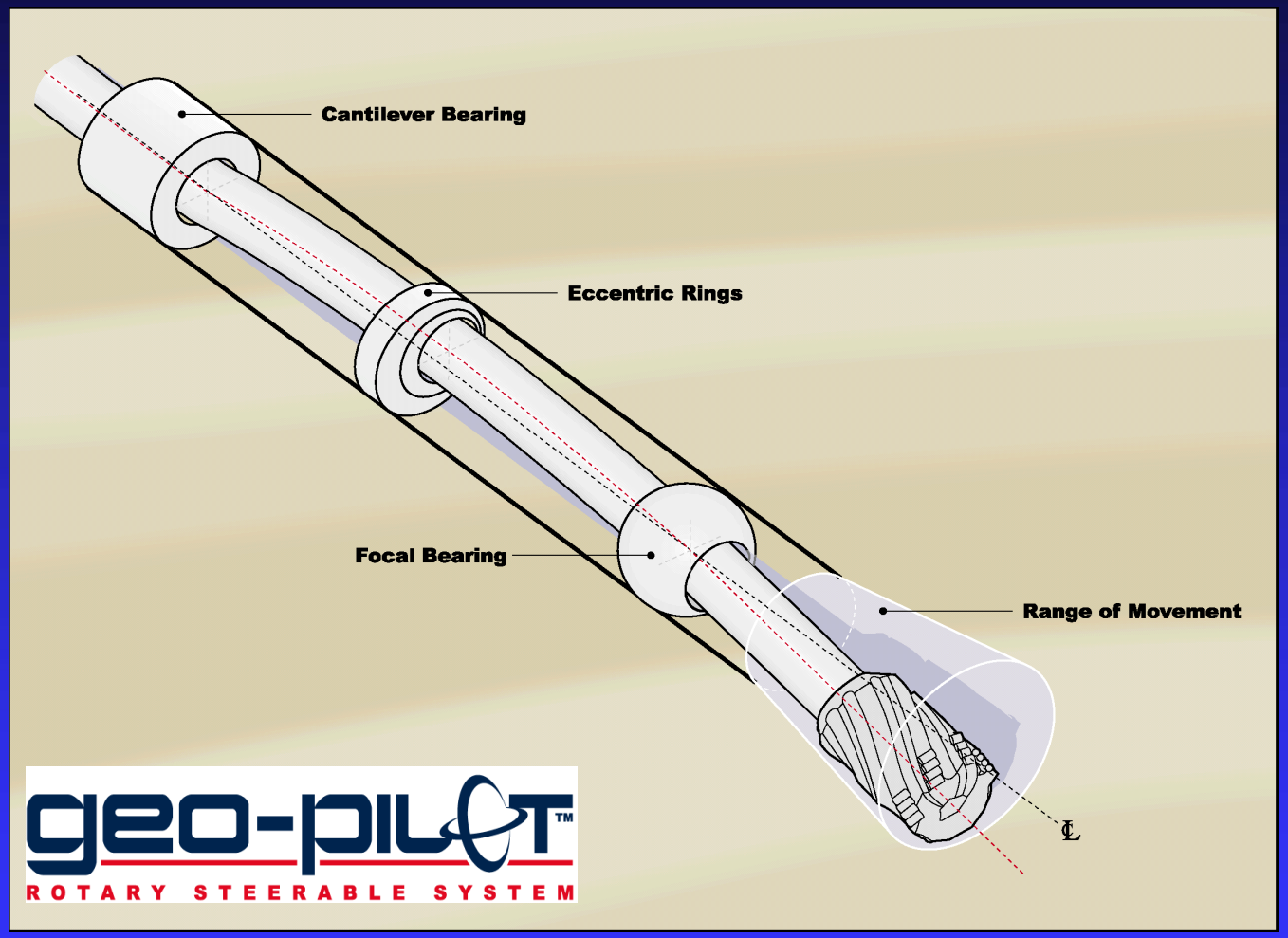
Benefits of Geo-Pilot™ Steering

- **DRILL FASTER - Higher Overall Rate of Penetration due to:**
  - **Elimination of sliding and resulting friction**
  - **Less time spent on short trips and backreaming**
  - **Fewer sticking pipe incidences**
- **DRILL FARTHER - Beyond the technical limit of conventional steerable technology**
  - **Longer reach with lower drag due to rotating 100% of the time.**

Benefits Continued . . .

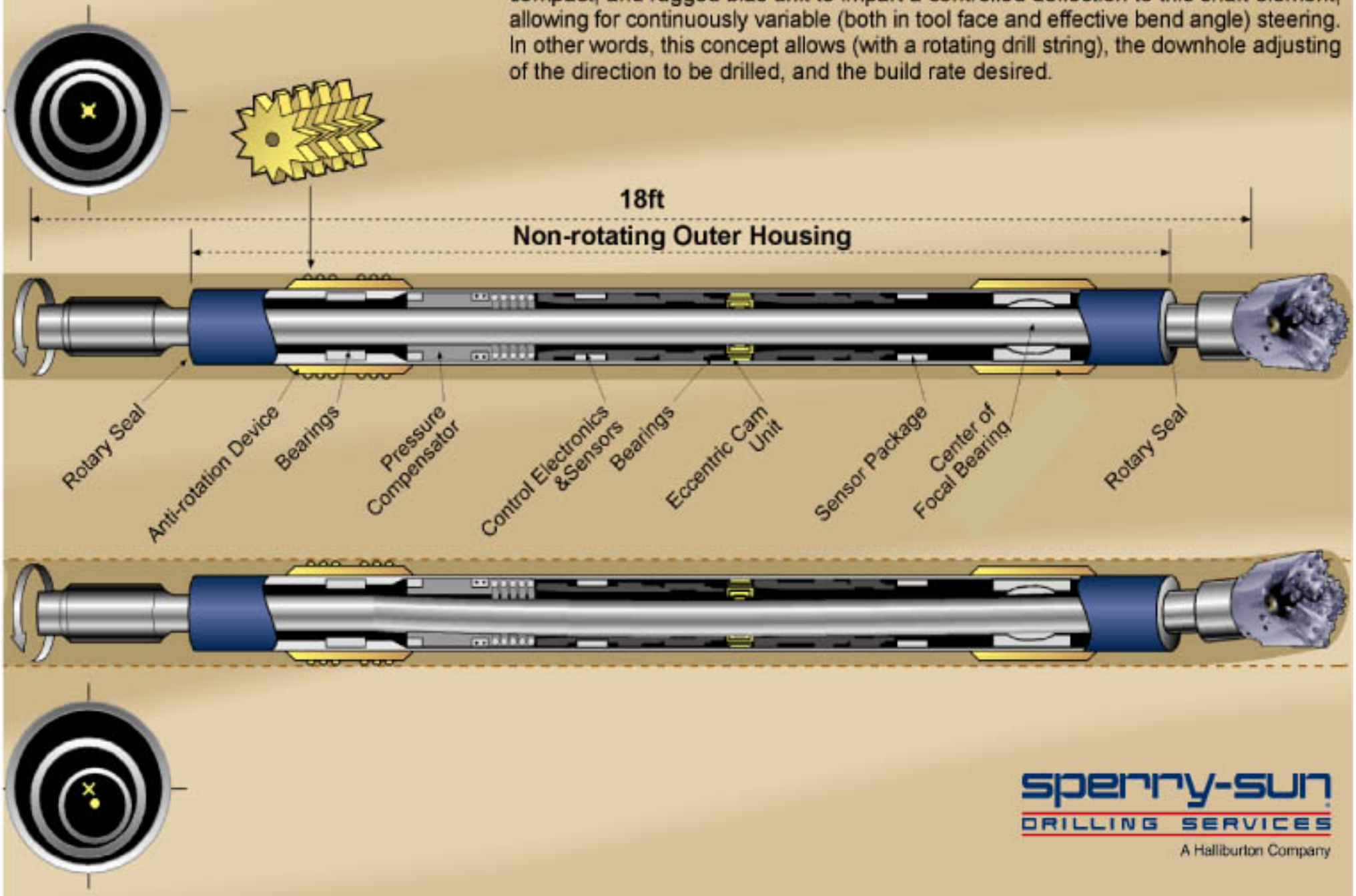
- **DRILL STRAIGHTER - A more precisely drilled well due to:**
  - **Better toolface control as reactive torque does not affect toolface**
  - **Lower well bore tortuosity and hence less drag, due to At-Bit Inclination measurement 3’ from bit**
- **DRILL MORE COMPLEX WELL TRAJECTORIES**

Geo-Pilot Basic Operating Principle

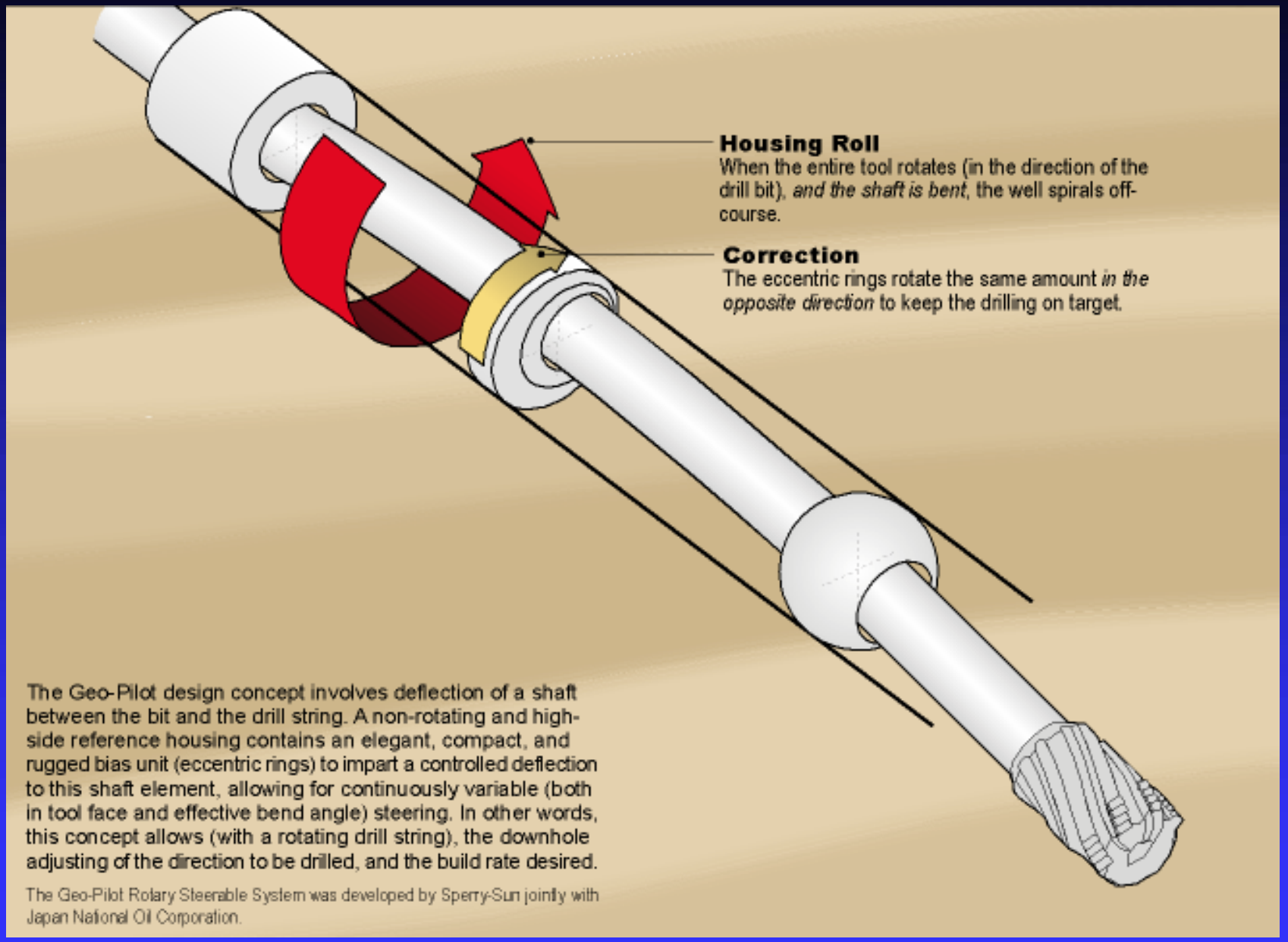


- Rotating Shaft is deflected in center between bearings with dual eccentric cams
- Results in bit tilt in opposite direction

The Geo-Pilot design concept involves deflection of a shaft between the bit and the drill string. A non-rotating and high-side reference housing contains an elegant, compact, and rugged bias unit to impart a controlled deflection to this shaft element, allowing for continuously variable (both in tool face and effective bend angle) steering. In other words, this concept allows (with a rotating drill string), the downhole adjusting of the direction to be drilled, and the build rate desired.



sperry-sun
DRILLING SERVICES
A Halliburton Company

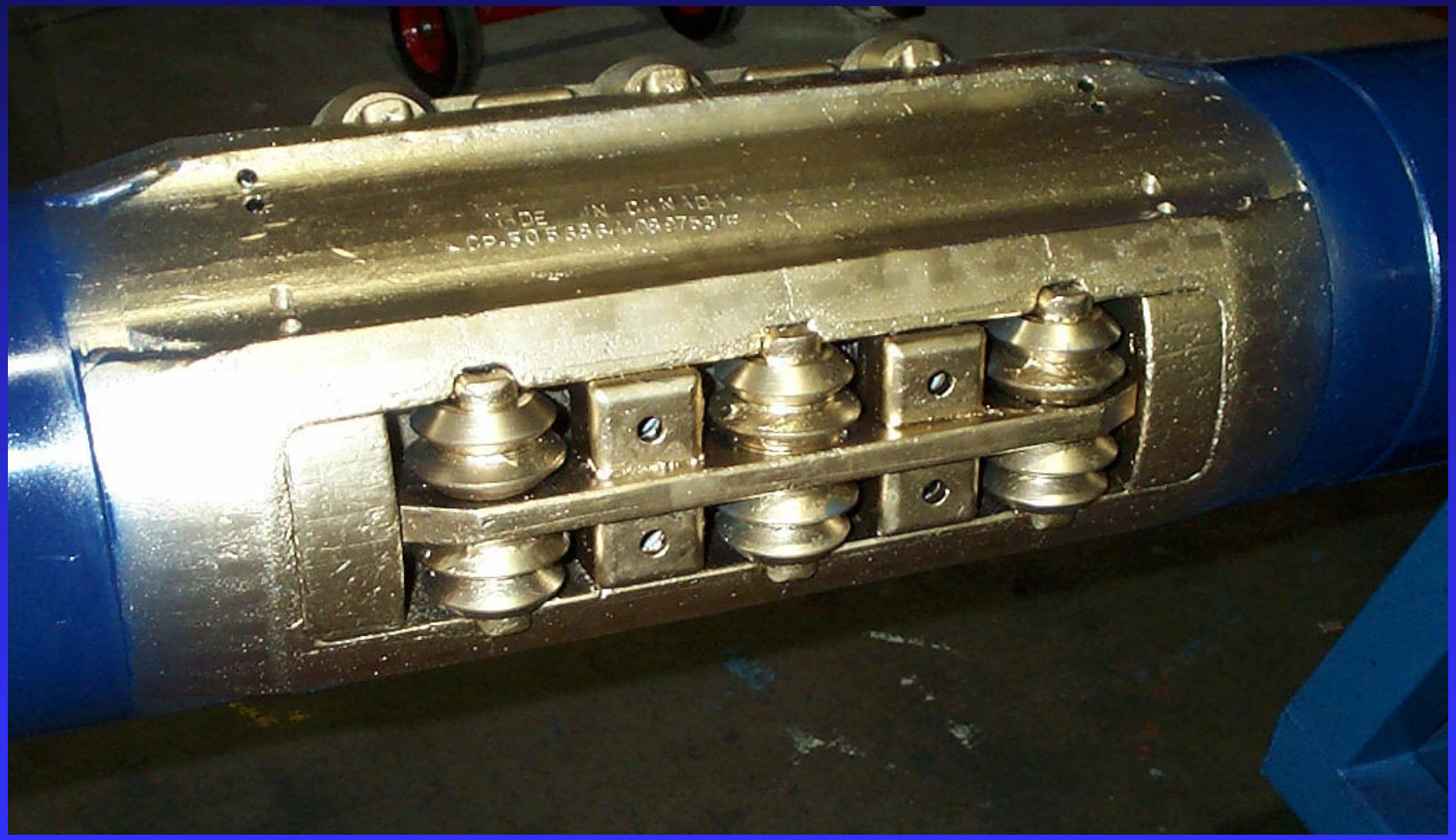


The Geo-Pilot design concept involves deflection of a shaft between the bit and the drill string. A non-rotating and high-side reference housing contains an elegant, compact, and rugged bias unit (eccentric rings) to impart a controlled deflection to this shaft element, allowing for continuously variable (both in tool face and effective bend angle) steering. In other words, this concept allows (with a rotating drill string), the downhole adjusting of the direction to be drilled, and the build rate desired.

The Geo-Pilot Rotary Steerable System was developed by Sperry-Sun jointly with Japan National Oil Corporation.

Geo-Pilot™
Rotary Steerable System

Reference Stabilizer (Spring Loaded Rollers)



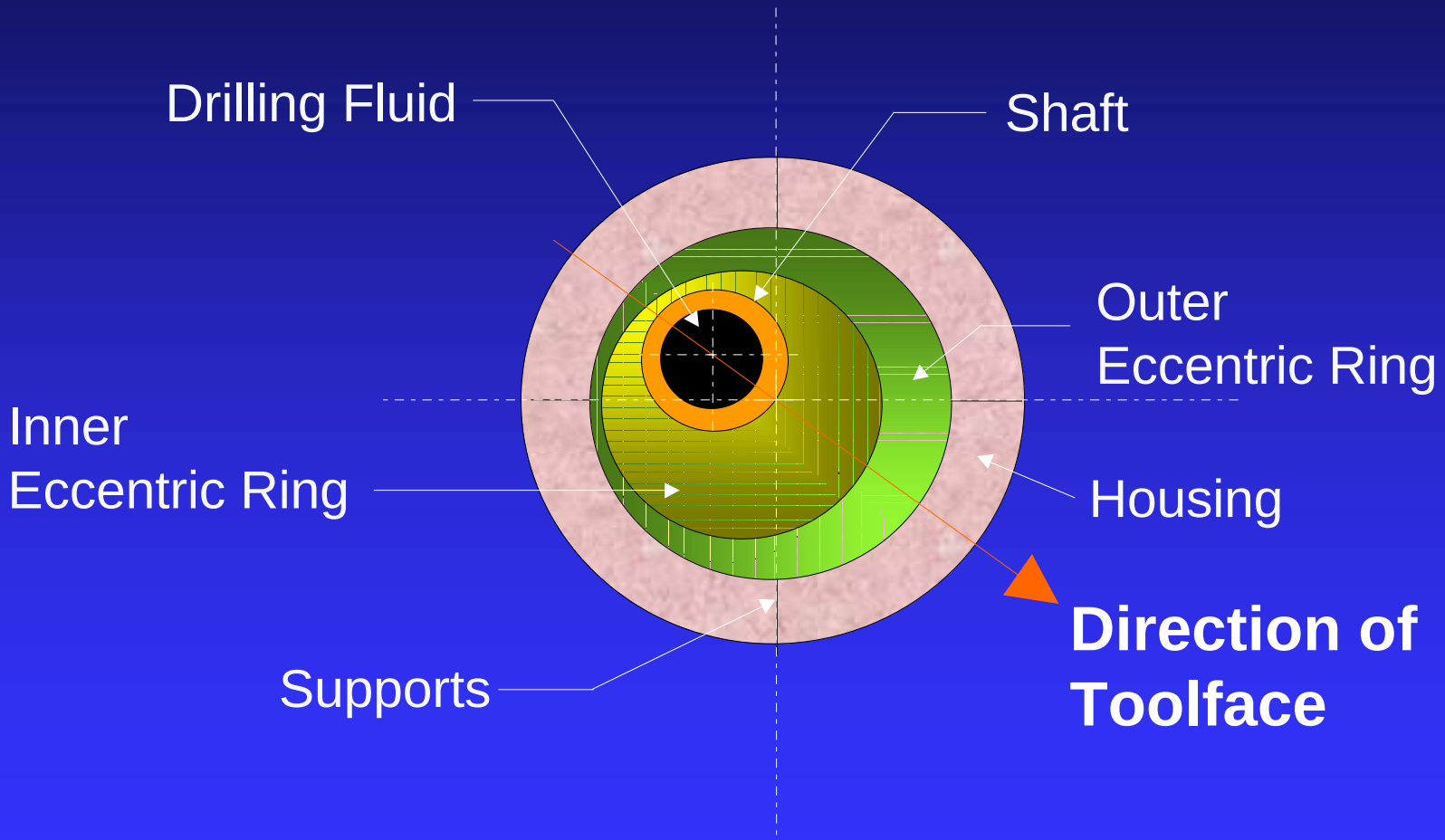
Principle of Operation

Cantilever Bearing prevents shaft from bending above it.

Focal Bearing Allows Bit To Tilt

Drill Bit Tilts in Opposite Direction of Bend Creating a Toolface

Shaft Deflection by Eccentric Rings

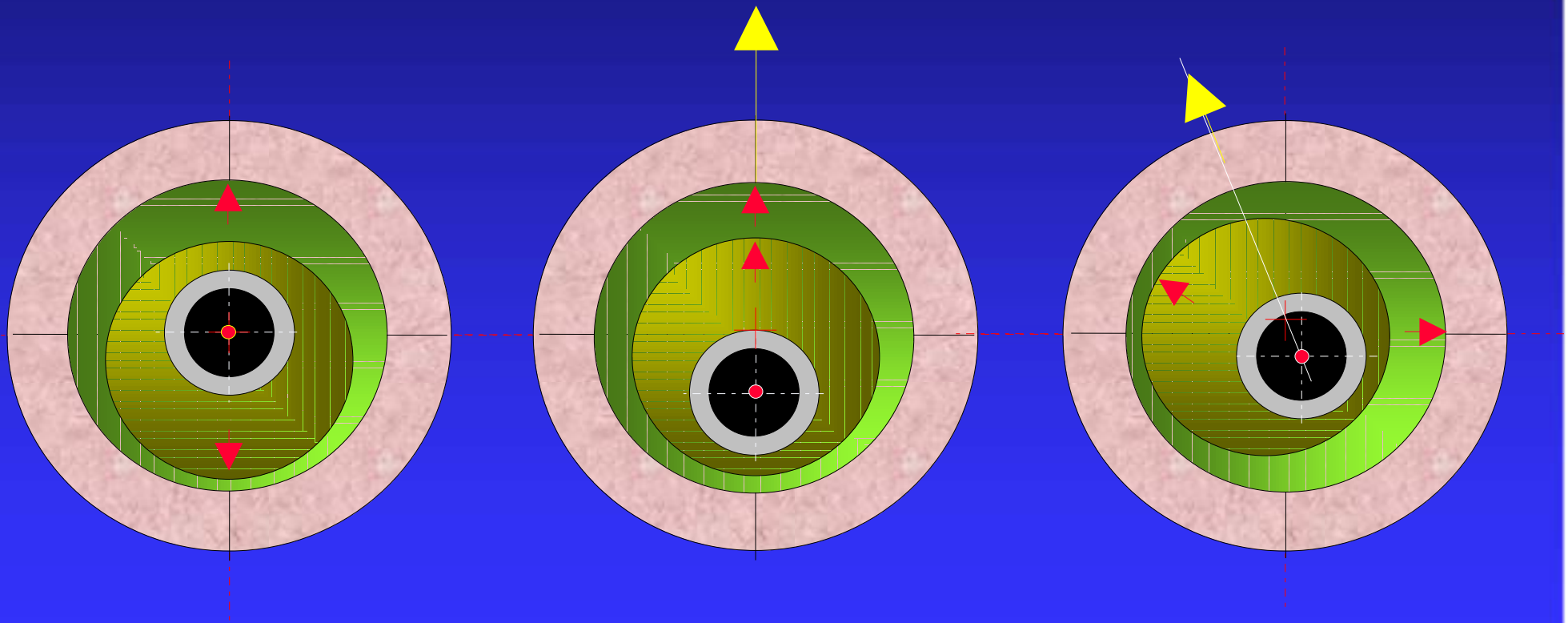


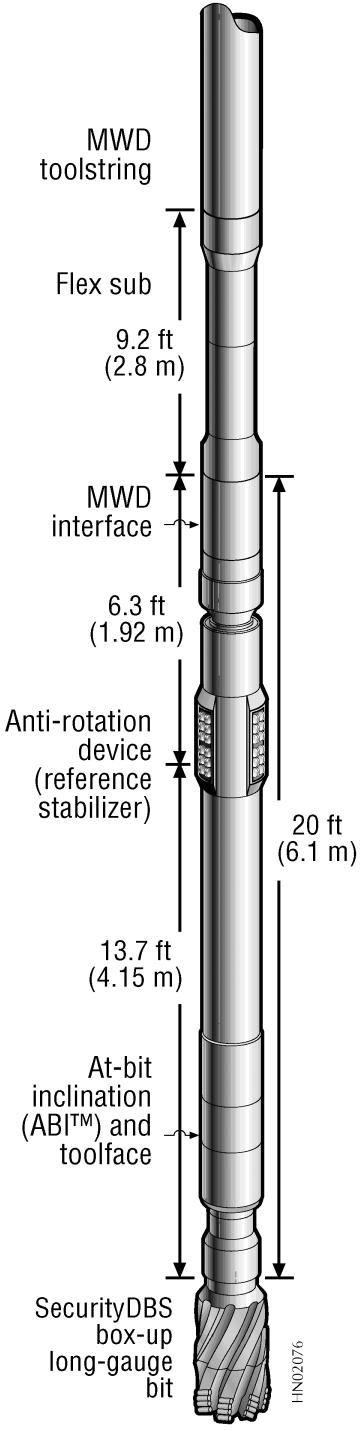
Deviation of Shaft

Neutral Position

Maximum Deflection

Intermediate Deflection





System Description

- 2nd Generation - “Point-the-Bit”
  - Capable of utilizing long gauge bits
- Tool Length - 20 ft. + 10 ft. flex collar
- At-Bit Inclination (ABI™) - 3 ft. from bit
  - 3-axis Azimuthal Gamma - December ’00
- 6 of 8 electronics boards come from proven Sperry-Sun LWD tools
- Completely integrated into LWD system for real-time data transmission
- 2-way tool communication from surface
- Backup tool communication via RPM and pump sequences

Operating Considerations, cont.

- Max Flow Rate: 650 gpm
- Max Build Rate: 4.38° / 100’
- Max Drop Rate: 5.20° / 100’
- Max Turn Rate: 5.00° / 100’
- Max Build Rate Phase B: 6-7° / 100 ft*
- Minimum Inclination 5°
- Max LCM Same as LWD

- Note: Bend Aggressiveness can be adjusted prior to run from 0-100%. 100% corresponds to numbers above.

SlickBore Bit

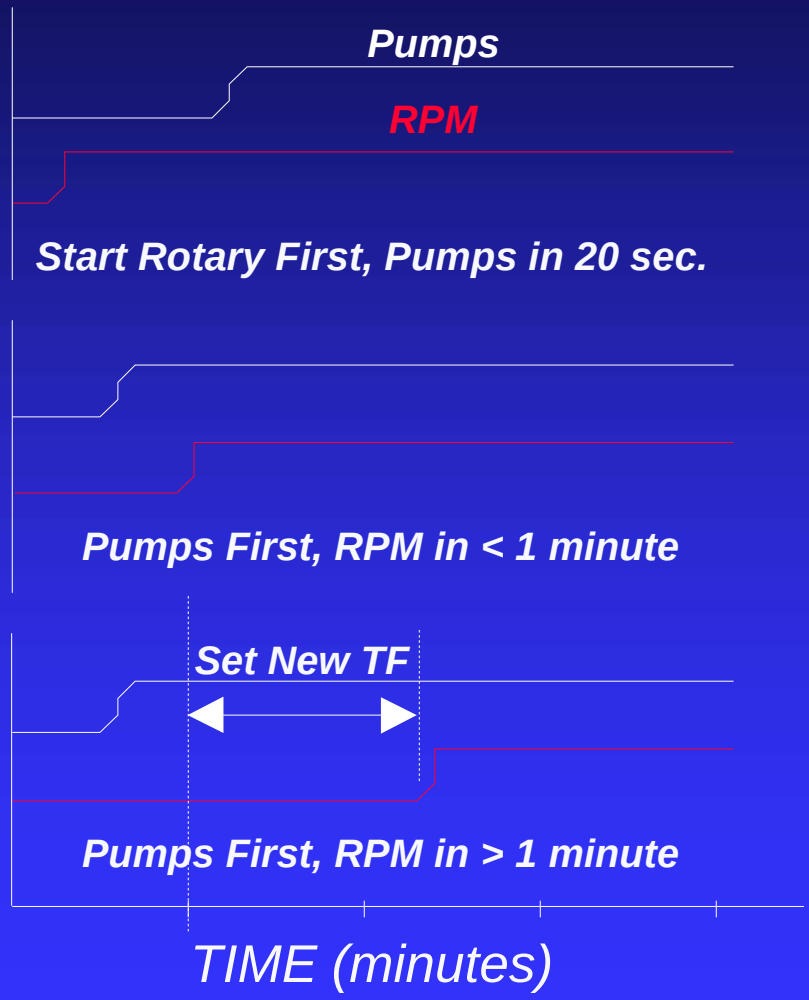
- Centralizes bit so hole is drilled straighter
- Minimizes destructive motion and vibration

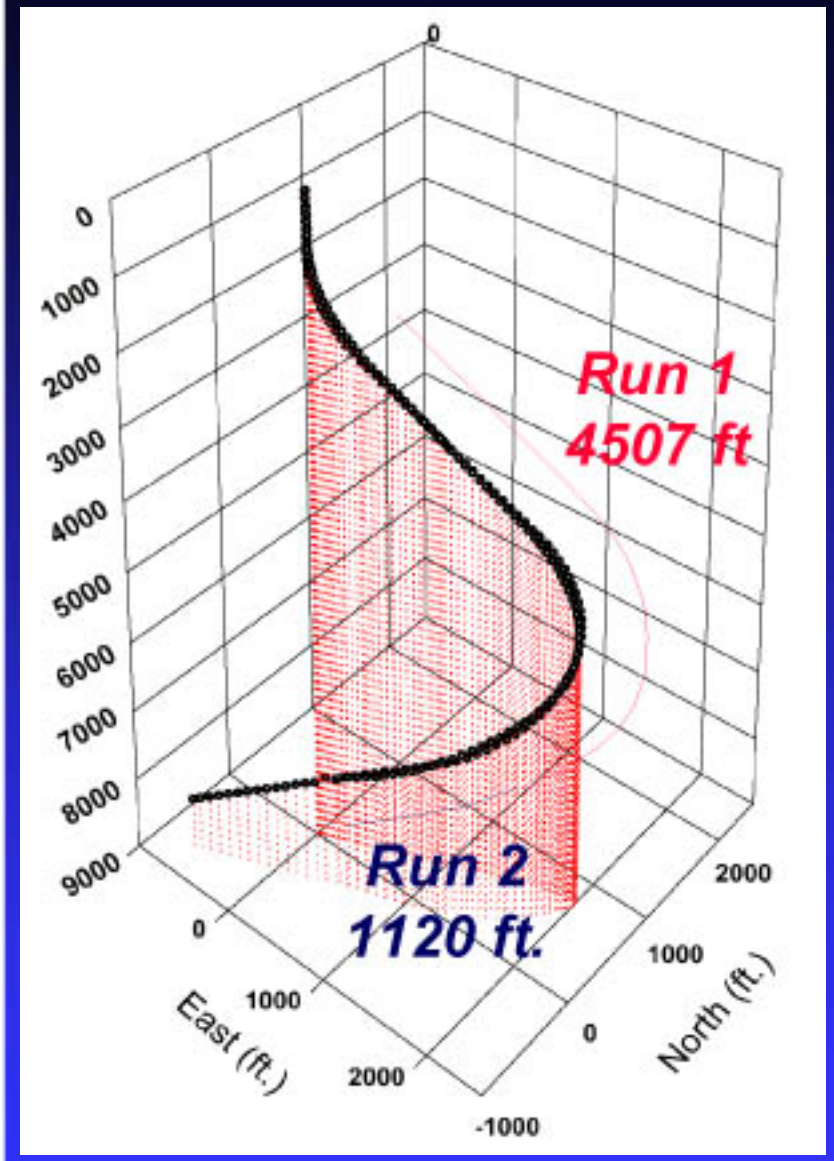
Backup Communication Sequence

MODE 1
Straight Position

MODE 2
Oriented, Same TF

MODE 3
Oriented, New TF

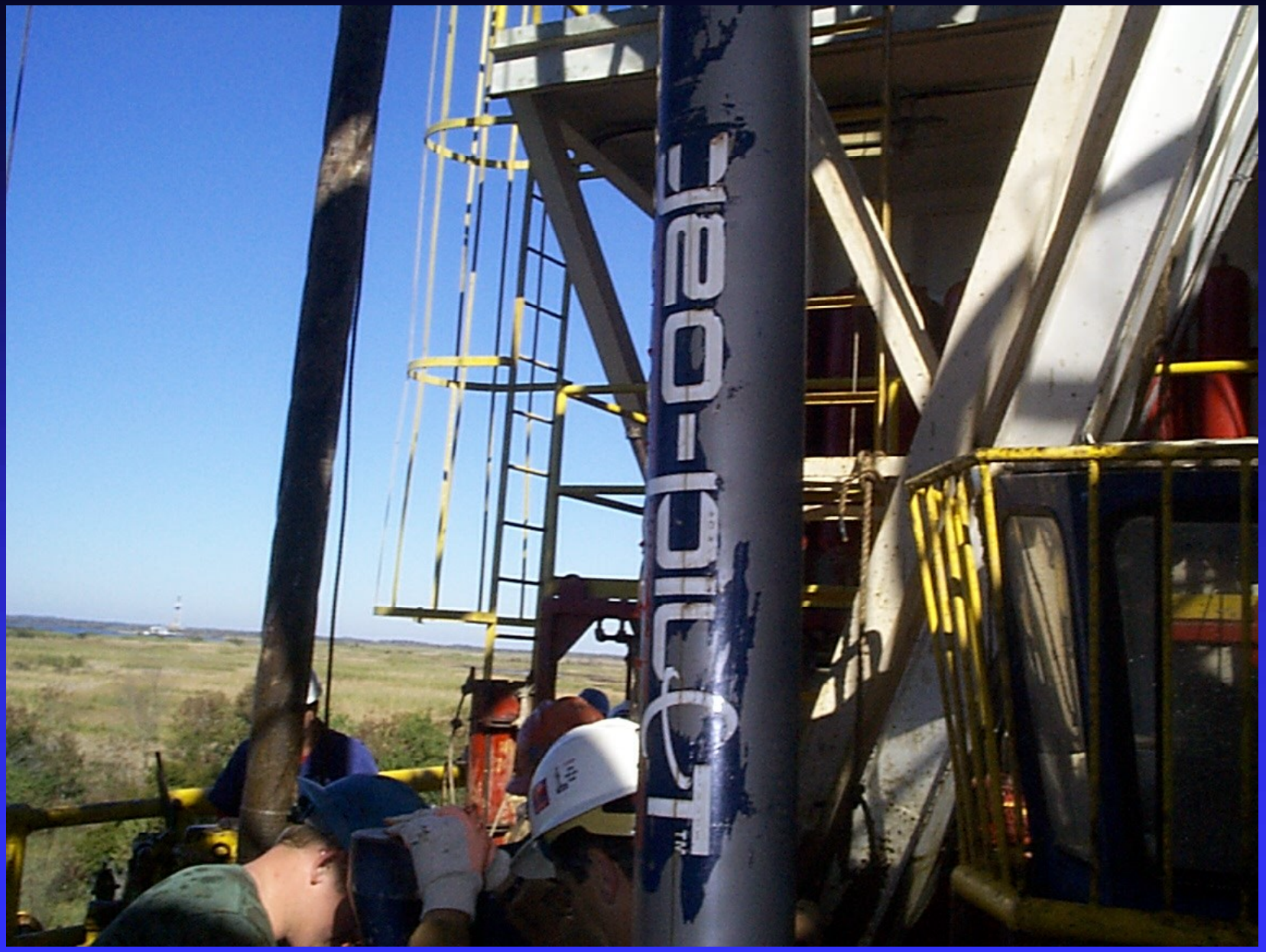




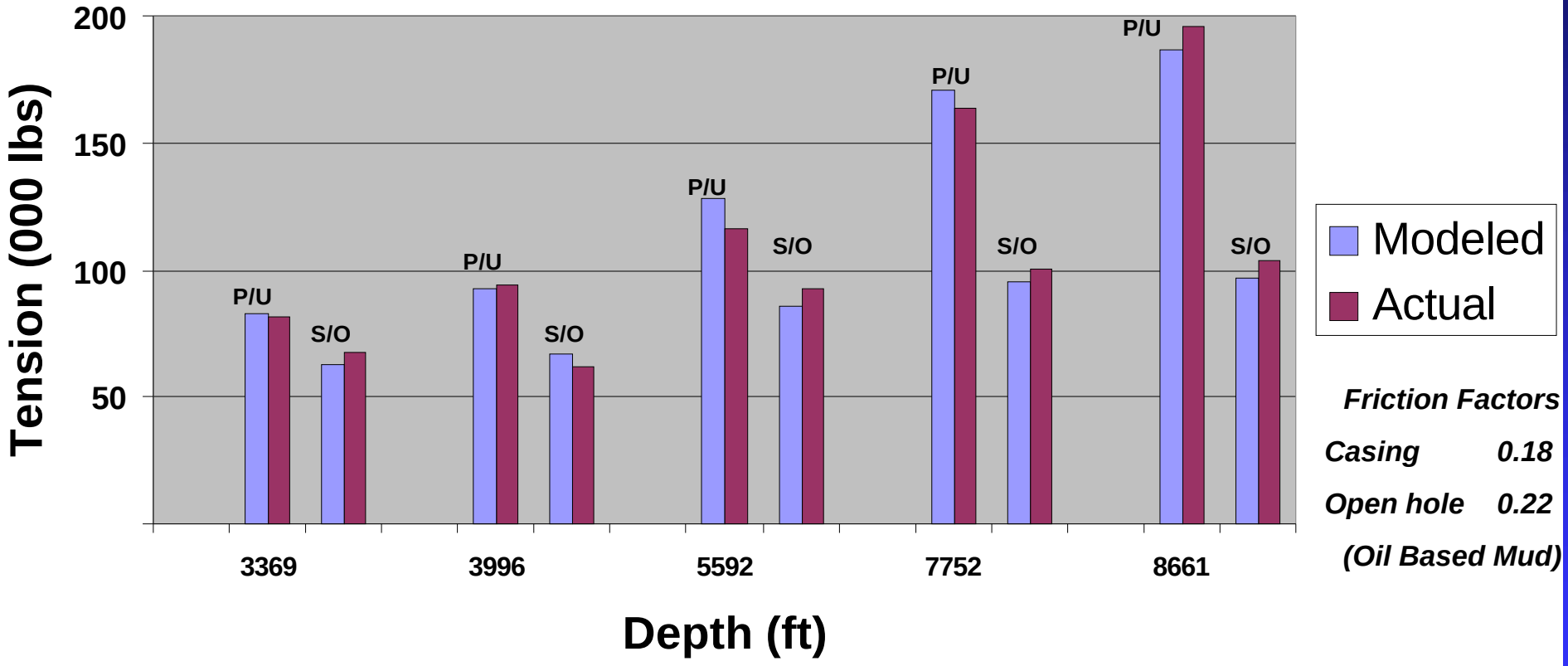
Spirit Energy 76 - Second Well

- 3330’ - 9006’
- Total 5676 feet in 2 runs
- Starting Inclination - 33°
- Dropped 2.5°/100’ while turning 182° and building back to 55° inc at 3°/100’
- Oil based mud system
- Tool performed flawlessly up to failure

Ready to Run


Petrobras

Geo-Pilot Wellbore Drag
Spirit Energy 76 Sweet Lake



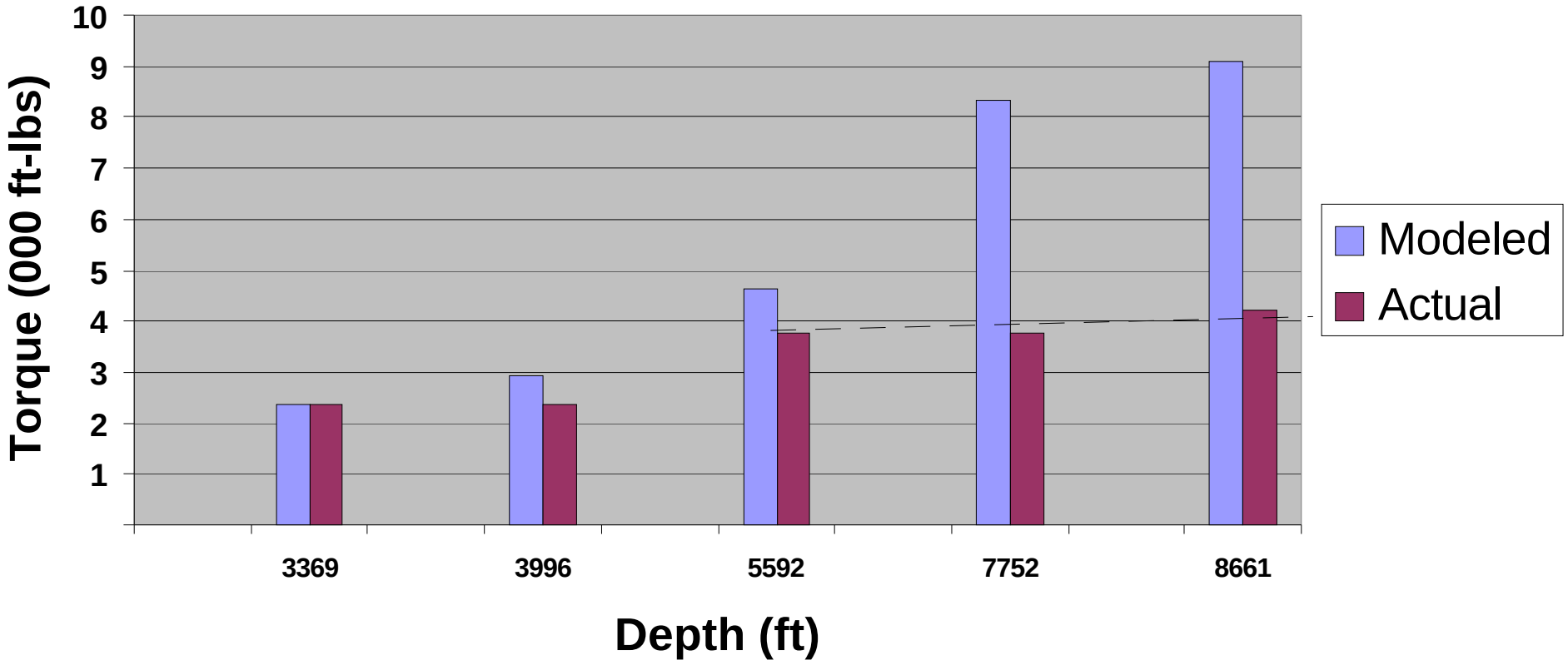
Friction Factors

Casing 0.18

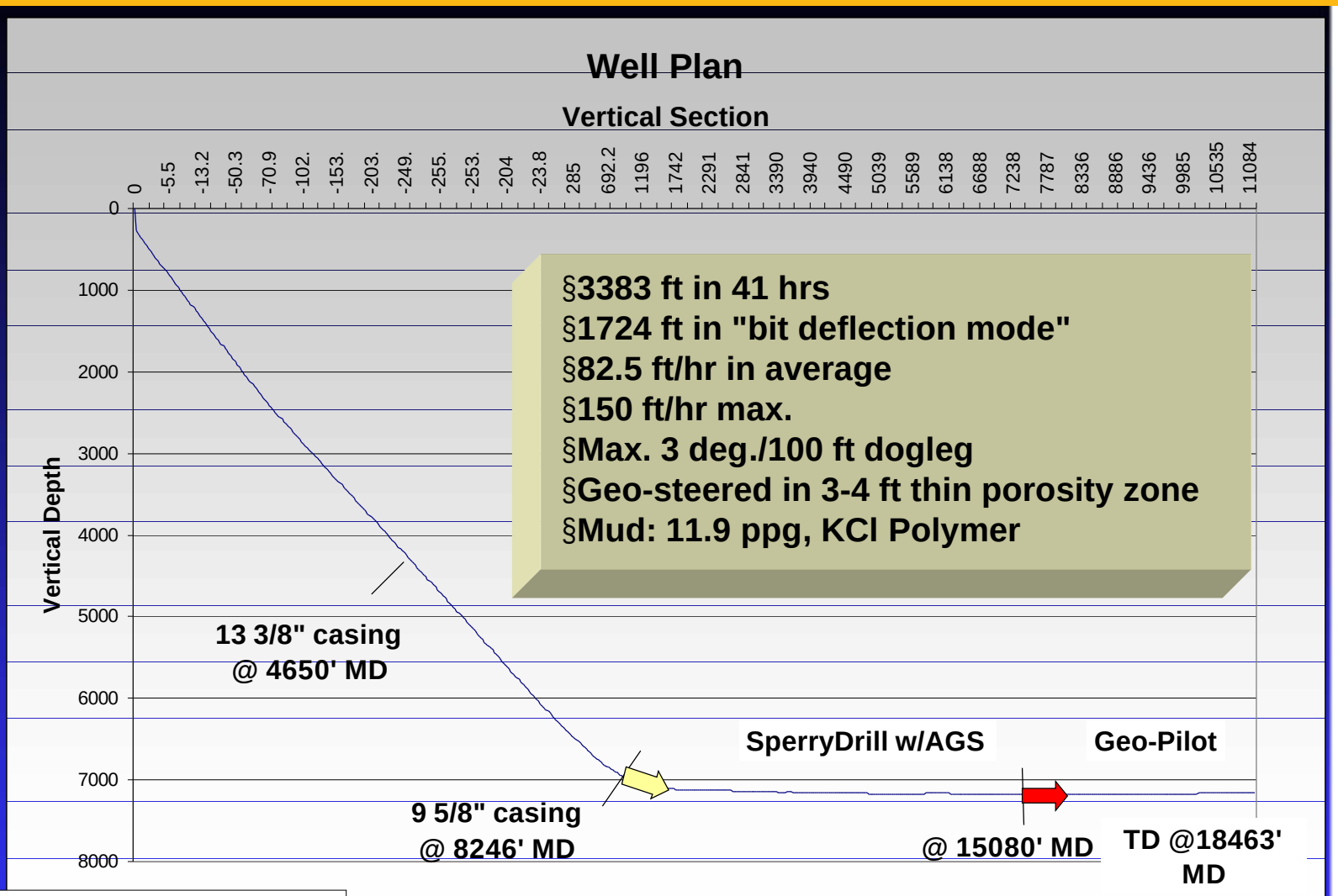
Open hole 0.22

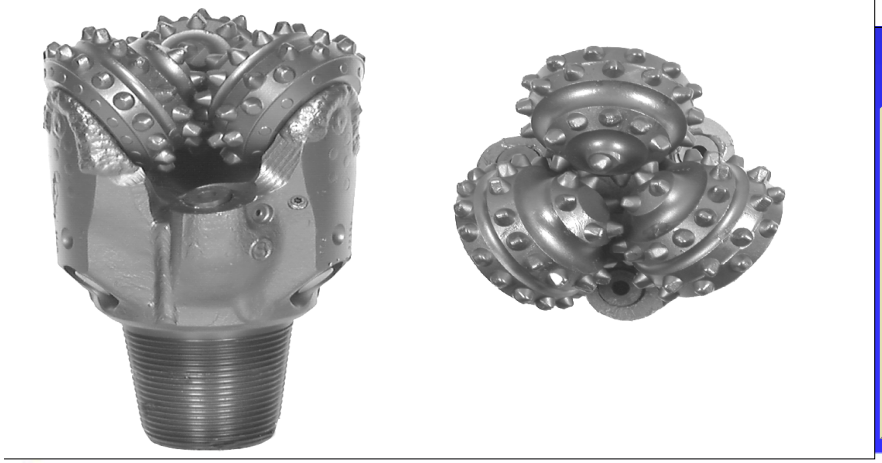
(Oil Based Mud)

Geo-Pilot Wellbore Torque
Spirit Energy 76 Sweet Lake



Maersk North Sea Project





8 ½” SDBS XSD20DL specially made for the specific application.
10” specially designed sleeve

Diamond enhanced gauge row inserts for reduced gage wear

Diamond claw surf inserts for minimized gauge wear

Premium silver-plated friction bearing featuring solid bearing concept

Shirttails protected with proprietary hardfacing and tungsten carbide inserts

Integral body stabilizer pads for improved directional performance

Geo-Pilot Friction Factors from North Sea Project

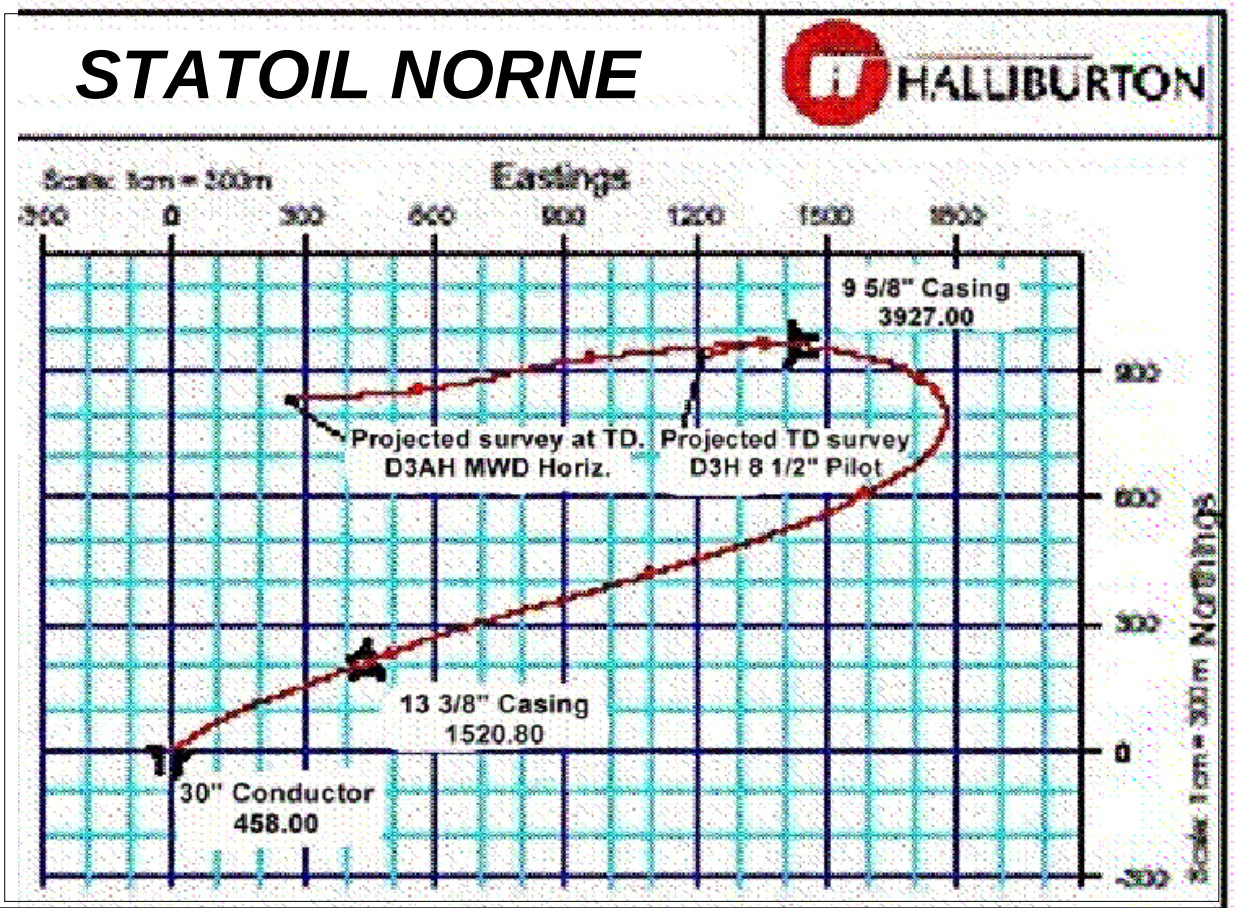
Depth	Inc	Pick Up (all weight values in klbs)					Slack Off (all weight values in klbs)				
feet	degrees	Actual	Calibrated	ff=0.1	ff=0.2	Calculated ff	Actual	Calibrated	ff=0.1	ff=0.2	Calculated ff
8411	77	155	164	174	175	0.10	105	114	120	119	0.19
11242	88	195	192	178	187	0.26	105	102	113	106	0.26
11952	88	195	191	178	189	0.22	75	71	112	103	0.49
12385	88	195	192	181	192	0.20	75	72	112	103	0.45
12996	91	205	207	181	194	0.29	85	87	110	99	0.30
14114	90	205	207	185	201	0.23	75	77	108	95	0.31
15214	90	215	228	237	238	0.00	55	68	73	71	0.34
16724	91	215	226	239	246	0.00	55	66	64	49	0.08

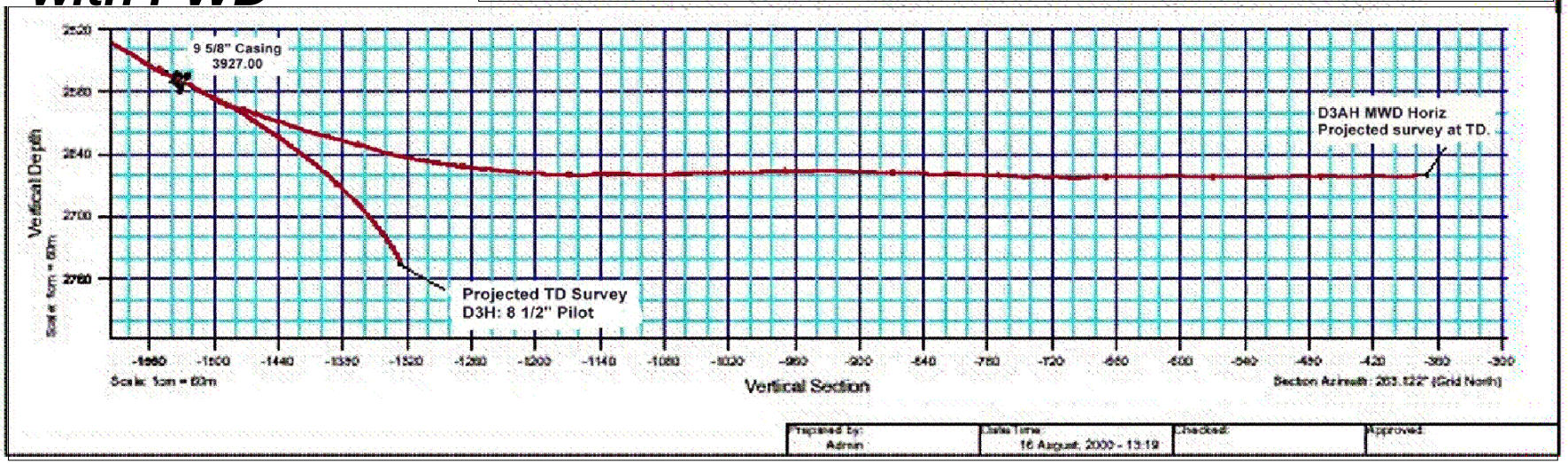
Conventional Assembly - 8-1/2” Hole
*Average Friction Factor - **0.30***

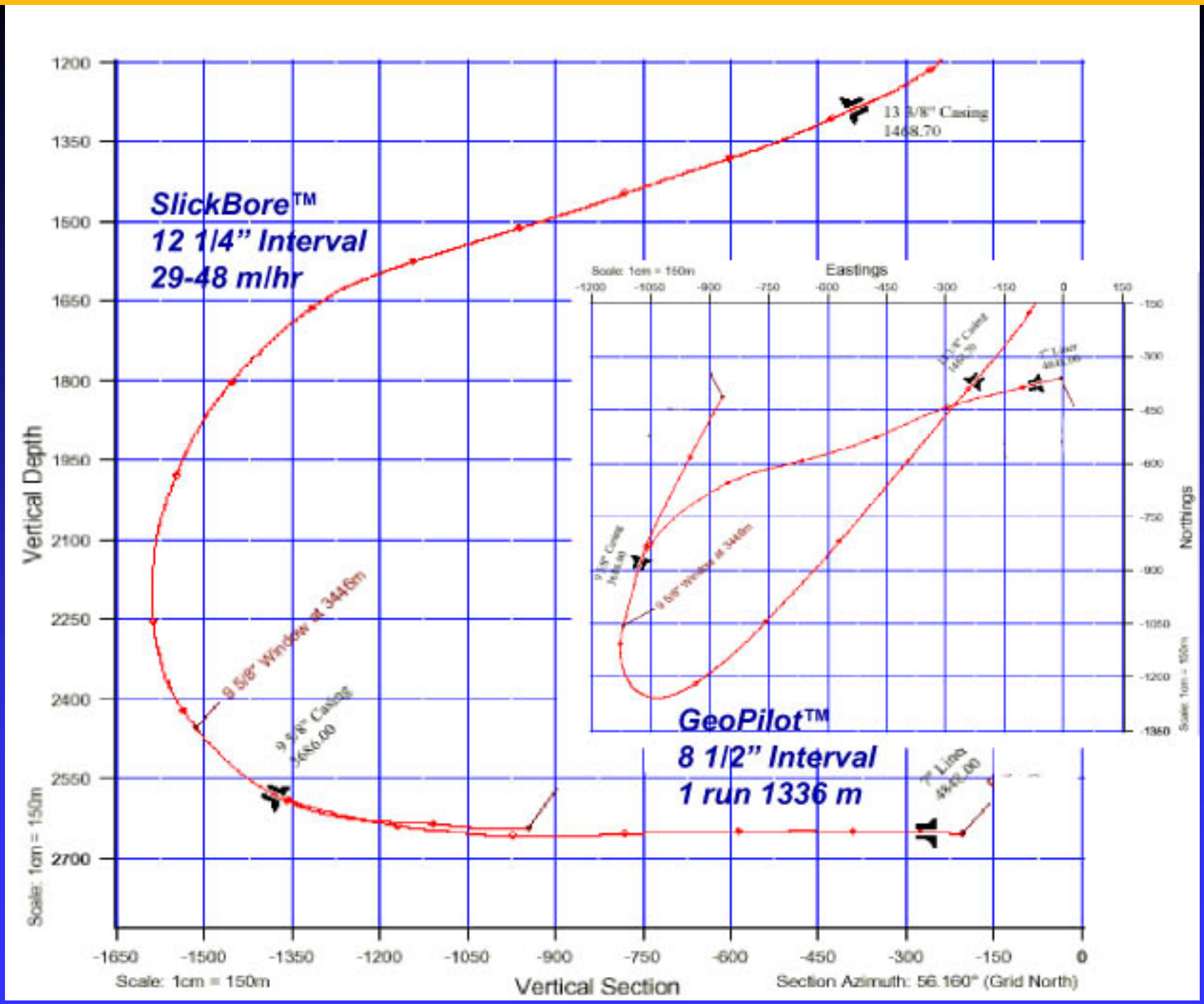
Geo-Pilot Assembly - 8-1/2” Hole
*Average Friction Factor - **0.11***

- *Drilled 3570 ft without a failure*

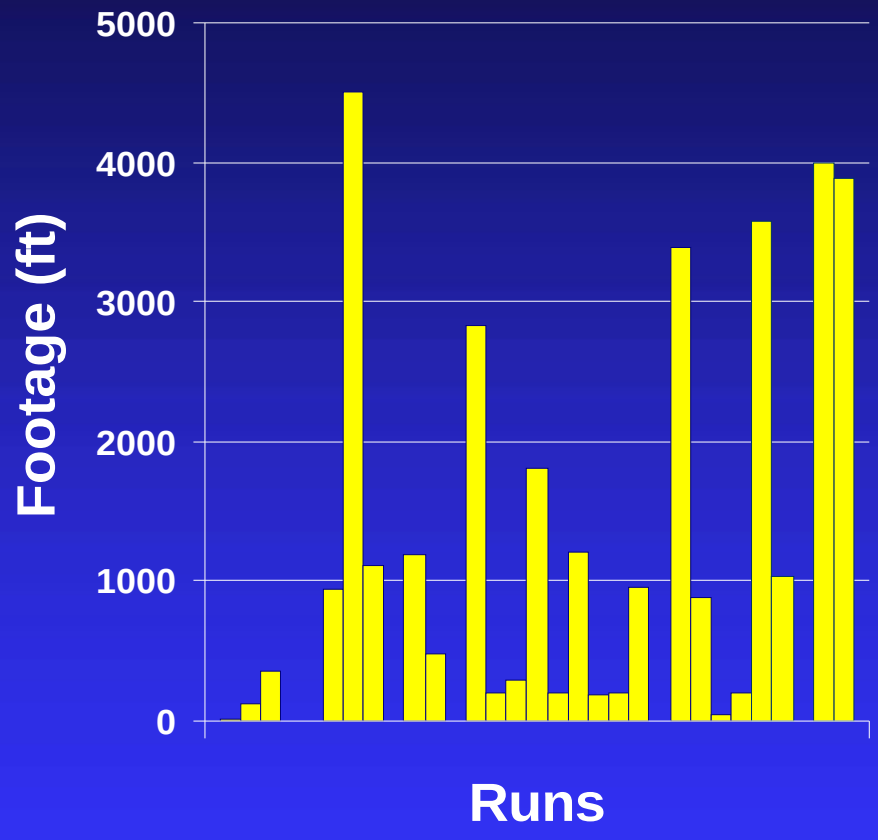
- *Triple Combo with PWD*






SlickBore™
12 1/4" Interval
29-48 m/hr
13 3/8" Casing
1468.70
9 5/8" Window at 3446m
9 5/8" Casing
3686.00
7" Liner
4645.00
GeoPilot™
8 1/2" Interval
1 run 1336 m
Vertical Depth
Scale: 1cm = 150m
Vertical Section
Scale: 1cm = 150m
Section Azimuth: 56.160° (Grid North)
Eastings
Northings
Scale: 1cm = 150m

Geo-Pilot™ Track Record (9/2000)

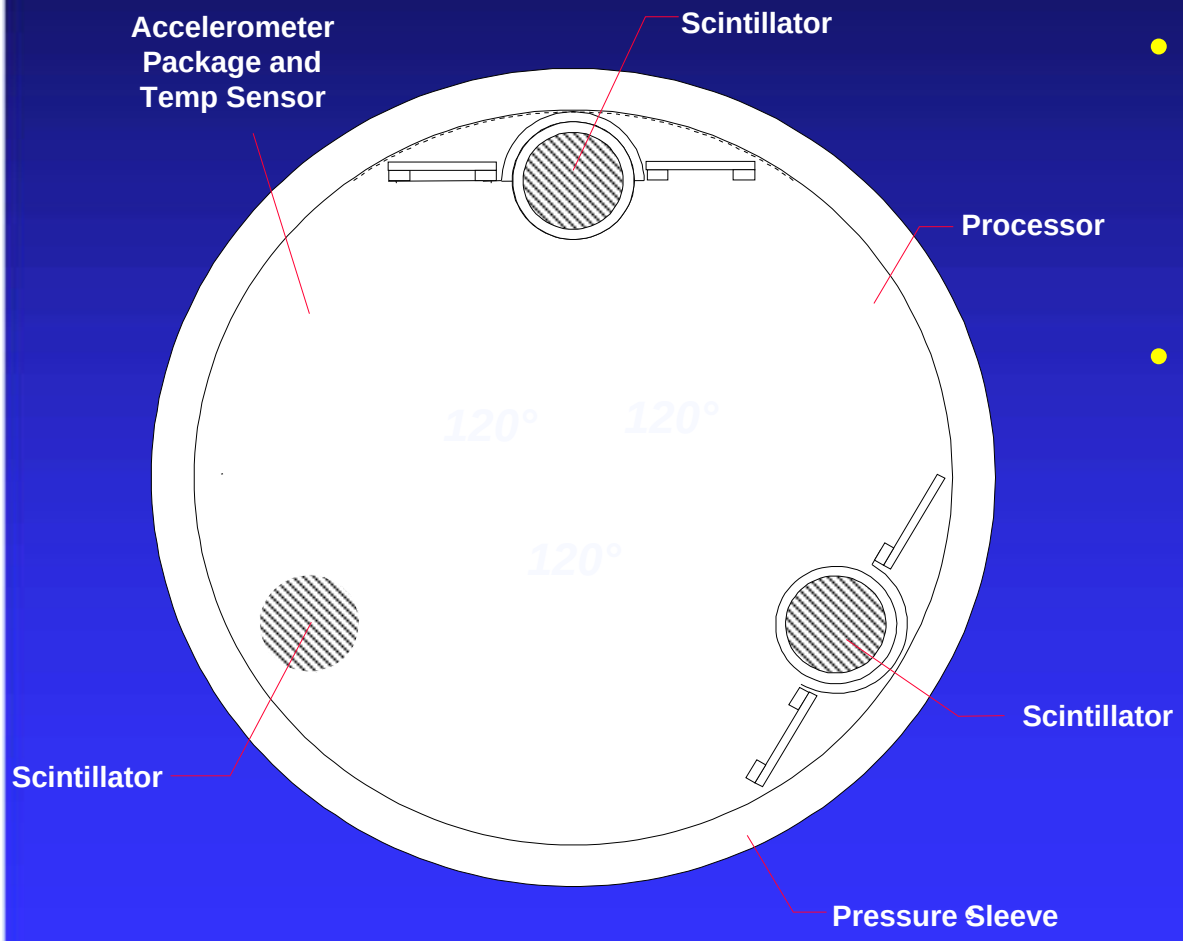


- 31 Runs to date
- 10,279 m / 33,724 ft drilled
- 654 hours on bottom
- 828 hours circulating
- 7 Commercial Runs / 4 jobs
  - 1 failure (2033 psi pressure surge blew rotary seal)
  - 325 hours MTBF
- 4 Well sections completed
- 3/4 jobs done with 1 tool
- 3/4 jobs impossible without Rotary Steerable technology

http://www.petroweb.co.uk

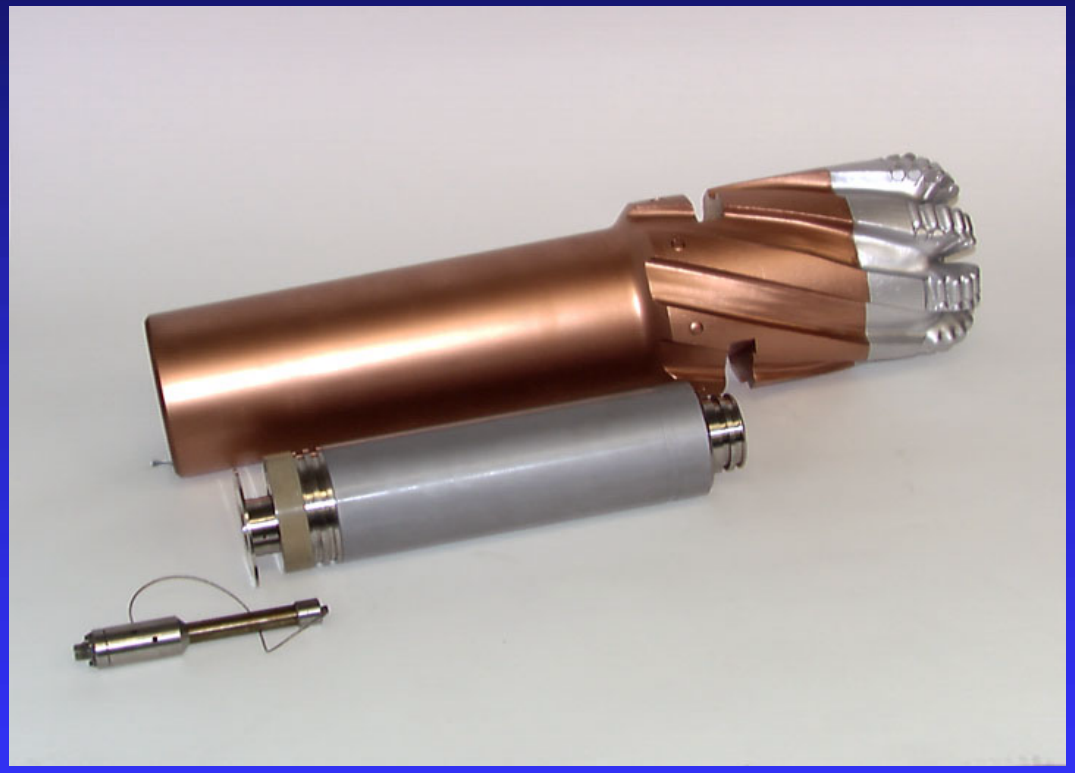
- **Discussion Forums**
  - **Rotary Steerables**

Future Developments for Geo-Pilot



- Adding Azimuthal Gamma Ray to current At-Bit Inclination sensor package
- Sensor Distance - 3 ft

Further Developments for Geo-Pilot



IN-BIT TECHNOLOGY™

- **Box-up design allows room for instrumentation package**
- **Currently testing with vibration and temperature**

Future Developments

- 2-way communication
  - Conducted first test at Halliburton Fort Worth test well
  - Able to pulse down and up simultaneously
  - Working to refine downhole detection algorithm

Rotary Steerable Questions

- How do we compare to Baker and Anadrill?
- What sizes will be available when?
- What about borehole washout?
- Do we have to use a long gauge bit?

Economic Evaluation

60 well project with High Angle / Extended Reach challenge

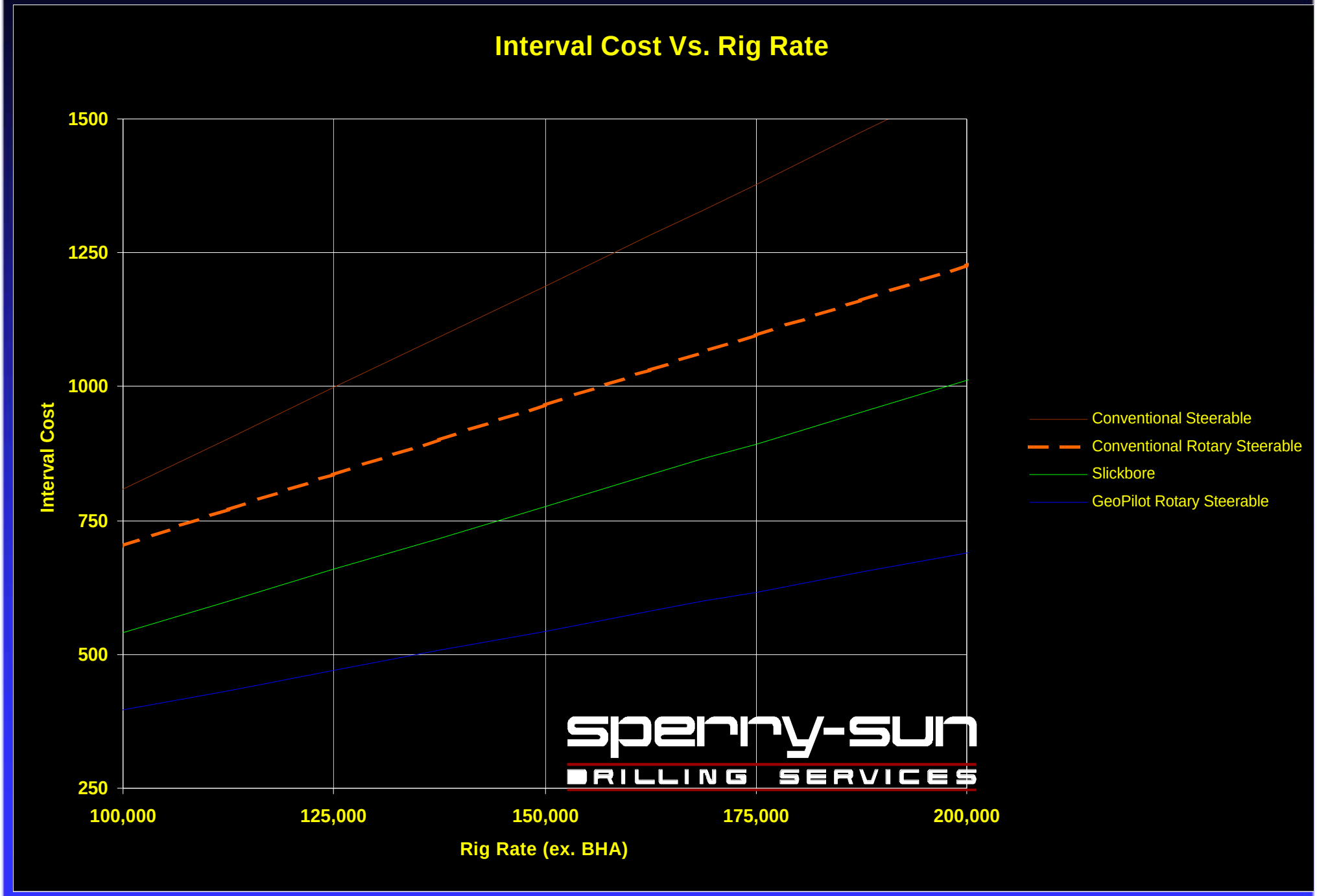
	WELLS	COST/ DAY	DELTA COST FOR 15 DAYS / WELL
WITHOUT SPERRY-SUN			
WELLS DRILLED CONVENTIONALLY	40	-	-
WELLS DRILLED WITH ROTARY STEERABLE	20	$40k	$ 12,000,000
TOTAL			*$ 12,000,000*
WITH SPERRY-SUN			
WELLS DRILLED CONVENTIONALLY	40	-	-
WELLS DRILLED WITH SLICKBORE	10	$5k	$ 750,000
WELLS DRILLED WITH GEO-PILOT R/S	10	$40k	$ 6,000,000
TOTAL			*$ 6,750,000*

DIFFERENCE: ***$5,250,000***

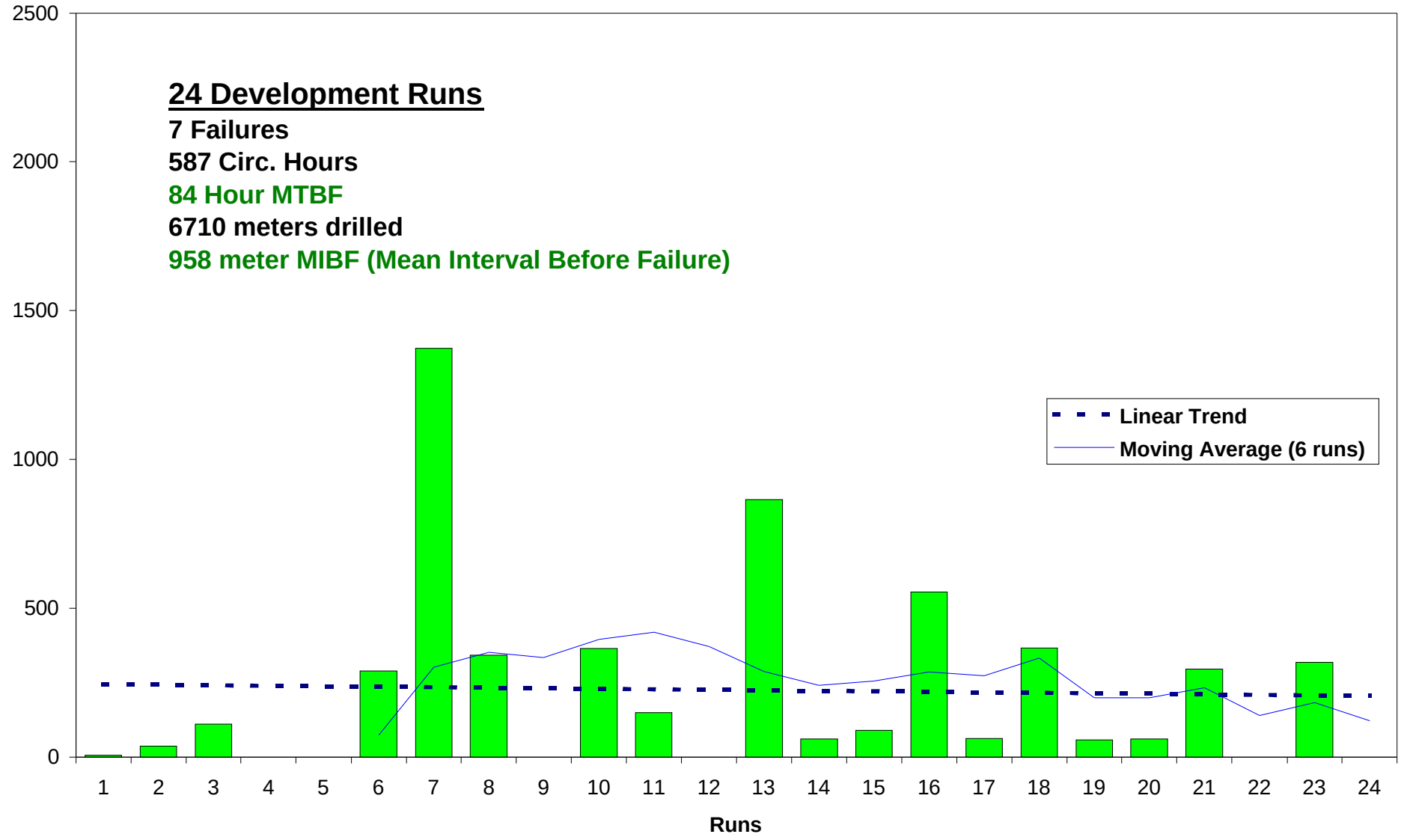
Input - Economic Justification

ITEM	INPUT	UNITS
Rig Cost (excluding MWL/LWD/DirDrlg)	$ 125,000.00	US$/DAY Spread Rate
Interval Start Depth	4,325	FT or Meters
Interval End Depth	5,100	FT or Meters
Trip Time	300.0	FT/M per Hr
Cement Success (Conventional)	90%	Percent of Jobs
Cement Success (SlickBore)	100%	Percent of Jobs

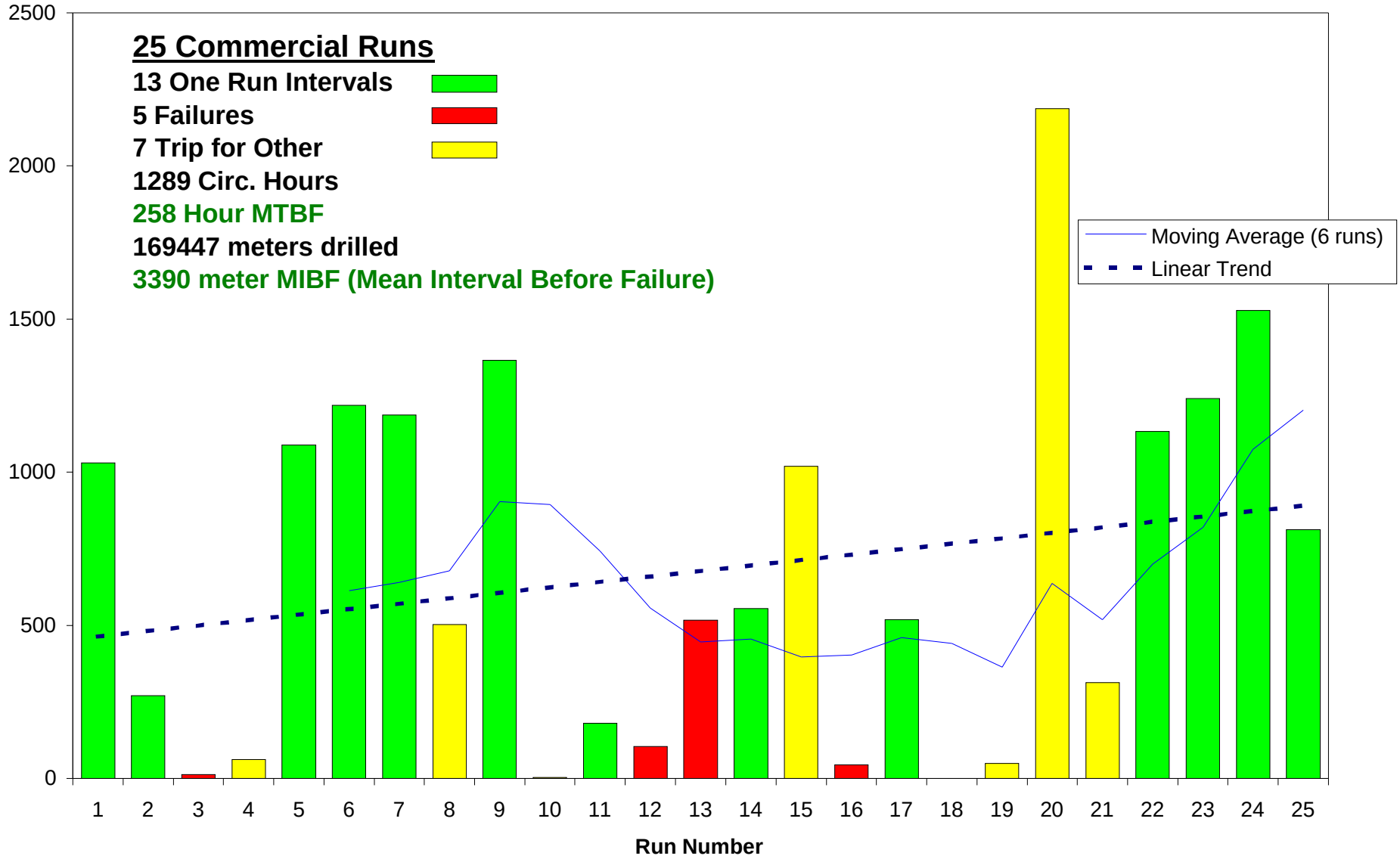
System Data	CONVENTIONAL STEERABLE	CONVENTIONAL ROTARY	SLICKBORE	GEOPILOT	
Reliability	900	75	900	270	MTTSI (Circ Hrs)
ROP Oriented (Non-Rotating)	2.0		3.0		FT/HR or M/HR
ROP Rotating	14.9	14.9	27.7	27.7	FT/HR or M/HR
Rotating Percentage (Depth)	85.0%	100.0%	85.4%	100.0%	Footage Percent
Circulating/Drilling Percentage	34.4%	34.4%	28.3%	28.3%	Circ/Drlg Percent
MWD/LWD/DirDrlg Service Cost	6000	35000	15000	35000	US$/Day Total
Short Trip Freq	150	150	0	0	FT or Meters


Interval Cost Vs. Rig Rate
1500
1250
1000
750
500
250
Interval Cost
100,000
125,000
150,000
175,000
200,000
Rig Rate (ex. BHA)
Conventional Steerable
Conventional Rotary Steerable
Slickbore
GeoPilot Rotary Steerable
sperry-sun
DRILLING SERVICES

GeoPilot Development/Prototype History (Meters/Run)



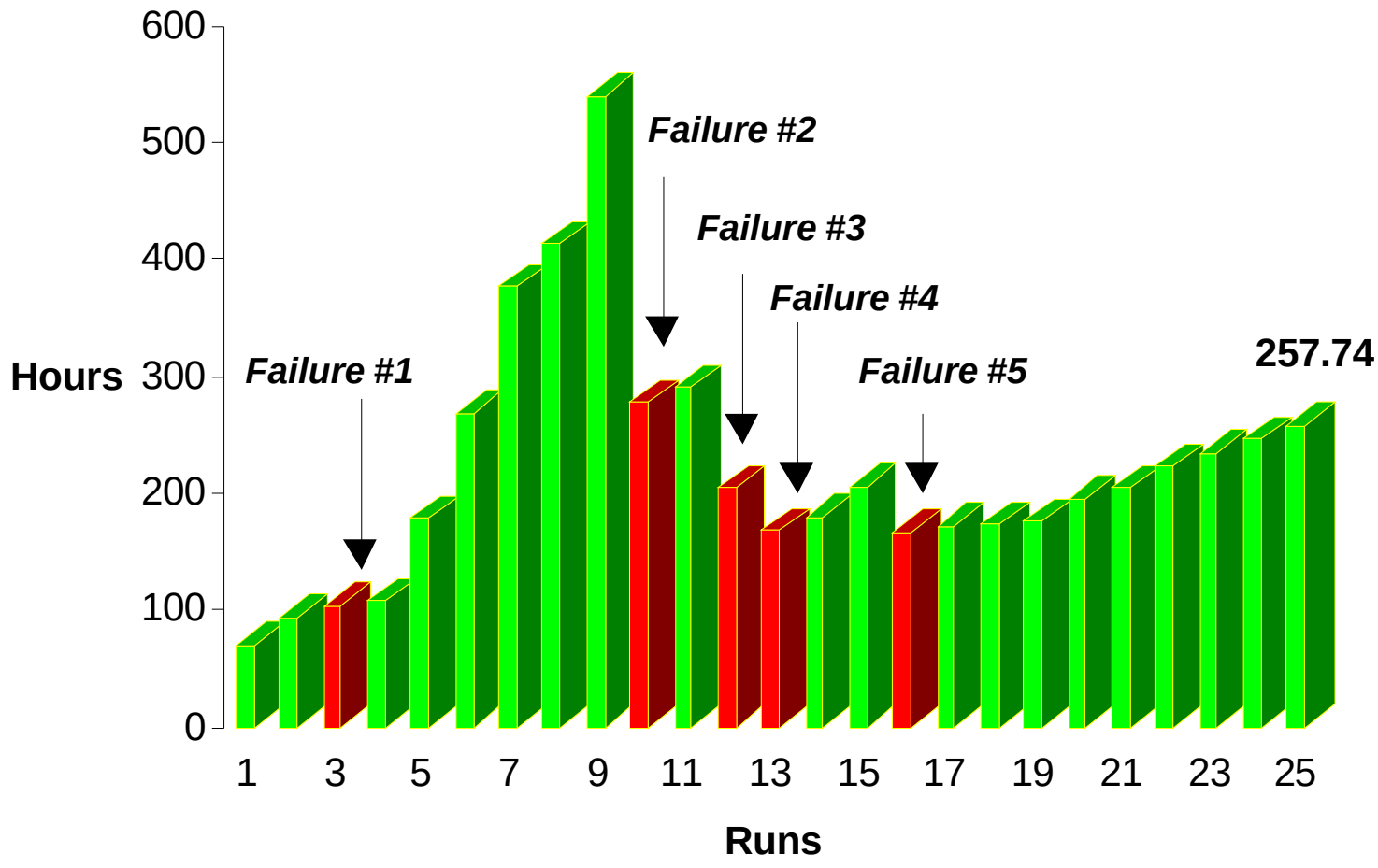
GeoPilot Commercial History (Meters/Run)



Directional System Comparison - 12.25" Interval	Conventional Steerable	Conventional Rotary Steerable	Slickbore	GeoPilot Rotary Steerable
Rig Cost	$ 250,000	$ 250,000	$ 250,000	$ 250,000
Interval Start Depth	3,220	3,220	3,220	3,220
Interval End Depth	4,127	4,127	4,127	4,127
ROP Steering (m/hr)	10	20	15	30
Percent Steering	50%	0%	50%	0%
ROP Rotating (m/hr)	20	20	30	30
Percent Rotating	50%	100%	50%	100%
Reliability, MTTSI	1,000	100	3,000	325
Service Cost	4%	20%	8%	24%
BRT Time, Drilling	68.03	45.35	45.35	30.23
BRT Time, Circulating	20.01	14.34	12.07	9.05
Short Trip Freq, meters	150	150	-	-
BRT Time, Short Trip	7.56	7.56	-	-
Trip Time, Hrs	13.76	13.76	13.76	13.76
Total Trip Time w/Failures	1.50	11.14	0.33	2.24
Casing Run Time	20.64	20.64	18.57	18.57
Cement Success	75%	75%	100%	100%
Cement Squeeze, hrs	6	6	0	0
Total Interval Time, hrs	137.49	118.78	90.07	73.85
Interval Time, Normalized	100%	86%	66%	54%
Rig Cost + Service Cost	$ 1,489,426	$ 1,484,759	$ 1,013,339	$ 953,936
Normalized Interval Cost	100%	100%	68%	64%
Interval Days (excluding casing and cementing	4.62	3.84	2.98	2.30

geo-pilot™ ROTARY STEERABLE SYSTEM

Geo-Pilot Rotary Steerable System
Mean Time Between Failures (Hours)
01/30/01



SUMMARY
Our Plan of Attack

- **Identify appropriate technology for each interval**
  - **Optimize number of wells requiring Rotary Steerable technology**
  - **Extend envelope of non-Rotary Steerable interval with SlickBore**
- **Drill superior quality hole with SlickBore System**
- **Utilize the Geo-Pilot for its superior reliability**

SUMMARY
Recommended Implementation

- **Identify appropriate technology for each interval**
  - **Optimize number of wells requiring Rotary Steerable technology**
  - **Extend envelope of non-Rotary Steerable interval with SlickBore**
- **Drill superior quality hole with SlickBore System**
- **Utilize the Geo-Pilot for its superior reliability**

Questions?