Changing the Way We Drill

Automated drilling systems decrease risk to rig personnel, reduce costs and improve efficiency. Operating these systems remotely will be the next progression in a maturing oil and gas industry, allowing operators to utilize their most qualified experts at any location to monitor and control drilling operations.

On November 19, 2004, a remote command sent across the Atlantic Ocean from Cambridge, England, successfully changed a drilling operation in Cameron, Texas, and in the process, may have changed the way wells are drilled in the future. This achievement was not a stand-alone event; it was supported by the collaboration of experts, enabling technologies and a long history of innovative developments in drilling automation.

As industries advance and mature, automation enters almost every level of operation. Automation enables companies to achieve consistency in both processes and products, improve safety and efficiency, and reduce risk and costs. Automation breakthroughs have allowed companies to be more competitive by replacing manual and cognitive tasks done by humans with those performed by machines. A prime example of the indispensability of automation is in automobile manufacturing, because machines do repetitive tasks better and faster with highly consistent results. In addition, automation removes humans from inherently dangerous tasks, such as welding.

Automation is also evident in the commercial aviation industry, which has undergone a major transformation since the 1970s. Increased passenger counts and cargo loading led to more airlines, more planes and more congestion in the Early 1860s
Rodolphe Leschot, a French mining engineer, developed the first “automatic” bit feedoff into the formation.

1935
Dillon, Dreyer and Jenks of Westinghouse Corporation patented an automatic driller for rotary drilling equipment.

1940s
Pneumatically actuated feed control of band brakes was introduced.

1955
Paul Scott developed the first hydraulic power swivel and hydraulic hoist.

Early 1960s
First drillships included the pipe-racking system, and also used the first power swivel and power subs.
With the advent of computers and microprocessors in the 1980s, local automated systems were developed for roughneck and pipe-handling operations. Just as in automobile manufacturing, many rig tasks comprise repetitive motions and therefore lend themselves to automation. These methods captured the attention of the drilling community and helped drive the ongoing improvement in safety and efficiency in difficult operating environments.

### Minds and Machines
The evolution from mechanized to semiautomatic to fully automated drilling systems is under way. Semiautomated and locally automated drilling systems are common today. Generally, semiautomated processes necessitate regular human involvement, but still offer significant safety advantages. For example, mechanized roughnecking equipment developed in the 1970s removed people from the most dangerous operations and improved rig safety from that time forward *(previous page and below)*.²

In the 1970s, hand tools were replaced with labor-saving devices, such as power slips and spinning wrenches. The first power slips were spring-assist designs to reduce roughneck fatigue. The first pneumatic slips, developed in the early 1980s, gave way to hydraulically operated bodies with interchangeable slips for various pipe diameters.

Since the 1970s, automation in exploration and production (E&P) drilling operations has developed steadily for many of the same reasons. Just as in other industries, E&P drilling companies seek improved efficiency, reduced risk, and higher degrees of precision and repeatability, even when drilling complicated well trajectories in challenging environments. This article reviews advances in automated drilling and examines available levels of control. It also highlights the recent milestone in remote automated drilling and considers its possible business implications.


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Varco introduced the Iron Roughneck in the late 1980s, first as an extension of power tongs for drillpipe only. Casing tongs were added next. In the latest designs, the machine size was reduced to fit on land rigs, allowing automation to reach a wider market.

Developments in automated rig systems have primarily focused on reducing personnel exposure to fatigue and risk during pipe-handling activities. These activities still require human input and supervision from a local control console or drilling control room. Over time, significant advances in automating roughneck and pipe-racking tasks have decreased risk in more dangerous operating environments, such as on semisubmersible rigs floating in rough seas (above).

Pipe-racking machines were developed first to trip and rack stands of drillpipe. Offline stand building allowed faster drilling operations by making up the bottomhole assembly (BHA) while drilling. Dual-operation deepwater rigs have two penetrations through the rig floor to enable running drilling riser and surface casing simultaneously. With pipe-rackers, the need for someone in the derrick disappeared, but remotely operated elevators were required. With more rig automation, control systems were ergonomically designed to allow the driller and assistant driller to coordinate drill-floor activities and monitor all facets of the drilling operation.

Fully automated rig systems, which must function without rig personnel and specialists on site, require extensive monitoring and control capabilities. These systems potentially offer significant advantages in deepwater subsea environments, but a fully automated rig remains a challenge for the future. Although initial efforts to reduce rig manpower had only limited success, recently, the industry has been interested in monitoring several operations from a remote facility staffed with experienced support personnel who can assist relatively new drilling crews.

Automated drilling systems address the mechanics of drilling in the subsurface, and tripping in and out of a wellbore. These systems require real-time surface and downhole data to effectively control drilling processes, and have recently become more practical as oil and gas monitoring and control technologies continue to advance. This increased real-time data availability promotes early detection of drilling problems, which can now be mitigated by human intervention, or in the future, by automated systems using simulations and models.

Under Control

Judicious and effective control of complex drilling processes requires data, experience and expertise. Automatic drilling control can be accomplished by surface or downhole actions. In the 1970s, the first semiautomatic systems were surface controlled and required drillers to manually set standard drilling parameters such as weight on bit (WOB), torque, rotations per minute (rpm) and pump pressure. Generally, these early systems had serious reliability problems, did a poor job of controlling drilling parameters, and were not able to set and maintain the rate of penetration (ROP).

As time passed, several different methods were used for automatic feed control—the gradual application of weight to the bit to facilitate the cutting and penetration of subsurface strata. Feed control is accomplished through the use of the brake on the rig floor. As early as the 1940s, the automated actuation of rig braking systems was accomplished pneumatically. However, drillers using manual systems overwhelmingly outperformed these semiautomatic systems. Eventually, with improved valve design and integrated system testing, pneumatic control systems became successful.

Throughout the 1980s and 1990s, system capabilities were boosted by increased computer power and by the quantity and quality of measurements-while-drilling (MWD) data. These data provided crucial information on drilling conditions and helped pave the way for automated rig systems capable of controlling drilling parameters, including ROP (next page). Multiparameter control systems by Wildcat and Varco were built to regulate the payout of drill line based on desired WOB, ROP, torque and standpipe pressure. The standpipe pressure was representative of the position of the drill bit relative to the bottom of the hole, which is critical for horizontal and extended-reach drilling.

In addition, the combination of a new proportional current-regulated electric brake controller, developed by the Baylor Company, and clutch-type and disk brakes manufactured by Eaton and National Oilwell, respectively, gave more precise braking than self-energizing band brakes. New control algorithms by Varco, an advanced data acquisition system developed by
M/D Totco and similar systems by Hitec and others, enabled improved control of braking torque. This advance brought improved bit-feed control to new automated drilling systems, which soon significantly outperformed drillers using manual systems.7

As the performance of automated drilling systems continued to improve, the system software became increasingly complex and more difficult to use and troubleshoot. It became necessary to design software that would simplify control and remove the need to have a skilled driller operate the system. The new software also automated the changing, or tuning, of drilling parameters within practical limits. Much of this tuning was required because of changing formation characteristics as the bit drilled subsurface strata. Extensive modeling of the dynamic rig system led to the development of improved software control, which incorporated formation models to control WOB and ROP.

Faster response time to changes facilitated fine-tuning, which produced smoother application of the bit to the formation. This reduced vibration, extending the life of BHA tools and bits, and improving fullbore core recovery. This technology produced more consistent drilling practices than were possible with humans at the controls, leading to improved borehole quality, formation evaluation and cementing. Mistakes made by human drillers when tripping in and out of the borehole, such as accidental fracturing and swabbing of formations, were also decreased as automation took hold. Improved automation was tested in south Texas, USA, on a Helmerich & Payne (H&P) drilling rig equipped with automated drilling hardware and software. This first-generation system drilled wells faster, with 37% less rotating time, and used 34% fewer bits than nonautomated rigs in the same area.8

An essential component of improving both surface and downhole control was having more information at hand to direct control decisions. An expanding array of important data also became available from logging-while-drilling (LWD) and pressure-while-drilling (PWD) tools.9 Geologists and engineers can now ascertain formation properties to direct a well path for formation evaluation and cementing. Mistakes due to human error can be eliminated.

New information along with advances in rotary steerable drilling technology have improved drilling efficiency, directional drilling control and hole quality. In addition, problems associated with stuck pipe, casing installation and hole cleaning have been reduced.10 New technologies, such as PowerDrive rotary steerable systems, have improved directional drilling capability because of the immediate response to high-level commands sent downhole.11

Reservoirs to determine rock-strength parameters for predicting sand production.12 Real-time monitoring of crucial drilling data reduces risk while drilling wells by bringing step-change improvements to prevent stuck pipe, fishing jobs and loss of wellbores.

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to the system-control unit with real-time feedback from MWD and LWD measurements. Commands are sent downhole using changing flow-rate patterns, and data are returned uphole through the mud column as pulses using rugged telemetry tools, such as the PowerPulse MWD telemetry system.

**Remotely Possible**
The next step in automated drilling will be to control the process from afar. Computer and satellite telecommunications technologies have advanced to the point where monitoring and control systems are now common in hydrocarbon-production operations around the world. Local remote-control operations, also called local automations, exist today on modern drilling rigs for automated pipe-handling, topdrive and integrated drill-floor operations. To date, long-distance remote data communications in drilling operations have been used exclusively for monitoring and reporting.

Local remote-control operations reduced manpower requirements and risk to personnel. Initial designs moved the operator from the drill floor into an environmentally controlled cabin out of harm’s way. Recognizing that the life-style associated with working on a drilling rig is demanding, companies have found it easier and more beneficial to hire and retain employees if they could work from an office environment, doing many of the same tasks remotely. For example, technicians can now test and analyze equipment performance from the safety of an office. Remote systems are also being used to automatically install applications and virus-software updates for rig-based software. More importantly, these new capabilities allow drilling experts to track and analyze historical drilling data and statistics, which helps rig companies and operators formulate improved procedures that increase efficiency and reduce operating costs.

As the oil and gas industry ages, an older workforce is retiring, and much of the expertise is not being replenished because of cyclic demands (below). Some industry observers have referred to this as “the big crew change.” With fewer drilling experts and workers available to help tap remaining hydrocarbon reserves, innovative and automated technologies will play an increasingly important role in moving the industry ahead and changing the way wells are drilled. Remote-control capabilities will deliver expertise to wellsites anywhere in the world.
Transatlantic Waves
To realize the full power of remote-control operations, drilling professionals must have the capability to apply their expertise from anywhere in the world. This concept became reality on November 19, 2004, when a command to change a pump rate, sent by scientists at Schlumberger Cambridge Research (SCR) in England, was received and executed by a drilling rig at the Schlumberger Cameron Test Facility in Texas (above).

From almost 5,000 miles [8,000 km] away, drilling parameters, such as WOB, rpm and flow rate, were adjusted remotely, marking the first transatlantic control of a drilling operation. This achievement was a result of months of collaboration with M/D Totco and teamwork between the SCR remote-drilling project members and the Cameron engineering and rig staff.

Along with the collaborative aspects, the success of the project also depended on key technical requirements. Significant expertise was required in deciding what parameters would be controlled remotely and how the desired actions would physically take place. M/D Totco installed crucial systems at the Cameron site—the automated driller hardware that physically controls the existing brake system, and the automated rig controller, which directs the input and output control of key electrical systems on the rig. Vital communication systems also were installed, such as a VisiWear wireless video-communication system and a camera on the drilling floor. Effective communications through high-quality and reliable videoconferencing proved extremely valuable to team members during the course of this project.

The success of this project required clearly defined roles for all participants and contingency plans to ensure personnel safety, prevent accidents from occurring on the rig and eliminate the potential of damaging, or losing, the test well or downhole equipment—above). Both the SCR and Cameron teams collaborated to define the roles and responsibilities necessary for project success and how these might evolve through time.

During drilling operations, audio and video communications were established between the wellsite and remote drillers, with a backup procedure that used a communications person to relay messages if necessary. All team members were required to provide support for both the wellsite and remote drillers, with all commands going through either the wellsite or remote driller, depending on who was in control. During the testing of remote-control drilling, the wellsite driller, following normal disengagement procedures, was always to take control at a safe distance from the kelly bushing down position. Moreover, the wellsite driller was empowered to take control of the rig at any time. To ensure a complete record of commands, it was also important that the wellsite and remote drillers log all commands manually.

Face-to-face communication between SCR scientists and rig personnel, both in person and by video, reinforced confidence in the remote drillers and promoted project acceptance among the rig crew—key factors when moving to remote automation. The human part of the equation was very important. Prejob visits with the rig personnel to develop use cases and fail-safe mechanisms ensured safety and understanding of the tests long before the first remote commands were sent.

Commands from the remote driller were sent through the Schlumberger intranet directly to the M/D Totco automated rig controller, which verified the receipt of commands and routed them to the appropriate rig equipment, such as pumps, rotary table and brake system. Sensor systems constantly monitored the affected equipment, and sent that data to the rig acquisition system and to local displays. Monitoring data also were transmitted through the Schlumberger intranet to the remote drilling-control center, allowing the remote driller to observe operation changes using PERFORM Performance Through Risk Management Process software.

Performing remote operations inevitably introduces latency, a time lag—up to a few seconds—between commands being issued and the remote system actuation. This time lag is critical either when a system becomes unstable because of the time response of the system, or when some limit must not be exceeded. A good example of the latter is setting the bit on bottom, which directs the wellsite system to safely execute a closed loop process of setting the bit on bottom.

Remote monitoring and control software tools installed at the SCR remote drilling-control center were a crucial element of the project (next page). The PERFORM software integrates several drilling-process tools, including rig-state detection, real-time torque and drag, hydraulics modeling and event detection. In addition, a specialized software package was used to set, change and verify drilling parameters.

**Drilling into the Future**

Advances in information and computing technologies have fostered new breakthroughs in long-distance, remote-control technology. Increasing bandwidth capacities allow transmission of massive amounts of data. Satellite communication with extremely remote locations is now commonplace. Also, rig automation has become much more affordable and reliable.

In addition, important human factors have promoted the trend toward automation. Because of the accelerated rate and pervasiveness of technological development in all aspects of modern life, most people are reasonably comfortable with emerging new technologies, particularly those that involve automation. In the E&P industry, real-time permanent monitoring of producing wells and fields is widely accepted and should prove pivotal in advancing remote automated drilling.

On the surface, the application of remote and automated drilling systems seems best suited for high-cost, high-risk environments. However, the high performance and efficiencies that this technology introduces could also prove advantageous for other drilling programs, in which operating costs have a dramatic impact on the viability of hydrocarbon exploitation. The Schlumberger and M/D Totco remote-drilling project team took a bold approach to design a system that works across a range of available field technologies. It was far more challenging to devise a simple and universal system that can be deployed on older land rigs as well as advanced drilling rigs, which are already outfitted with sophisticated equipment.

Automated rig systems can be designed specifically for unique operating environments. For example, lower cost, automated and lighter rigs are required for rigorous North Slope, Alaska, drilling and rig transportation. There, automation allows operators to optimize reservoir development through fast-track drilling programs to produce high-quality boreholes at lower cost, with less risk, in less time.
This new way to drill wells will allow qualified people across multiple disciplines to have greater involvement in drilling decisions. It will also reduce logistical costs and minimize transportation-related risks. Combined with ongoing efforts in collaboration and visualization, remote automated drilling has the potential to move the industry forward significantly. However, those from other E&P disciplines can become involved in actual drilling processes only when they are adequately cross-trained and have acquired both knowledge and experience in drilling.

Intertwined with the progression and application of remote automated processes is the all-important human element. Although they anticipated skepticism from the drilling community, the remote-drilling project members at SCR were buoyed by the drillers’ wide acceptance and eagerness to move the remote-drilling project forward. This acceptance was largely because the rig personnel were directly involved in use-case developments and fail-safe designs that covered all operational scenarios. Other human factors have yet to be encountered. Can we anticipate the possible dynamics and mitigate the potential downfalls of having a single expert at a remote location managing several drilling operations at once? Will we underestimate the complexity of drilling and revert back to simplified and ineffective models and control systems?

The marriage of automation and remote-control capabilities in drilling operations further reduces wellsite personnel exposure to hazardous environments and bolsters efficiency gains already realized in automation. The synergy of automation and remote-control capabilities utilizes expertise at central locations more efficiently by placing experts at the controls of multiple and simultaneous drilling operations. Remote collaboration also brings the opportunity to directly incorporate more crossdisciplinary knowledge into decision making, for example, in subsurface target selection and directional drilling processes.

In the future, remote automated operations could directly connect drilling operations to mechanical earth- and reservoir-modeling software tools, which are not practical to run and support on drilling rigs but could be run from centralized control facilities onshore. This might also enable automated real-time control, simulation and model updating under the watchful eye of experts.

Drilling takes place in some of the most hostile environments on earth. Out of necessity, well drilling has become a precise science. And while the industry must depend on a decreasing number of drilling professionals, it is strengthened by technological advances that help accomplish the vital task of drilling wells with greater precision and efficiency, and decreased risk and cost. Remote control from afar is the next step in automated drilling operations, but reaching that goal will require universal acceptance and ownership by the drilling community. Just as complex tasks have been performed remotely by other industries, remote automated drilling, with its obvious benefits, will inevitably change the way we drill.

—MGG