In the current drilling climate, efficiency is king: do more with less. This motivation drives disruptive technological innovations in automation of the drilling process. Automating the sliding process is a key factor in driving efficiency and delivering a more consistent result.

In an attempt to slide more efficiently, even the best, most experienced drillers often fail to properly compensate for multiple variables and conditions occurring while drilling a well. Automation of this process allows digesting of a higher volume of data at a higher speed, leading to real-time continuous improvement with additional analysis not possible by a human alone. One operator in the Eagle Ford play of South Texas recognized H&P Technologies proactive stance in drilling automation and began utilization of AutoSlide SM.

The operator had initially used the MOTIVE® Bit Guidance System for approximately one year. This provided a foundational component of AutoSlide implementation. AutoSlide software was installed and tested on the rig, and then deployed on a multi-well pad for initial observation and analysis. All teams agreed to resist the need for traditional human intervention allowing the machine learning to adapt.

The automated decision-making system compiled detailed drilling set points and specifications used to form the most consistent and efficient method to drill the well, formation by formation. After deployment, the rig successfully completed all slides in all surface sections on the pad using AutoSlide. The first complete well on the pad successfully completed slides using AutoSlide in the vertical, curve and lateral sections. The rate of automated sliding exceeded initial goals, and the rig proceeded to drill three more wells at 100% AutoSlide utilization rates. This alignment with initial goals gave the operator the confidence to reduce on-site personnel. This reduction in the total number of third party directional drillers increased overall safety and lowered well costs.

**OBJECTIVE**

In the current drilling climate, efficiency is king: do more with less. This motivation drives disruptive technological innovations in automation of the drilling process. Automating the sliding process is a key factor in driving efficiency and delivering a more consistent result.

**RESULTS**

Based on operator’s key performance indicators (KPI)

**Toolface Precision**
- 26% improvement in toolface precision in the curve section
- 25% increase in toolface precision from Well 1 to 4

**AutoSlide Utilization**
- Exceeded utilization percentage goal on first well and executed 100% of sliding on remaining three walls

**Personnel Reduction**
- 50% reduction in on-site directional drilling personnel
As we at H&P continue to increase performance, it is important we develop new and disruptive automation technologies that will increase repeatability, quality and accuracy of wellbore execution for our customers.

That’s just what H&P Technologies has achieved with AutoSlide™. AutoSlide is a suite of drilling services that automates the control of surface equipment and steerable mud motors to optimize sliding in deviated and horizontal well drilling.

AutoSlide leverages several FlexApps and includes the MOTIVE® Bit Guidance system, which makes decisions on when to slide and when to rotate automating the decision-making part of the process to a true single button execution making consistent performance possible. These decisions and executions are made automatically to optimize performance and economic ROI for our customers.

Manually controlling the orientation of the bit while sliding is a unique and valuable skill held by a limited number of exceptional directional drillers. Quality and approach to this execution requires simultaneous calculations and adjustments which increases the chance for human error. With AutoSlide, that difficult manual control becomes completely automated – helping to reduce risk and variability by making multiple corrections in real-time.

AutoSlide simultaneously controls the drawworks, top drive and mud pump parameters during sliding, which improves efficiency and consistency by continuously searching for the optimized parameters to achieve tool face and ROP accuracy goals.

The system operates on rig sites, but also allows monitoring from remote operating centers.

Ultimately, AutoSlide provides a more intelligent approach to directional drilling. That means improved slide quality accuracy, wellbore quality and ROP performance. These combine to create longer laterals, higher repeatability and increased production performance.

“The type of wells we’re drilling today and the efficiency we’re seeing are much different than what we’ve ever seen. We believe automated sliding technology is a major performance driver that allows us to continue drilling better, more profitable wells.”

- John W. Lindsay, President and Chief Executive Officer

AutoSlide is a suite of drilling services that automates the control of surface equipment and steerable mud motors to optimize sliding in deviated and horizontal well drilling.
Multiple parameters simultaneously analyzed

AutoSlide technology analyzes many parameters to automate and optimize sliding including:

- Well economics
- Surface and reactive torque
- Toolface data
- Top drive radial position and rotation rate
- Drill string dynamics
- Differential pressure
- Weight on a bit
- Bit speed
- Mechanical specific energy
- Hook load
- Actual well path
- Mud system properties

An equitable pricing model

To demonstrate and promote our AutoSlide drilling services, H&P offers progressive pricing models that help build partnerships with operators who want to drill more profitable wells. Aligned with our customer’s requirements, AutoSlide pricing is based on pay-for-performance models teaming with operators who adopt automated sliding technology to drill their cost-effective wells with improved wellbore quality and placement.

Overcoming inertia is key

H&P Technologies is committed to a value-driven automation philosophy for drilling optimization. It is important for the industry to overcome inertia of traditional approaches that can block adoption of automation technology. Demonstrating improved well economics encourages operators and service companies to overcome the reluctance to forego the reliance on the subjectivity of human directional drillers at the well site. AutoSlide pre- and post-project scorecards use key performance indicators (KPI) to objectively measure results that bring a step change in critical economic value drivers.

“Operators will benefit from reduced human variability directly as AutoSlide provides increased and more consistent performance when sliding. Automated system such as AutoSlide simultaneously provide enhanced drilling execution and wellbore quality improvements that result in fewer downhole tool failure and reduce trips. This ultimately leads to improved operational safety on rig site and higher production results for our customers.”

- Todd Benson, President, H&P Technologies

The AutoSlide button signals the FlexRig® control system to optimize the slide without human intervention.
**WHY?**

**CONTEXT**
In recent decades, more and more technical knowledge has been transferred from operators to major service companies. This led to an unfavorable technical dependency.

**SOLUTION**
DrillScan provides independent technology using advanced and proven models.

**BENEFITS**
- Improve well integrity management through advanced simulations
- Prevent dramatic well collisions and increase production with advanced survey management
- Improve drilling performance using unique 3D Bit/BHA models
- Reduce well cost by choosing adequate equipment
- Avoid expensive drill string failures
- Reduce NPT

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**WHAT?**

**MISSION**
support the operator with tools to regain technical ownership, from the standard well planning process to highly sophisticated drilling optimization.

**SOFTWARE**
Develop three drilling engineering software platforms.

- **WellScan**: Well construction engineering:
  - Well planning: Trajectory design, anticollision
  - Directional drilling: BHA and bit design
  - Drill string mechanics: Torque and drag and buckling
  - Dynamics: Critical RPM, stick-slip, whirling
  - Well integrity: Casing wear, casing design, standoff
  - Survey Management: BHA sag, local doglegs
  - Drilling hydraulics: ECD, swab and surge pressure losses

- **LiveScan**: Real-time drilling simulations
- **BitScan**: PDC Bit Design/Simulation

**TRAINING**
Provide customized drilling engineering training sessions:
- Theoretical background, scientific models
- Use of the software, case studies

For drilling and completion engineers, managers, supervisors, superintendents, consultants.

**Research and Development**
Solve complex engineering challenges
- Continuous improvement of scientific models
- Lab tests and full-scale field validation
- Unique models
- Sponsored by major operators
- 30+ scientific publications

**SERVICES**
Provide engineering services to the drilling industry using WellScan®, LiveScan® and BitScan® software, experienced engineers and skilled scientists.

- **Engineering studies:**
  - Well design and reviews
  - BHA and tubular string design
  - Stuck pipe and DHT failure investigation
  - MSE and drilling performance
  - Survey management and QAQC
  - Casing wear and casing standoff calculations
  - Drilling Technology Screening Process (DTSP)
  - Independent benchmarking of DHT

- **Consultancy:** Deploy experts and engineers on rig site or customer’s office with advanced software.

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**WHO?**
Independence - Excellence - Experience

- Developers and ITs
- Ph.Ds and Scientists
- Drilling Engineers

**WHERE?**
International Presence

<table>
<thead>
<tr>
<th>HQ: IT and R&amp;D</th>
<th>North and South America</th>
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</thead>
<tbody>
<tr>
<td>Villeurbanne, France</td>
<td>Houston, US</td>
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<tr>
<td>Europe and Africa</td>
<td>Asia and Middle East</td>
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<tr>
<td>Pau, France</td>
<td>Abu Dhabi, UAE</td>
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</table>

HP Tech.com
A Century of Achievement

A REPUTATION FOR EXCELLENCE

Founded in 1920,
Helmerich & Payne (H&P) (NYSE: HP) is the oil and gas industry’s most trusted partner in drilling productivity and technological innovation. Through its subsidiaries, H&P designs, fabricates and operates high-performance drilling rigs in conventional and unconventional plays around the world. H&P operates with the highest levels of integrity, safety and innovation to deliver superior results for stakeholders.

A Winning Strategy
- Execute as the dominant U.S. land driller
- Grow international business opportunistically
- Maintain cash flow-generating offshore exposure
- Continue to lead industry and bring value to customers through technology and innovation
- Maintain and build upon solid financial foundation
- Adapt to changing market conditions

H&P Technologies:
Extracting Higher Value from Shale Assets
Our H&P Technologies segment drives the development of advanced technologies and directional drilling automation solutions through our Value-Driven Automation™ platform.
- Recognized as industry leader in drilling and technological innovation
- Provides leading technology solutions for wellbore quality and placement
- Acquisitions of Motive, MagVAR and AJC create a powerful platform and compelling value opportunity for E&P companies

Leading Market Share:
21% of U.S.
Land Fleet*

Uniform fleet is cost-advantageous and enables people, equipment and technology to reach maximum efficiency, providing consistent and reliable operations in increasingly complex basins

* As of July 2019
**MOTIVE and MagVAR remain available to all E&P operators and directional drilling service providers regardless of which drilling rig contractor is used**

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**AutoSlide**

AutoSlide automates the control of surface equipment and steerable mud motors to optimize sliding in deviated and horizontal well drilling.

### Improving Wellbore Quality
- Software enables drilling of higher quality wellbores with a scalable, repeatable, data-driven platform approach.
- The Bit Guidance System improves directional drilling economics by:
  - Lowering well construction costs
  - Reducing future lifting costs
  - Increasing hydrocarbon production potential
- Implemented on wells across all of the major U.S. shale plays and Canada
- Multiple U.S. Patents

### Improving Wellbore Accuracy
- MagVAR software increases surveying accuracy by 50-60%, increases horizontal well economics and reduces risks associated with uncertainty, including:
  - Reduced oil recovery
  - Well interference
  - Frac hits
  - Poor geological models
- Utilized by 60 E&P companies
- Nearly 8,500 wells corrected

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<table>
<thead>
<tr>
<th>Traditional Directional Drilling Challenges</th>
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<tbody>
<tr>
<td><strong>WITHOUT MOTIVE</strong></td>
<td><strong>MOTIVE RESULTS</strong></td>
</tr>
<tr>
<td>- <strong>Well Design Difficult to Achieve</strong></td>
<td>- <strong>Improved Accuracy</strong></td>
</tr>
<tr>
<td>- Poor drilling accuracy</td>
<td>- Well drilled to plan</td>
</tr>
<tr>
<td>- Missed targets/pay zones</td>
<td>- More time in pay zone</td>
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<tr>
<td>- <strong>Inconsistent Practices</strong></td>
<td>- <strong>Consistent Practices</strong></td>
</tr>
<tr>
<td>- Increased tortuosity</td>
<td>- Decreased tortuosity</td>
</tr>
<tr>
<td>- Poor hole quality</td>
<td>- Better hole quality</td>
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<tr>
<td>- Low rate of penetration</td>
<td>- Less drilling time</td>
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<tr>
<td>- Stranded hydrocarbons</td>
<td>- Improved/enhanced recovery</td>
</tr>
<tr>
<td>- <strong>Human Made Drilling Decisions</strong></td>
<td>- <strong>Reduces Human Error</strong></td>
</tr>
<tr>
<td>- Directional driller errors</td>
<td>- Converting Art to Science</td>
</tr>
<tr>
<td>- <strong>Elevated Lifting Costs</strong></td>
<td>- <strong>Decreased Lifting Costs</strong></td>
</tr>
<tr>
<td>- Increased rod wear</td>
<td>- Decreased rod wear</td>
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<tr>
<td>- <strong>Downhole Tool Failures</strong></td>
<td>- <strong>Fewer Tool Failures</strong></td>
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**Complete Solution for Optimized & Highly Accurate Wellbore Placement**

<table>
<thead>
<tr>
<th>Regulatory</th>
<th>Improved Performance/Enhanced Returns</th>
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<tbody>
<tr>
<td>- Increased wells within boundaries</td>
<td>- Reserve adds</td>
</tr>
<tr>
<td>- Reduced collision risk for future in-fill drilling</td>
<td>- Recovery factors</td>
</tr>
<tr>
<td></td>
<td>- Production</td>
</tr>
<tr>
<td></td>
<td>- Lower F&amp;D/BOE</td>
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</table>
Customer challenge: When drilling in congested fields, there is a significant danger of catastrophic anticollision with an existing (offset) wellbore. Apart from the economic damage of destroying two valuable wellbores, a collision may also result in an health, safety and environmental event. Operators therefore maintain anticollision policies aimed at preventing such collisions.

These policies state that new wellbores must maintain a statistical Separation Factor (SF) between existing wellbores. To increase the SF between a planned wellbore and its offset wells, the new wellbore can sometimes be moved or shortened. However, any such modifications of the well plan can result in sub-optimal drainage, stranded reserves and sub-optimal field development.

Instead of moving or shortening the planned wellbore, a more economical approach is to fundamentally increase accuracy with which the new wellbore and its offset wells are surveyed by enhancing and correcting measurements. As a statistical measure, SF takes the surveying accuracy into account to achieve that goal. The more accurately the existing and new wellbore positions are surveyed, the higher the confidence in their position and the higher the resulting statistical SF between the old and new wellbores to avoid catastrophic collision.

Therefore, prior to moving a new wellbore to a sub-optimal position, it is advisable and has become widespread practice in US Land, to first increase the wellbore surveying accuracy as much as possible by employing enhanced survey management techniques.

Well-established techniques of IFR, and advanced MWD analytics corrections strongly reduce the wellbore placement uncertainty by up to 60%. Applying these techniques will significantly increase the SFs between new well drilled in congested fields.

With increased SFs, fewer wells will require dispensations and less collision risk will be encountered. Thus, increased SFs further improve the safety in-fill drilling campaigns such a congested environment such as the Permian basin.
Main field geomagnetic models used in standard MWD do not capture local crustal anomalies of the geomagnetic field. IFR is a method of predicting the true magnetic field at a specific geographic location by accurately mapping local variations in the natural field caused by magnetic minerals in the Earth’s lower crust.

It is used to enhance MWD surveying by providing a highly accurate reference frame for azimuth calculation. IFR further defines the dip and total field strength, enabling better survey quality control. IFR is also a prerequisite for advanced MWD analytics corrections.

**ADVANCED MWD ANALYTICS**

Advanced MWD Analytics is a method of correcting MWD surveys for common sources of error. These include external magnetic interference from the drill string and magnetized mud, as well as internal sensor errors, such as biases, scale factors and misalignments. By comparing the magnetic and gravity measurements of an MWD survey set against the reference values predicted by an IFR model and Global Acceleration Reference Model (GARM), systematic measurement errors can be resolved for the MWD accelerometers and magnetometers.

This enables a more accurate inclination and azimuth to be calculated from the corrected raw MWD sensor measurements. This process greatly reduces potential error from poor instrument calibration, magnetic drill string interference, toolface dependent misalignments and magnetic mud.

**REAL-TIME OPERATIONS**

Advanced MWD survey corrections can be performed operationally while drilling to ensure the well is drilled as accurately as possible. Surveying professionals at the rig site upload MWD surveys into a web application after each survey is taken.

The survey data is automatically validated through independent quality checks to prevent clerical mistakes and identify gross errors. Survey quality engineers with specialized training and tools evaluate the MWD data from a remote operating center and correct for observable systematic errors. Surveys are re-calculated from the corrected data and posted to the rig web interface for steering and distribution.
Operator pad drilling horizontal wells with multiple surface locations on same pad. Ideal lateral spacing for hydrocarbon extraction was not feasible due to failing anticollision rules of SF < 2.0 approximately 2,700ft MD from planned well TD. Operator could not drill under SF < 2.0 and would have needed to increase spacing.

Used operationally, IFR and advanced MWD analytics increased SF to > 2.0 for the entire length of the lateral.
CUSTOMER CHALLENGE
Tighter well spacing, multi-wellpad designs and longer laterals result in drilling conditions with higher anticollision risk and the need for greater positional accuracy. Using highly accurate In-Field Referencing (IFR) models will improve anticollision separation factors (SF) by as much as 40% as compared to main field magnetic models used in standard MWD surveying. This not only reduces collision risk, but also enables more accurate well placement. IFR does NOT require additional surveying tools, personnel or rig time!

SOLUTION: IN-FIELD REFERENCING (IFR)
IFR is an industry recognized and low-cost method for reducing wellbore positional uncertainty associated with MWD surveying. Applying IFR can significantly increase the SFs between new wells drilled in congested fields. Higher SFs will require fewer dispensations and reduce risk of well to well collision or lease line infractions. Reducing positional uncertainty also enables future in-fill drilling campaigns in congested fields.

Main field geomagnetic models used in standard MWD do not capture local crustal anomalies of the geomagnetic field. IFR is the industry leading method for predicting the magnetic field direction accurately for a specific geographic location and time. IFR relies on independently acquired measurements of the local magnetic field to accurately map regional variations caused by magnetic minerals in the Earth’s lower crust.

IFR improves MWD surveying by providing the most accurate reference direction possible for azimuth calculation. IFR also provides more accurate estimates for magnetic dip angle and total field strength, which enables more precise MWD survey quality control.
The MOTIVE® Bit Guidance System leverages the computational horsepower of modern processors coupled with advanced self-learning algorithms to automate directional drilling decisions in the operator’s best interests and much better than even the most experienced directional drillers.

The Bit Guidance System continuously analyzes millions of potential well paths to get back to plan, and then selects the highest value option for the operator. This real-time analysis includes determining the costs related to drilling speeds associated with rotating or sliding, risk associated with induced wellbore tortuosity, and the possible loss of future production. The human mind simply can’t consider all these factors with any precision when making steering decisions.

In contrast, the system is able to continuously perform all of these calculations, and more, to provide explicit, easy to follow, turn-by-turn bit navigation guidance in realtime. The Bit Guidance System is also able to modify these instructions on-the-fly based on the driller’s current performance, a far more accurate forecast of the bit location, and automated detection of possible target changes.

The Bit Guidance System is also a state-of-the-art secure collaboration platform for the driller, the geologist, field coordinators, and the asset manager. The system provides complete transparency to all past, current, and future directional drilling activities for personnel on the rig, in remote operations centers, and anywhere else with an internet connection.

A study comparing dozens of wells drilled with the Bit Guidance System vs. wells drilled without the system in four different areas and with four different operators show an average reduction of drilling costs of $12,166/day and an increase in hydrocarbon production potential of $16,571/day. The daily cost of deploying the Bit Guidance System is just a fraction of the value of these proven benefits.

**MOTIVE proven results**

**REDUCED DRILLING TIME**
The MOTIVE Bit Guidance System helps drillers to consistently reduce average drilling time by over 15%, significantly reducing drilling costs.

**LOWERED RISK**
MOTIVE reduces dogleg severity and the associated risks related to stuck pipe, casing running and/or production problems.

**INCREASED HYDROCARBON RECOVERY**
MOTIVE has proven to deliver twice the accuracy of traditional directional drilling tools leading to increased hydrocarbon recovery.

**WITH & WITHOUT THE MOTIVE® BIT GUIDANCE SYSTEM DRILLING FEET/DAY**

**TREMENDOUS PROVEN VALUE FROM USING THE MOTIVE® BIT GUIDANCE SYSTEM**

![Graphs showing drilling performance and cost savings]
Horizontal well drilling has been one of the keys to unlocking the unprecedented growth in unconventional oil and gas resources. Drilling horizontal wells is expensive and risky, about 10 times the cost of drilling conventional resource plays. One of the main reasons costs are high is because the complex geology associated with unconventional plays makes it difficult for directional drillers to follow the path defined by geologists, geophysicists and reservoir engineers.

Continuous corrections are required to follow that path and to mitigate divergence caused by geologic variability of hardness and orientation. For operators depending on traditional directional drilling services, this geologic complexity can be too great for the driller to react to quickly. This leads to both higher drilling costs and to reduced hydrocarbon recovery. The Bit Guidance System drastically improves the performance of directional drilling in horizontal wells.