IADC/SPE 189691
Automated Directional Drilling Software and Remote Operations Centers Drive Rig Fleet Well Delivery Improvement

Colin Gillan, Nabors Industries; Matt Isbell, Travis Visitew, Hess Corporation
Introduction: **Automated Remote Drilling Project (ARD)**

- Automate directional drilling decision-making workflow and implementation
- Centralized Command Center
- Distributed software systems
- Enable directional supervisors to control a larger number of rigs
Conventional Directional Drilling Business Model

- Approved Well Plan
- Rules and Guidelines
- Daily Communication

- High cost operation
- Requires many trained DD
- Inconsistent execution
- Incomplete measurement
- Limited accountability

MWD and Directional Drillers – Rig Based
- 2 DD and 2 MWD hands per rig
- Varied Experience Levels
- On site Calculation and Directional Decisions
- Basic Reporting
- Daily Communication
- No Key Performance Indicators

Drilling Engineer
Office-Based
New Directional Drilling Business Model

- Reduced DD resources
- Experts at ROC can supervise numerous rigs
- High speed data link
- Shared visualization and data

- Enforces operator policies and guidelines
- Consistent drill down instructions and execution
- Experts can modify calculated instructions
- Tracks outcome of directional drilling decisions

Drilling Engineer and,
Expert Dir. Drillers

Remote Operations Center

Live
Rig Data Portal

Rig Server
DD Navigation Software

Rig Server
DD Navigation Software

Rig Server
DD Navigation Software

Rig Server
DD Navigation Software

Roving
Directional Driller
(For well site troubleshooting)
Geometrical Directional Drilling System

• Directional drilling sufficiently stable to permit automation of geometrical steering with steerable motor
• Geo-steering workflow not stable enough for automation
• Directional drilling elements:
  – Operational policies and guidelines
  – Directional drilling instructions generated on demand
  – Directional drilling instruction execution
  – Outcome of a directional drilling decision and execution
• Selected rig contractor with shared vision for eventual automation of the stand drill-down process.
Automated Stand Drill Down Process

**DD Navigation Software**
- Task: Obtain positional data
  - Take Survey
  - Validate/Accept Survey
  - Advanced survey management, as required

**Rig Based Data Aggregator**
- Task: Record survey and other data to understand performance
  - Review position and adherence to plan
  - Analyze effectiveness of slide
  - Analyze drilling KPIs
  - Document performance and decisions

**Top Drive Quill Controller**
- Task: Consistently execute slide
  - Automation of directional control
  - Steer on Target
  - Repeatable consistent performance

**DD Navigation Software**
- Task: Create plan for next stand and deliver detail to driller
  - Detailed drill down instructions
  - 3D visualization of wellbore for drilling and geology
Important Elements of the DD Navigation Software

- Visualization
- Drilling Windows or Drilling Tunnel
- Geo-Steering Support
- Drilling Parameters
Downhole Visualization

This view is available at the driller’s chair, on other client computers at the rig and in the Remote Operations Center.
Drilling Windows

- The Drilling Window is our tolerance area around the planned wellpath or the geo-steering line.
- Progress stand by stand is easily visualized with bit position updates every 0.3ft while drilling.
### Geo Steering with Dip Angle Changes and Window Offsets

<table>
<thead>
<tr>
<th>Window Start at Plan MD</th>
<th>Width</th>
<th>Height</th>
<th>Offset (-L/+R)</th>
<th>Offset: from Plan (-U/+D)</th>
<th>Offset: from Last Window (-U/+D)</th>
<th>Inclination Angle</th>
<th>Dip Angle</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>9500 (a)</td>
<td>60</td>
<td>30</td>
<td>10</td>
<td>92</td>
<td>-2</td>
<td></td>
<td></td>
<td>Up dip by 2 degrees, down 10’ from last W.</td>
</tr>
<tr>
<td>13500 (b)</td>
<td>60</td>
<td>30</td>
<td>0</td>
<td>88.1</td>
<td>1.9</td>
<td></td>
<td></td>
<td>Down Dip by 1.9 degrees from last W.</td>
</tr>
<tr>
<td>15200 (c)</td>
<td>60</td>
<td>30</td>
<td>-5</td>
<td>88.1</td>
<td>1.9</td>
<td></td>
<td></td>
<td>Window offset 5’ up from plan line</td>
</tr>
</tbody>
</table>

- This functionality allows close to real time geo-steering collaboration and implementation with all involved on same data set.
- DD’s, geo-steering specialists, driller and company man all seeing the same recorded, archived changes.
Drilling Parameters

<table>
<thead>
<tr>
<th>From Plan MD (ft)</th>
<th>Slide Max (ft)</th>
<th>Slide Min (ft)</th>
<th>Max DLS (deg/100ft)</th>
<th>Min MO (deg/100ft)</th>
<th>Max MO (deg/100ft)</th>
<th>Survey Interval</th>
<th>Comment</th>
<th>Author</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>18</td>
<td>12</td>
<td>95</td>
<td>No slide zone for drill out down to 2200</td>
<td>RDir-Suprv@com</td>
</tr>
<tr>
<td>2200</td>
<td>5</td>
<td>5</td>
<td>12</td>
<td>18</td>
<td>12</td>
<td>95</td>
<td>Allow 1st slide. Limit slides to 8(^\circ) max - build tangent angle.</td>
<td>RDir-Suprv@com</td>
</tr>
<tr>
<td>2700</td>
<td>5</td>
<td>5</td>
<td>12</td>
<td>18</td>
<td>12</td>
<td>95</td>
<td>Allow 9(^\circ) max slide to maintain tangent angle. RDir-Suprv@com</td>
<td></td>
</tr>
<tr>
<td>3800</td>
<td>1.25</td>
<td>12</td>
<td>18</td>
<td>95</td>
<td>Top of XXXX (no slides) RDir-Suprv@com</td>
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<tr>
<td>6150</td>
<td>0</td>
<td>0</td>
<td>1.8</td>
<td>16</td>
<td>10</td>
<td>95</td>
<td>Base of XXXX (able to slide) Allow max 1.9 DLS. RDir-Suprv@com</td>
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<tr>
<td>6470</td>
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<td>1.8</td>
<td>16</td>
<td>10</td>
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<td>Top of YYYY (no slides) RDir-Suprv@com</td>
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<tr>
<td>7625</td>
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<td>0</td>
<td>1.4</td>
<td>16</td>
<td>10</td>
<td>95</td>
<td>100(^\circ) Past Base of YYYY No Slide Zone RDir-Suprv@com</td>
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<td>0</td>
<td>1.4</td>
<td>16</td>
<td>10</td>
<td>95</td>
<td>KOP minus 600(^\circ) (no slides) RDir-Suprv@com</td>
<td></td>
</tr>
<tr>
<td>9220</td>
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<td>0</td>
<td>1.4</td>
<td>16</td>
<td>10</td>
<td>95</td>
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<tr>
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<td>0</td>
<td>1.4</td>
<td>16</td>
<td>10</td>
<td>95</td>
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<tr>
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<td>32</td>
<td>8</td>
<td>7</td>
<td>14</td>
<td>95</td>
<td>95</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Best practice rules are supported in the navigation software by a drilling parameter table
- Drilldown instructions conform to these drilling parameter rules
Navigation software receives survey data from the MWD system, and calculates drilling instructions based on current position, well plan, geo-steering offsets and drilling window.
Toolface Dial During Slide Drilling

Toolface dial shows when sliding with real time toolface updates, slide scoring, resultant toolface and advisory toolface sector.
DD Grading of Navigation Software Results

• All drilldowns in 24 wells assessed by Hess DD’s
• Verticals (Nudge and Tangent)
• Curves
• Laterals
Results: Vertical Sections
Results: Curve Sections
Results: Lateral Sections

ARD Project Historical Laterals

Averages: 67% Green, 23% Yellow, 10% Red, 90% Acceptable
The Human Factor – Culture Wars

- Change is often a challenge in an industry with legacy methods, roles and ways of doing things

- This relates especially to directional drilling in our industry

- Tools to assist the directional driller in carrying out the role are regarded as positive, such as pipe oscillation/orientation systems

- Innovations which enter the directional drillers decision making space are not necessarily regarded in a positive way, therefore some cultural opposition has to be expected and planned for

- It’s like this …progress always brings change
Conclusions

• An automated directional drilling project developed an effective, fit for purpose DD advisory system

• Navigation software integrated with the rig control system enabled a framework of guidelines to control directional drilling process

• Software was refined during field trials to improve results in vertical, curve and lateral sections

• Software enabled a highly trained directional driller in remote operating center to supervise operations on three rigs with upside to go further

• Advisory system enables transition to new directional drilling business model with fewer on-site personnel

• Field results show potential of automating stand drill downs, initially in vertical sections.
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Comments and Questions??