Navigator™
Directional Platform
Automated Directional Workflow for Precise Well Placement and Improved Drilling Efficiency
NABORS
Navigator™ Platform: Automated Directional Workflow for Precise Well Placement and Improved Drilling Efficiency

The Navigator™ platform is an automated directional drilling workflow that serves as a digital advisor, a documenter, and a performance tracker. Compared to the legacy approach to drilling unconventional wells, the Navigator™ platform provides a step-change improvement in the directional drilling process to help you make faster, more accurate directional decisions and place your well where you need it to be.

**DIRECTIONAL DRILLING CHALLENGE**

Accurate well placement is critical for operators drilling horizontal wells in unconventional formations. The curve must be landed at the right depth and long laterals must be drilled precisely through the most productive intervals. In traditional operations, success depends on the skills and experience of the directional driller and the quality of directional decisions made as each stand is drilled. Following current practice, there has not been the ability to use analytics based tools to determine course corrections and identify areas that need improvement. Also, using the traditional process, operators can recommend rules or best practices, but have no means to enforce them or verify whether they have been followed.

**NAVIGATOR™ PLATFORM SOLUTION**

The Navigator™ software delivers a 3-D visualization of the well path in relation to the planned well trajectory, and shares this view with drillers at the well site and with experts at remote operating centers. Using advanced algorithms, current surveys, data on past experience, and geosteering adjustments, the software calculates directional drilling recommendations faster and more accurately than traditional directional drilling supervisors. The operator can set rules for best practices that are programmed into the calculations to ensure that they are followed, using the Navigator™ software.

The platform also documents every directional drilling decision made as the well is drilled, and it evaluates directional performance using key performance indicators, identifying areas for improvement and assigning accountability. On Nabors rigs, the Navigator™ software is integrated into the rig control system, providing further efficiencies during the drilling operation.
The Navigator™ platform provides real-time 3D visualization of the well path in relation to the planned well trajectory. This user-friendly 3D visualization is used on location to understand the situation down hole and is shared with directional and geosteering experts at remote operations centers.

The 3D visualization is like a fighter pilot’s heads up display that provides the project team with a common vision of the directional drilling process by showing a clear picture of the downhole situation. The camera view can be moved to any viewpoint and can be traversed up and down the well to provide multiple views of the well’s progress. The visualization shows the actual well path and drill string in relation to the original well plan. Survey stations are clearly marked as spheres on the actual well path line.

The Navigator™ software displays the operator-specified drilling window and continually tracks the well’s position in relation to that window and the well plan, which is shown in blue. The actual well path is depicted in red when it is outside the drilling window and green when it is within the acceptable zone. The program easily incorporates geosteering course adjustments, as shown by a purple line above or below the well path.

The directional drilldown instructions are displayed on the screen along with the actual and planned wells and the drilling window. The visualization also includes the steering rose used to track the directional drilling process as each stand is drilled down. During real time toolface updates, the ROCKit® toolface dial shows the resultant toolface and slide scoring.

3D visualization provides a detailed downhole view to improve directional decision-making.

Drilldown routes are shown in the 3Directional™ view and can be moused over for detailed calculations.

Drilldown advice is shown on all screens.

The program’s downhole visualization provides multiple views of the planned and actual well paths for a better understanding of the downhole situation.
Enables Operators to Set Best Practices and Drilling Windows

In the traditional directional drilling workflow, the operator may instruct directional supervisors on location to follow set procedures at specific depths during curve building, lateral drilling, and in difficult formations. However, standard daily reporting and manual documentation typically do not provide confirmation that these rules have been followed.

► RULES AND BEST PRACTICES

The Navigator™ platform enables operators to set and enforce best practices for directional drilling to match the well’s drilling prognosis. Rules for dogleg severity, no-slide zones and acceptable drilling windows can be specified by the operator, and will enforce those rules, while automatically recording decisions and actions taken from spud to TD.

► DRILLING WINDOW

Following legacy practices, onsite directional drillers may attempt to keep the drilled well as close as possible to the planned well path, which can require abrupt course corrections and excessive slide drilling. The Navigator™ platform addresses this shortcoming by enabling the operator to set the dimensions of a drilling window around the well path that will allow the well to reach its target objective efficiently.

Specifying an acceptable drilling window avoids unnecessary sliding and doglegs that would result from adhering strictly to the original well plan. This contributes to better drilling efficiency and a smoother wellbore that can be cased and completed with fewer problems. The Navigator™ platform displays the operator-specified drilling window and continually tracks the well’s position in relation to that window and the well plan.
Automated Directional Instructions Assure Consistent Performance

At each stand, the Navigator™ platform uses current survey data, the planned trajectory, and the drilling window in advanced algorithms to provide recommended toolface corrections and slide section lengths to guide the well path and keep it in the specified target window.

Automated instructions are generated considering several possible steering options and provide a more consistent approach than relying solely on individual directional supervisors on location. The instructions can be reviewed and modified if necessary by onsite personnel or experts at the remote operations center. The process avoids unnecessary sliding and doglegs that would result from the legacy directional drilling process.

The Navigator™ platform automatically measures directional drilling performance on each stand based on quantifiable key performance indicators (KPI).

ROCKit® Pilot Automates Stand Drilldowns

Nabors has developed the ROCKit® Pilot software to automatically execute the Navigator™ software’s instructions, including target toolface and slide distance for the stand drill down.

ROCKit® Pilot controls the top drive and draw works, performs any needed rotary action, and adjusts torque. Once an adequate course correction is completed, the system automatically switches to rotary mode to drill the stand down. The Pilot program has been applied successfully, and is expected to be fully commercial by the end of 2018.
Shared Data Enhances Collaboration and Simplifies Geosteering

The Navigator™ platform is a powerful tool that enables real-time collaboration throughout the drilling process. The 3D visualization and the directional data that The Navigator™ platform captures are shared by personnel at the rig site, the operator’s office and remote operations centers (ROC). This shared data enhances teamwork during a highly dynamic process, because everyone involved in drilling the well has a common understanding of the current situation. Operations can be scaled up so that experts at the ROC can monitor and supervise activities on several rigs simultaneously, with the Navigator™ software.

The Nabors Rigline 24/7™ center provides continuous support for all RigWatch® products, including the Navigator™ platform. Nabors directional and drilling operations experts monitor rig site activity and can troubleshoot problems and advise rig personnel as needed. The Navigator™ platform can also provide the full range of visualization and data at oil company remote centers.

**IMPROVED GEOSTEERING WORKFLOW**

Most horizontal wells involve some geosteering to adjust the well path, based on gamma ray logs or surface logging, to keep the well in the most productive zone. During this process, the geosteering geologist may revise the target many times while the lateral is being drilled. These changes are passed on by the oil company engineer to the directional supervisor, who makes frequent course adjustments. There typically has been no shared visualization of this process, which relies on 2D plots, and there is limited documentation or accountability for decisions made and actions taken. This process begs for improvement.

The Navigator™ software can improve communication, impose order, and keep a record of the geosteering process. Everyone involved in the operation has a shared view of the 3D visualization and the rig data from the well in progress. Geosteering decisions are recorded automatically. The software incorporates the revised drilling windows, generates instructions, and evaluates results based on the KPIs.

<table>
<thead>
<tr>
<th>Window Start at Plan MD</th>
<th>Width</th>
<th>Height</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>Up dip by 2º, down 10' from last W.</td>
<td></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>Down Dip by 1.9º from last W.</td>
<td></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>Window offset 5' up from plan line</td>
<td></td>
</tr>
</tbody>
</table>

Drilling Window defines “tunnel” for geosteering.

Geosteering with Dip Angle Changes. As formation dip angles change, the drilling window is adjusted to define a new “tunnel” for the well to pass through the target interval. On this well, the original drilling window was adjusted three times based on geosteering decisions.
KPIs Measure Directional Drilling Performance

Nabors has developed a set of measureable KPIs for the directional drilling process. Using these KPIs, the Navigator™ platform provides an objective evaluation of performance.

The Navigator™ platform automatically measures directional drilling performance on each stand based on these KPIs. They measure drilling proximity relative to the drilling window and specific aspects of the drill down process, like connection time, and total slide and rotating footage.

After each stand, the RigWatch® system provides detailed performance feedback that scores the effectiveness of the directional process. Motor output (or the amount of dogleg imparted by the motor), sliding score, and resultant toolface are measured and reported, using ROCKit® top drive measurements and survey data.

The RigWatch® system generates a complete record of the well's progress on a stand-by-stand basis, performance analysis dashboards, and customizable end-of-well reports. This documented workflow assigns accountability for decisions and provides insights for continuous improvement on subsequent wells.

<table>
<thead>
<tr>
<th>KPI</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximity Measures for Each Stand</td>
<td>- Waypoint Vector Target Achieved (yes/no)</td>
</tr>
<tr>
<td></td>
<td>- Distance from Waypoint Target</td>
</tr>
<tr>
<td></td>
<td>- % in drilling window</td>
</tr>
<tr>
<td>Pre-slide Time</td>
<td>Time taken to work out trapped torque, adjust</td>
</tr>
<tr>
<td></td>
<td>drilling parameters and target toolface</td>
</tr>
<tr>
<td>Toolface Setting Time</td>
<td>Top drive quill adjustments intended to set</td>
</tr>
<tr>
<td></td>
<td>toolface position pre-slide</td>
</tr>
<tr>
<td>Burn Footage</td>
<td>Initial footage drilled in the wrong direction</td>
</tr>
<tr>
<td>Slide Score</td>
<td>Metric to evaluate consistency of toolface</td>
</tr>
<tr>
<td>Slide/Rotating footage</td>
<td>Amount of sliding and rotating footage in each</td>
</tr>
<tr>
<td></td>
<td>stand</td>
</tr>
<tr>
<td>Effective ROP</td>
<td>Footage made over Total time to execute slide</td>
</tr>
<tr>
<td></td>
<td>versus on bottom ROP</td>
</tr>
</tbody>
</table>

Proven in field operations

- Used on more than 100 wells in North America
- Real-time visualization shared between rig sites and ROCs
- 90% Stand drill down instructions implemented without changes by directional experts
- KPI ratings were equal to or better than or wells drilled conventionally
- Operators guidelines embedded into the directional software
- One experienced directional driller supervised three rigs from operator’s ROC
- Demonstrated strong potential to fully automate the stand drill down process
Nabors Software to Enhance Drilling Performance

- **Nabors’ RigWatch® Suite** collects, organizes, analyzes and presents data from surface and downhole instrumentation, drilling equipment, tour sheets, reports, and third-party service providers.
- **RigWatch®** is an onsite EDR/PVT/Reporting system that provides data acquisition, communications, analysis, alarms and dashboards to monitor drilling performance.
- **myWells.com®** collects remote data in a central location and provides customers with a Web-based view of RigWatch® data on their entire operation.
- **RigWatch® Pulse** provides mobile-device access to essential live and historical data, and allows chat-to-rig conversations.
- **Rigline 24/7™** services provide 24/7 support for all RigWatch® products from Nabors’ remote operating center or on location.
- **Automated KPIs** evaluate operating performance and enable RigWatch® to create daily and end-of-well reports used to improve safety and increase drilling efficiency.
- **Navigator™** directional platform delivers a 3D visualization of the directional drilling process, calculates directional drilling instructions, documents all decisions, and rates performance at each stand against quantifiable KPIs.
- **ROCKit® Pilot** automatically implements the directional instructions generated by the RigWatch® Navigator program to fully automate the directional drilling process.
- **Related software applications** include the proven ROCKit® directional steering control system, the REVit® stick slip mitigation system, and the DrillSmart® automatic driller.

For more information on how the Navigator™ software can bring step-change improvements to your directional drilling process, contact Nabors Drilling Solutions or visit www.nabors.com.