Scientific Drilling

Directional Drilling in Coal

Bob Godbolt, Business Development Coordinator, UK, Caspian and Africa.

Monday 21st March 2011
Contents

- Introduction to Scientific Drilling
- Horizontal Wells and why we use them
- An overview of Drilling Systems and Techniques used for horizontal drilling in coal
- Drillstrings and BHA
- Navigation Technology used for critical well placement in thin zone coal horizontals
- Summary
Who is Scientific Drilling?

- Scientific Drilling is a Directional Drilling Service Provider that provides a very wide range of in-house built Drilling and Navigation Systems.
- We will plan and engineer the well and supply any downhole equipment required to drill it.
- We provide a complete directional drilling plan to be included in the drilling program.
- We do the Torque and Drag Analysis to insure that the customer gets as much of the reservoir as possible with the least amount of problems.
- We supply expert engineers to liaise with the client and to run the tools and equipment provided.
- Scientific is a company that custom builds all equipment, tools, sensors and instruments in-house.
WHERE SDI OPERATES

- Operations on six continents
- Permanent facilities in North America, Europe, Asia, Australia and the Middle East
Company History

1975 - Survey Division formed and opened offices in U.K.
1977 - Started Norway, Holland and Middle - East- operations.
1979 - Commenced Far East and Canadian operations
1981 - Scientific bought by AMF corporation. Started D/D in the US.
1983 - Introduced Pressure Gauge Services.
1986 - Scientific bought by Don Van Steenwyk
1986 – Introduced 1st Continuous N.Seeking Gyro Finder
1994 – Introduced 1st twin Gyro Continuous N.Seeking Gyro Keeper
1996 - Opened office in Australia
1997 - Introduced new Memory Production Systems
1997 - Launched Electromagnetic MWD System
1999 - Launched Mud Pulse MWD
1999 - Introduced world first Memory Pulsed Neutron tool.
2000 - Launched gMWD
2001 - Opened office in Alaska and launched TITAN range of Motors
2002 - Launched Adk high accuracy drop Keeper
2002 - Introduced Enhanced Magnetic Ranging System – MagTraC
2003 - Introduced A/P and Resistivity system
2004 – Opened Satellite operations in Russia and China
2005 - Scientific Drilling gMWD Drills 1 Million Feet
2005 - Successfully completed CBM Multi-Seam Directional Drilling Projects
2006 - Launched the GAIN (Gamma and Inc. near Motor) tool in the US
2006 - Continue to develop CBD (Coal Boundary Detection), Short Hop EM Transmission & Smart Motor for Horizontal Drilling Projects
2006 – Introduction of Worlds First 600 F 33K PSI EMS Survey Tool
2007 - Introduced EM gMWD,Rattler Drilling Tool, Tuning Fork Density Tool
2008 – Introduced 3 ¾ Smart Motor
ATA R&D Facilities

Engineering Facility

Manufacturing Facility

Logging Facility
Testing Gyro Tools

World-Class laboratories
ATA Engineering & Manufacturing Facilities

Keeper Lab

Pulsed Neutron Lab

Digital Circuit Board Assembly

1 of 3 Cleanrooms

Digital Machine Shop

Mechanical Assembly

Precision equipment producing high-accuracy tools
Testing Magnetic Tools

The MagLab is located in a “greenfield site” for high-accuracy testing of all magnetic sensors.
Our Test Wells

The test wells provide known entry and exit points and non-magnetic casing
# Directional Drilling

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<tr>
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| Total Market                     | $1,867| $2,204| $2,797| $2,709| $3,000| $3,523| $4,655| $6,568| $8,381| $10,081| $8,660| $9,445| $10,578|
| Annual Market Change             | 18%   | 27%   | -3%   | 11%   | 17%   | 32%   | 41%   | 28%   | 20%   | -14%  | 9%    | 12%   |       |
Research and Development

Scientific Drillings research organization A.T.A. has vast experience in several fields:

- Aerospace Industry
- Geo-thermal Industry
- Military - Navigation Systems
- Tool and Sensor Manufacture
- Software Development
- Oil & Gas Industry
- Worldwide Staff = 1800, 20% work in R&D.
Horizontal Wells

What are they and why do we use them
What is Directional Drilling?

- The intentional deviation of a wellbore from the path it would naturally take.
- This is accomplished through the use of various down hole tools. The directional driller can also exploit certain drilling parameters such as weight on bit and rotary speed to deflect the bit away from the axis of the existing wellbore. While many techniques can accomplish this, the general concept is simple: point or push the bit in the direction that one wants to drill.
Reasons for Drilling Directionally

1. Inaccessible Locations
2. Geological
3. Remedial
4. Environmental
5. Trenchless Drilling
6. Economic
Reasons for Drilling Directionally

1. Inaccessible Locations

Historically prime reason for drilling a directional well was that it was not possible to rig up vertically above the target. Environmentally protected area Economically non-viable to develop a site Someone else owns the surface location!
2. Geological

Formations in many parts of the world present difficulty in drilling vertical wells.

e.g. Salt formations are very unstable, thus drilling extended vertical sections through salt leads to poor hole stability issues, even after casing is run, tubulars are still at risk of being crushed.

Severe dip formations – difficult to drill vertically through, bit wants to follow angle of dip. Fault could slip and shear casing.
Reasons for Drilling Directionally

3. Remedial

- Having to re-drill the well due to stuck drilling assemblies “junk”

- Drill relief well to control blow out downhole.
Reasons for Drilling Directionally

4. Environmental

By drilling directionally it is possible to drill a large number of wells from a relatively small area. With the rig on location for a greater length of time, greater care can be taken over site preparation with more effective pollution control measures in place. Many oil formations lie below environmentally sensitive areas. It is possible to develop these formations by sitting the rig out with the area.
Reasons for Drilling Directionally

5. Trenchless Drilling

For installation of utilities and pipes close to surface; minimizes or eliminates the need for surface excavation, reduces environmental damage and reduces the associated costs for underground work.

Example: Paso de Los Libres “River Crossing”.

1230 Metres crossing under the Uruguay river between Argentina & Brazil for gas pipe line installation.

“Punch out” achieved within 0.4 metres of the exit target centre!
Reasons for Drilling Directionally

6. Economic
By optimising the wellpath through the producing formation, production can be increased considerably. Many formations cannot be developed economically without drilling directional wells.

- More footage of formation
- Increased cleat & fracture exposure
- Increased production!
- 2-10(x) Production
- 2(x) Total Well Cost
6. Economic – (continued)

Offshore daily rig rate: +/- $350,000
Onshore daily rig rate: +/- $25,000

Ultimately the main reason to drill any well is economically driven, the additional cost of directional drilling has to be justified.

Cost Savings:
- Several targets acquired with one well without separate cost of establishing separate wellheads / or separate sites.
Obvious rig site prohibitively expensive to use (drilling offshore from onshore, under lakes and under hilly terrain).
Drilling may be made more efficient when directional drilling tools and procedures are utilised (even vertical wells).
# Horizontal Classification

<table>
<thead>
<tr>
<th>Horizontal Class</th>
<th>Horizontal Class Identifier</th>
<th>Horizontal Build Rate deg. / 100'</th>
<th>Hole Radius (feet)</th>
<th>Wellbore Size Diameter</th>
<th>Nominal BHA Tool Diameter</th>
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<tr>
<td>Long Radius (Up to 6°/100')</td>
<td>LRH2</td>
<td>2°/100'</td>
<td>2865</td>
<td>8-1/2&quot;</td>
<td>6-1/2&quot; 4-3/4&quot; 3-1/2&quot;</td>
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<td>LRH4</td>
<td>4°/100'</td>
<td>1432</td>
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<td></td>
<td>LRH6</td>
<td>6°/100'</td>
<td>955</td>
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<td>Medium Radius (7°/100' to 40°/100')</td>
<td>MRH8</td>
<td>8°/100'</td>
<td>716</td>
<td>6-1/2&quot;</td>
<td>4-3/4&quot; 3-1/2&quot;</td>
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<td>MRH12</td>
<td>12°/100'</td>
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<td>MRH30</td>
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<td>164</td>
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<td></td>
<td>MRH40</td>
<td>40°/100'</td>
<td>143</td>
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<td>Short Radius (40°/100' to 60°/100')</td>
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<td>SRH60</td>
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### Horizontal Well Classification

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<th>Type</th>
<th>Radius (Feet)</th>
<th>Achievable Lateral Length (Feet)</th>
<th>Method</th>
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<tr>
<td>Zero</td>
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<td>10</td>
<td>Telescopic probe with hydraulic jet</td>
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<td>Ultra-Short</td>
<td>0.5-5.0</td>
<td>200</td>
<td>Coiled tubing with hydraulic jet</td>
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<tr>
<td>Short</td>
<td>35-45</td>
<td>1,500</td>
<td>Curved drilling guide with flexible drill pipe; entire string rotated from surface</td>
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<tr>
<td>Medium</td>
<td>300-500</td>
<td>1,500</td>
<td>Steerable mud motor used with compressive drill pipe; conventional drilling technology can also be used</td>
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<tr>
<td>Long</td>
<td>1,800-2,800</td>
<td>1,500+</td>
<td>Conventional directional drilling equipment used; very long curve length of 2,800 to 4,400 feet needed to be drilled before achieving horizontal</td>
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<td>In-Mine</td>
<td>N/A</td>
<td>5,000</td>
<td>Uses underground drilling rigs with steerable motors and position systems to achieve long, in-seam boreholes</td>
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**Rule of thumb used to be the Total Horizontal Length of the well is three times the length of the Lateral.**

**Curve Build Rates**

- **Long:** 2 - 6° / 100’
- **Medium:** 6 - 40° / 100’
- **Short:** 40 - 70° / 100’
- **Ultra Short:** 70 - 150° / 100’
The Leading Force in Wellbore Navigation

**Torsion**

**Dogleg & Tortuosity**

**Torque**

**Rotation on Bottom Stress**

**TORQUE DRAG MODEL**

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<th>LOAD CONDITION</th>
<th>STRESS / BUCKLING</th>
<th>TORQUE AT THE ROTARY TABLE</th>
<th>TOTAL WINDUP WITH/WITHOUT BIT TORQUE</th>
<th>MEASURED WEIGHT</th>
<th>TOTAL STRETCH</th>
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<th>NEUTRAL POINT DISTANCE FROM SURFACE / BIT</th>
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<td>11120.8</td>
<td>5.3</td>
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**LEGEND**

- Tension
- Dogleg & Tortuosity
- Torque
- Rotation on Bottom Stress

**Diagram**

- Measured Weight (kip)
- Dogleg Severity (Depth) x (1/100th)
- Measured Depth (ft)
- Stress (psi)
SDI > 10,000 Onshore Horizontal Wells Drilled in the last decade

> 5,500 Coalbed Methane Horizontal Wellbores

> 2,800 Total Horizontal Shale Gas projects (Barnett, Woodford, Caney, Marcellus, Haynesville, Eagleford, Chattanooga, Floyd, Fayetteville, etc…)

> 2,000 Horizontals since 1999 in the Barnett Tight Shale Gas
WELL DESIGN
CONSIDERATIONS
Figure 9 Directional drilling options for VCBM
Figure 10  Multi-seam drilling for VCBM (Thompson et al)
HORIZONTAL DOWNDIP INTERCEPT

- DOWNDIP HORIZONTAL ACCESS TO VERTICAL PRODUCTION
DUAL LATERAL TO VERTICAL WELL DESIGN

Exhibit 9: Typical Stratigraphic Section and Lateral Well Trajectory

Source: www.ch4.com.au
CBM Multi-Lateral Examples
SAN JUAN – 2-SEAM FOUR LATERAL EXAMPLE – 2 WHIPSTOCK EXITS

WELL DETAILS:

Ground Level: 6785.0

Slot

Dewatered Zone (Lower Pressure)

Offset Well

Original Hole/As Drilled

Offset Well

Lateral #1/As Drilled

Lateral #2/As Drilled

Lateral #1 ST #1/As Drilled

Lateral #2 ST #1/As Drilled

West(-)/East(+) (500 ft/min)

Ground Level: 6785.0

Slot

Dewatered Zone (Lower Pressure)

Offset Well

Original Hole/As Drilled

Offset Well

Lateral #1/As Drilled

Lateral #2/As Drilled

Lateral #1 ST #1/As Drilled

Lateral #2 ST #1/As Drilled

West(-)/East(+) (500 ft/min)
HORIZONTAL FIELD DEVELOPMENT
SINGLE WELL SIDETRACK TO VERTICAL

- Start Build 29.528
- 5-1/2" CSG WHIP
- KOP 365 m Start Build 2.953
- Start 288.25 hold at 477.52 MD
- Start DLS 3.937 TFO 180.00
- Vertical TGT
- TD at 1901.41
- Design #1
- Start 944.88 hold at 956.53 MD
- Vertical Dewatering Well, Wellbore #1, Design #1 V0
- Start 14.48 hold at 942.05 MD
RADIAL PATTERN COAL SEAM WELL DESIGN

MULTIPLE SIDETRACKS AND MULTI-LATERALS IN ONE PRIMARY COAL SEAM
MagTraC MWD Ranging has been designed and engineered to aid directional drilling by giving a distance and direction to a nearby source of magnetic interference or “target”. This information can be used to intercept or avoid targets and can also act as a real time confirmation on the position of nearby wells.

Used extensively in the North Sea and around the globe by Shell, Chevron, ConocoPhillips, Exxon Mobil, Occidental and Total (to name a few), MagTraC has quickly become another essential tool in the drilling engineer’s arsenal.
MWD Ranging is accomplished by measuring the magnetic field magnitude and direction at several locations along the active wellbore, using our standard MWD tools.

The MagTraC software processes these measurements of the complex magnetic field that results from the combination of the background earth (reference) field and the magnetic interference from the nearby “target” casing string.

As we are using the directional MWD tools already in the hole, no extra trips or wireline runs are required. Also, no access is required to the existing well, saving both time and money.
North Sea Example

MagTraC was recently used on a project in the North Sea that highlighted its many capabilities. Initial ranging was done to confirm that the sidetrack had taken place and that we were heading away from the motherbore. Interference from the target well was picked up much earlier than expected. Without using MagTraC to range against this source of interference, the oil companies only other course of action would have been to abandon the well. However, utilising MagTraC allowed us to tell the client that the new well would pass under the target by 14ft. Using MagTraC allowed the client to update his positioning of the target well, moving it 45ft laterally and 12ft on TVD.
Drillstring and BHA Components
DRILL STRING / BHA

DIRECTIONAL DRILLING EQUIPMENT

- Drill Bit
- Positive Displacement Drill Motor
- MWD System (MP or E-Field)
- Logging While Drilling Tool
- Non-Magnetic Drill Collar
- Push Drill Pipe or Collars
- Heavy Weight Drill Pipe
- Drill Pipe from Surface
The Leading Force in Wellbore Navigation

**E-Field MWD**

4-3/4” BHA with a 3-3/4” MOTOR & 3-1/2” GAIN

Assumes 20ft of NMDC below gap sub and 3 ft Float Sub - Otherwise adjust for different lengths

3-¾ 7:8 2.3 Stage Motor & EM4 MWD Configuration

Ext. Focus Gamma Extensions

EM tool Anchor pt.

1. **EM tool Anchor pt.**
   - 35’
   - 35.3’

2. **Gap/hanging sub**
   - 21’10”
   - EM Mag. sensor pt.

3. **NMDC**
4. **Gap/hanging sub**
5. **NMDC**

GAIN: Gamma And Inclination Near Motor

**GAIN: Gamma And Inclination Near Motor**

- Bottom of motor to EM MWD sensor pt. = +/- 38 ft.
- Bottom of motor to Gamma sensor pt. = +/- 21-23 ft.

**GAIN:**

- **Bottom of motor to EM MWD sensor pt. = +/- 38 ft.**
- **Bottom of motor to Gamma sensor pt. = +/- 21-23 ft.**
DRILL BITS

PDC Bit

Roller Cone Bit
Maintaining the BHA heading within the Target Zone – Correct bit selection can mean the difference between staying in the coal or drilling into the boundary above or below.
KEY COAL DRILLING ISSUES

FAULTING AND FRACTURING

Under Clay

Sandstone

Upper Coal Seam

Middle Coal Seam

Sandstone

Lower Coal Seam

Shale

Steer Up 1st

Steer Down 2nd

FIGURE 19. - Two methods of following the coalbed. Method B is recommended.
Possibility of steering up into another coal seam
DIRECTIONAL DRILLING TOOLS

DRILLING STEERING SYSTEMS

- STEERABLE POSITIVE DISPLACEMENT DRILL MOTOR (PDM)
  - Downhole Steerable PDM with a Rotary Drilling Rig
  - Coiled Tubing, PDM with down-hole orientation system

- ROTARY STEERABLE SYSTEM (RSS)
Drill Motors
STANDARD, AIR, ERT, EXTENDED, SUPER-EXTENDED

MOTOR CONFIGURATION

- LOBE (7:8, 4:5, 1:2, …)

- NUMBER OF STAGES

- ELASTOMER PROPERTIES

- ROTATION PER GALLON

- CLEARANCE FIT

- PITCH

(Courtesy Robbins & Myers, Inc)
PDM Drill Motors

ABH (Adjustable Bent housing Motors);

Adjustable bent housing
Allows the bend on the motor to be
Adjusted to different angles. (0-3 Degrees) on location.

Wear pad on opposite side of bend increases side force on the bit.

The steerable motor will drill, when oriented, at a constant dogleg severity. Still industry standard for drilling complex directional wells in areas where the latest rotary steerable systems cannot be justified or are unavailable.

The near bit stabiliser sleeve will normally be undergauge (+/- ¼’’). This will result in a tendency to drop inclination in rotary. The gauge of the stabiliser above the motor will be chosen to counteract this drop to allow the assembly to drill straight in rotary.
Animation showing mud flow through a Motor
ERT Drill Motors

**TITAN**

High Performance Mud Motor

**Improved Drilling Performance through:**
- Higher Torque for less stalling and improved ROP
- Higher RPM for better hole cleaning
- Higher Temperature Limits
- Higher Weight on Bit

**Titan ERT™ Drill Motor**

**ERT** Even Rubber Thickness) Stators

- Higher loading per stage
- A thin even layer of rubber provides uniform fit
- Increased torque and power - Drill faster
- Shorter motors improves directional and MWD/LWD performance
- Increased stator life
- More consistent performance in hostile drilling fluids

Scientific Drilling
### EFFECT OF LOBE CONFIGURATION

**Conditions:** 475M Power Section • 100 GPM • OD 4.75”

<table>
<thead>
<tr>
<th>Power Section Configuration</th>
<th>Number of Stages</th>
<th>No-Load RPM</th>
<th>Operating Pressure (psi)</th>
<th>Torque at Operating Pressure (ft-lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:2</td>
<td>3.0</td>
<td>225</td>
<td>380</td>
<td>440</td>
</tr>
<tr>
<td>4:5</td>
<td>3.5</td>
<td>100</td>
<td>505</td>
<td>1192</td>
</tr>
<tr>
<td>7:8</td>
<td>3.0</td>
<td>70</td>
<td>485</td>
<td>1455</td>
</tr>
</tbody>
</table>

**Increasing the number of lobes lowers rotor speed and increases torque within the same physical space.**
## EFFECT OF STAGING (LENGTHENING)

**Conditions:** 4:5 Configuration • 475M Power Section • 100 GPM • OD 4.75''

<table>
<thead>
<tr>
<th>Number of Stages</th>
<th>Stator Length (in)</th>
<th>No-Load RPM</th>
<th>Operating Pressure (psi)</th>
<th>Torque at Operating Pressure (ft-lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>41</td>
<td>100</td>
<td>159</td>
<td>280</td>
</tr>
<tr>
<td>3.5</td>
<td>116</td>
<td>100</td>
<td>505</td>
<td>1192</td>
</tr>
<tr>
<td>6.0</td>
<td>187</td>
<td>100</td>
<td>867</td>
<td>2100</td>
</tr>
</tbody>
</table>

**Bar Chart:**
- **X-Axis:** Torque at Operating Pressure (FT-LB)
- **Y-Axis:** Number of Stages

The effect of power section staging on pressure and torque.

*Note: The bar chart visually represents the data with bars for each number of stages.*
Rotary Steerable Systems (RSS)

The greatest problem with steerable motor drilling is having to stop the rotary when there is a need to adjust the direction of the well. Often hole conditions make it difficult to drill without rotary (Rotary creates more turbulence down hole and stirs up cuttings – more chance of getting stuck sliding). Long horizontal wells: impossible to slide due to accumulation of drag along high inclination sections. Rotary steerable tools allow continuous rotary drilling whilst maintaining directional control.

**Advantages:**
- Greatly improve long reach capability
- Large decrease in orientation time
- More economic in high cost areas
- Smoother well paths with fewer dog legs (easier to run casing)
- Reduced Torque & Drag
- Improved hole cleaning
- Reduced stuck pipe frequency
- Reduced bit to sensor spacing
- Overall faster drilling rate & fewer trips
Focus Gamma Ray & Inclination 60” above the drill Bit!
Wi-Sci Moves Sensors Closer to the Bit

TOO LATE!

Standard MWD
inclination
focused gamma?

SHALE

COAL

SHALE

SDI MWD

SMART MOTOR
with Wi-Sci
TECHNOLOGY

Inc & Focus Gamma
Focused Gamma module as part of the LWDM (Logging While Drilling Motor) - Navigation payload in the motor assembly drive assembly.

LWDM – SMART MOTOR FOCUS GAMMA RAY

Cross section view

LWDM Gamma Ray Measured Up

LWDM Gamma Ray Measured Down
RATON BASIN EXAMPLE: +/- 90.4% IN COAL

RATON CBM HORIZONTAL
2’-3’ Thick Coalbed Seam
+/- 1223 COAL
+/- 1353 LATERAL
+/- 90.4% IN COAL
Geological Steering?

As capabilities of MWD / LWD improve to include increasingly sophisticated formation evaluation sensors, once the DD has “landed the well into the target formation it is now possible to continuously modify the well plan whilst drilling to ensure the well is placed as accurately as possible within the producing formation.
SDI have tied up with United Oil & Gas consulting LTD to utilize their 3d geo modeling software.

3D mapping, characterization and visualization: 
*Geosteering Services for Horizontal Wells*

Integrated MWD, LWD and Real-time Geo-modelling for Successful Well Placement Programs (Planning, Monitoring and Geosteering)

A 24/7 Service
The Process

E&P Geologists, Operations Staff & Management

Scientific Drilling

& Other Stakeholders

Pason / Petrolink

SMART Motor, Gain tool, Radial Gamma, etc.

Integrated While Drilling

MWD, LWD

10 Minute Frequency Web Based Reports

3D Geo-Modelling and Visualization

Protected website

Pre-drill Geo-model + While Drilling Mapping

Wellsite Geologist Input

Copyright UOGC 2009 ©
Multi-lateral Wellbore in Allison Unit Messa Coals, NM

Motherbore (MB)
Upper Lateral (UL)
Upper/Blue Coal

3D Map after drilling of MB

Lower/Green Coal
Lower Lateral (LL)
Lower Lateral (LL) Integrated Gamma Presentation:
Lower/Green Coal Horizontal Profile

Gas

Pre-Drill Trajectory Plan
(Light Green Path)

Post-Drill Trajectory Path and
Structure Map after Geosteering
Upper Lateral (UL) Integrated Gamma Presentation: Upper/Blue Coal Horizontal Profile

Pre-Drill Trajectory Plan (Light Green Path)

Post-Drill Trajectory Path and Structure Map after Geosteering
MEASUREMENT SYSTEMS (INC & AZ)

MWD SYSTEMS

- E-FIELD (ELECTROMAGNETIC) MWD
- MUD-PULSED (POSITIVE OR NEGATIVE PULSE) MWD
- gMWD (Gyro MWD System – E-Field or MP)

WIRELINE STEERING TOOLS

- Magnetic Steering Tools
- Rate Gyro Steering Tools
- Camera Based “Conventional” Magnetic or Gyroscopic – Obsolete in most areas
Scientific Drilling is a leading provider of highly-accurate measure-while-drilling (MWD) services. With over 20 years of engineering and manufacturing excellence, our MWD systems have proven reliability and cost effectiveness worldwide.

**Advantages**

- Good for many well types. Has all standard collar sizes for multiple flow rates.
- Wide range of measurements. Fully programmable, it produces a variety of Real-time measurements.
- High quality real time output. Sophisticated algorithms correlate, analyse and Produce Accurate real time data.
MP MEASUREMENT WHILE DRILLING

- MUD PULSED MWD ILLUSTRATION

Courtesy of Landmark Graphics Corporation
EM MWD  Basic Theory of Operation

Transmission

Efield MWD uses electromagnetic wave propagation to send data from the downhole MWD sensors back to a surface antenna.

The hybrid sub isolates and separates the 2 injection points from each other.

This system is ideal for air operations as regular MWD requires a column of fluid to transmit the data.

This system gives very fast data rate transmission.
ELECTROMAGNETIC MWD FEATURES

Features

- Inclination
- Azimuth
- Toolface (highside + magnetic)
- Vibration (peak + average)
- Gamma (optional)
- Focused Gamma (optional)
- Gamma Near Bit
- Pressure While Drilling (PWD)
- Annular-Pipe-Differential
- “Short Hop” communication to additional tools, i.e. Smart Motor, SRX, Bit Subs, etc...
gMWD - The System

- Pulser
- Power Pack
- Gamma Sensor
- Golden Eye Magnetic Probe
- Power Pack
- Keeper Gyro
SYSTEM APPLICATION

Kick off/surface hole in high congestion areas.

- Kick well off with continuous gyro toolface from Keeper module in an MWD format.
- Typical time for TFU’s 14 secs.
- Survey data up after 3 min still time and 3.8 min pumps on.
- Establish magnetic interference point by sending survey data from gyro and mag probes simultaneously – 3 min still time and 6.6 min. pumps on.
- When drilling ahead rotary, gyro system is “put in sleep mode”. System is then powered up and gyro survey taken after 3 mins.
- Benefit from Gyro sensor point to bit depth at approx. 30ft.
KEEPER GYRO OVERVIEW

Keeper Gyro – Latest generation high speed, high accuracy borehole surveying system.

Keeper operates in a continuous survey mode from vertical through horizontal and is capable of providing definitive surveys, orientations and gyro while drilling at all inclinations and orientations including due East/West and Horizontal.

It is more accurate, more versatile and much faster than any system available in small diameter.
WELLBORE SURVEY
Earth Rate Gyro Configurations

- Casing wireline mode decentralized

- Wireline Mode centralized in D/Pipe, Memory mode on Slickline, Sightline mode

- Drop or ADK Mode

- Gyro steering mode on wireline

- Gyro MWD configuration (gMWD)
SUMMARY

- Have a Team Approach & Keep the Team Consistent
- Work together for a common goal
- Make a detailed plan but be flexible
- If you don’t need it, don’t run it in the hole!
- Maximize wellbore stability by drilling a smaller wellbore diameter using the right tools
- Develop new tools and methods to help horizontally drill a higher percentage of coal
THANK YOU