Slickline Signaling a Change

Well intervention techniques have long been dependent on mechanical and hydraulic systems for actuation and measurement. As a consequence, the outcomes of many downhole operations—for which depths were often approximate—depended as much on the skill of the operators as on the design of the tools. For one intervention method, these limitations were eliminated when engineers developed digital slickline.

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Slickline operations in oil and gas wells have been performed for more than 75 years, and until recently, practices have changed little. Technicians and engineers in the field perform basic downhole operations through manipulation of downhole tools attached to the end of a single-strand thin wire called a slickline; the name distinguishes it from a conducting cable used in electric line or a braided cable used for heavier mechanical work. These downhole operations may be as simple as running a gauge ring to TD or more complex wellbore maintenance and production optimization procedures such as setting or pulling valves and plugs. Operations also include removing production-hindering debris such as sand or paraffin from the well. More recently, devices with electronic memory have been run on slickline to gather data for pressure transient surveys or production logging.

Slickline has remained a staple of well intervention because it is cost-effective, reliable, efficient and logistically uncomplicated. It is deployed with relative ease using compact equipment that may be moved to and situated at a wellsite of nearly any size located anywhere in the world. It may be used in all types of wells, including HPHT, sour gas, high-angle and flowing. On locations with space or weight limitations, slickline is often the only feasible intervention option.

But the simplicity of slickline is also the source of its drawbacks. Engineers designed slickline initially to perform rudimentary mechanical operations. At that time, absolute depth was not an essential consideration for such operations. Drillers could not place tools precisely, and as a consequence, it was difficult to verify a tool’s precise downhole location. For some operations, particularly perforating or the setting of isolation tools, knowledge of exact tool depth is critical. Similarly, to ensure sensitive instruments and other tools are not damaged during setting or pulling operations, or to confirm the intended downhole action, it is sometimes imperative that a force—which must fall within a narrow range—be delivered downhole. Using slickline, it is impossible to determine with any certainty exact tool depth or amount of force delivered downhole.

All tubulars, wires and cables stretch to some extent as they are moved into and out of a well. Stretch in slickline wire, however, is significantly greater than that of other conveyance methods. Therefore, depth measurements taken using a mechanical device and displayed at the surface may not accurately represent the tool location. Indeed, displayed information is not a measurement of tool depth but of how much wire has been spooled on or off the drum. As a consequence, the standard accuracy for slickline depth measuring systems is about 30 cm/300 m [1 ft/1,000 ft]. This degree of accuracy is often sufficient for slickline operations for which depth is reckoned to within a few feet of some fixed point in the completion string. In wells that have no downhole marker, the margin of error may be unacceptable. Engineers have devised systems to correct for stretch as well as other variables, but such corrective measures are based on data estimates only, and sophisticated operations typically require more accuracy than these systems could deliver.

In addition, wellbore deviation can cause considerable inaccuracies in the weight indicator readings at the surface; these readings are the only indicator of forces being applied downhole. Typically, the weight downhole is measured using a load cell attached to a wellhead and then to a pulley through which the slickline is directed from the drum to the top of the lubricator (above). As the angle of deviated wells has increased, along with the number of such wells, there has been a corresponding increase in the frequency and degree of inaccurate weight readings. Such depth and weight inaccuracies may

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Battery-powered tools. The PS Platform service is a suite of battery-powered tools that can perform both memory and surface readout operations. The GHOST gas holdup optical sensor tool (top left) uses four sapphire optical probes to measure gas and liquid holdups, bubble count, average hole caliper measurements and bearing. The Gradiomanometer specific gravity profile tool (top second from left) measures the average density of the wellbore fluid and wellbore deviation, from which water, oil and gas holdups can be derived. The bubble count from the FloView holdup measurement tool (top center) identifies first fluid entry, water holdup and bubble count and includes a centralizer and average hole caliper measurements. The UNIGAGE pressure gauge system carrier (top second from right) contains a crystal quartz gauge that offers the option of a high-resolution pressure measurement. The optional inline spinner (top right) provides a bidirectional fluid velocity measurement inside the tubing. The basic measurement sonde (bottom left) provides gamma ray (GR) and casing collar locator (CCL) data for correlation, plus pressure and temperature measurements. The flow-caliper imaging tool (bottom right) measures the average fluid velocity, water and hydrocarbon holdups and bubble count from four independent probes. It also provides dual-axis X-Y caliper measurements and relative bearing measurements. Well deviation and accelerometer measurements provide the deviation correction for the measured fluid density.

Upgrading Slickline

Historically, depth accuracy has critically limited the scope of slickline operations that use conventional measuring devices. The primary factors affecting depth accuracy are elastic stretch, temperature, buoyancy, slickline and toolstring friction against the wellbore wall, lift and measuring wheel precision. The variety of sizes and materials used for slickline wire may also impact measurement readings. The most common slickline wire diameters are 0.092, 0.108 and 0.125 in. [2.34, 2.74 and 3.18 mm]. The materials from which they are manufactured—depending on their application—include carbon steel, stainless steel alloys and nickel- and cobalt-based alloys. Elastic stretch—the factor that causes the most variability in slickline depth accuracy—is a function of line tension and the modulus of elasticity of the wire. Length measurements may be increased or decreased by out-of-tolerance or poorly calibrated measuring wheel diameters. Changes in measuring wheel diameters can result from wheel wear, debris buildup or the disparity in the temperatures at which the measuring wheel was manufactured or lead to extended operation times or, in more complex well completions, to operational issues. In slickline perforating, for example, placing a gun a few feet above or below target depth may mean the difference between producing water, oil or gas—or nothing at all.

In recent years, engineers have developed numerous improvements to traditional slickline equipment. Most of these are incremental changes applied to tools run on slickline rather than to the wire itself. Battery-powered electronic tools, which acquire and store data in memory, have overcome some slickline shortcomings pertaining to actuation and confirmation of downhole actions. But once these tools have been deployed, they do not provide real-time downhole data or give the operator the ability to change settings, such as the depth or temperature at which triggers are activated. As a result, battery-operated tools cannot address the time and efficiency shortcomings that characterize many traditional slickline operations.

The most ambitious attempt to overcome these hurdles—using the slickline itself to deliver two-way signals between the tool and the surface—has been pursued for decades. Such a solution could be used to provide operators with precise tool depth, tool status, downhole weight, wire tension and wellbore data such as pressure and temperature measurements in real time.

Despite many years of effort, manufacturers had been unable to develop an acceptable solution using a slickline wire and equipment. That changed when engineers at Geoservices, a Schlumberger company, developed DSL digital slickline services.

This article describes enhancements made to slickline in the form of battery-powered and memory tools that allow engineers to expand slickline applications to include accurate depth measurements for perforating and production logging. Also discussed is DSL technology, which is an engineering breakthrough, rather than a slickline enhancement. Using telemetry over slickline, coupled with battery-powered electronic tools that incorporate a memory and telemetry interface, DSL services allow commands and data communication between the surface and downhole without compromising the mechanical integrity of the wire. These features expand slickline capabilities significantly by offering accurate depth correlation, tool status information and tool control to the operator in real time; this is critical to delivering precise, efficient and low-risk operations on slickline-conveyed mechanical, remedial and measurement operations.
calibrated and the temperature at which it operates. Measurement errors can be in excess of 0.6 m [2.0 ft] at well depths of 3,000 m [10,000 ft]. Temperature differences in the hole also affect wire length as the wire is lowered into the well. Unless wellbore temperature gradients remain constant, or temperature and measurement variations are included in depth corrections, it is difficult to compensate for this variable. In addition, buoyancy, friction and lift—which are functions of wellbore parameters such as fluid viscosity, flow rate, fluid type, deviation, tortuosity and wellbore geometry—affect tension measurements at the surface.

Although minimal differences in measurement occur at shallow depths, discrepancies may increase and become more significant with increasing depth. In recent years, engineers have addressed the depth accuracy issue through the development of electronic measurement devices that attempt to automatically correct for wire stretch.

Another slickline limitation has been the mechanical means by which tools are activated. Engineers addressed this issue through development of battery-powered tools. These tools, which store downhole data in memory that is accessed once the tool returns to the surface, may perform downhole slickline operations when activated by a timer or when a signal is generated through a predefined cable movement sequence. Memory devices have been used in remedial services, such as perforating and device setting, and have been used in measurement services such as production logging, while offering a cost or access advantage over electric line.

Battery-powered electronic triggering can enable safe detonation of explosives used for tubing and casing cutting and perforating, and electromechanical setting tools can replace explosive devices. The industry has welcomed electronic firing heads because they can be programmed to disarm automatically on retrieval to the surface if the pressure window that is a condition of their armament has been selected correctly. These concerns were formerly met using mechanically or hydraulically actuated firing heads.

The industry has also embraced the use of nonexplosive, electronically actuated setting tools in environments where logistics associated with explosives are restrictive or complex. Firing delays or pressure windows are two examples of safety measures added to traditional devices. But these add complexity and compromise precision because of variations in downhole conditions such as temperature and pressure and because of the time the tool has spent downhole. Electronic firing heads are immune to these variations and provide improved accuracy and control.

Many services that were performed using electric line or coiled tubing are now possible as slickline services because of battery-operated tools. These include sensors for pressure, temperature, gamma ray (GR), casing collar locator (CCL), flowmeter, caliper, bubble count, tool orientation, water holdup and gas holdup.

Despite these improvements, engineers continued to seek the next major advance in slickline capabilities—a method by which they could send signals to, and receive data from, downhole tools in real time. Their objective was to gain the versatility and accuracy of electric line telemetry communication without sacrificing the advantages of slickline.

For example, because slickline is a single component it is naturally balanced and so lends itself to operations such as jarring. In contrast, jarring with electric line may lead to destruction of the insulator between the conductor and the cable's armor. Electric line includes an outer and inner set of protective armor wires wound in opposite directions around the central conductors. This creates an inherent torque level within the cable that must be managed to avoid wire damage, particularly in deep or highly deviated wells. This damage may take the form of overlapping outer armor, or wires, that quickly wear and break and then hang up in pressure control equipment. When an overlapping wire breaks, it unravels as it enters wellbore, through the pressurized lubricator (previous page). This creates an inherent torque level within the cable that must be managed to avoid wire damage, particularly in deep or highly deviated wells.

The sealing mechanism at the top of the slickline lubricator also offers an advantage over that used for braided or electric line. A slickline stuffing box is far less complex than the grease tube assembly used for braided or electric line. A rubber packing element maintains a pressure seal even when a wire passes through it. It is thus easier to rig up than a braided cable grease-control flow-tube.

3. Modulus of elasticity is the ratio of longitudinal stress to longitudinal strain.
5. A pressure window is a preset condition that allows the tool to arm only when it is at a pressure greater than surface pressure.
7. Slickline jarring uses a downhole mechanical device called a jar to deliver an impact load to another downhole component. Jars include a lower section attached to a tool or other component, and an upper section that can travel freely. The jar may be opened upward and then quickly lowered to use the weight of the toolstring to deliver a downward blow to the lower section. In reverse, the slickline is reeled in at high speed to deliver an upward force to the lower section of the jar.
assembly, which requires grease to be injected across flow tubes at a pressure greater than that of the wellhead during the entire operation. Electric line operations performed under pressure require additional equipment, including a grease pump and a grease supply, which have implications for logistics and the environment. In addition, because moving the line through the grease tubes may break the grease seal, braided cable is restricted to running speeds of about 1,200 to 3,000 m/h [4,000 to 10,000 ft/h] in and out of the well. The mechanical slickline tools can be run at a faster rate without losing the pressure seal, saving valuable rig time.

**A Matter of Live and Depth**

While a true slickline telemetry system eluded engineers for decades, they were able to develop a power–telemetry slickline link using coaxial cable. However, because the cable sacrifices the tensile strength and inherent robustness that are essential to slickline applications, the technology has been abandoned.

Developing an insulator was the stumbling block to slickline telemetry, and engineers were further challenged to find a method to bond the insulating material to the wire. In 2002, engineers at Geoservices began work on a telemetry system based on previously developed MWD electromagnetic technology. However, telemetry was not the issue; the challenge was finding an insulating material and a method by which it could be bonded to wire that would allow it to survive the rigors of slickline operations. Initially, the team tested seven polymers, based on their resistance properties, as insulation material candidates. Under well conditions, however, these coatings did not adhere to the wire.

After years of effort, researchers developed a complex wire-coating material and an exacting bonding procedure. The finished product is made continuous, uniform and with a precise diameter to within 0.002 in. [0.05 mm] throughout its length. Applied to standard 0.108- and 0.125-in. [2.74- and 3.25-mm] stainless steel alloy line, the outside diameter of the coated slickline is 0.138 and 0.153 in. [3.51 and 3.89 mm], respectively.

The resulting LIVE digital slickline retains all the strengths of the original wire upon which it is built. The system maintains tool power requirements delivered from batteries and uses the slick line as a telemetry conduit rather than as an electrical conduit. Because engineers designed the service to be a digital telemetry system rather than an electrical conduit, they were able to reduce insulation performance requirements and so hasten development. Engineers created another advantage by not sending power through the slickline. This feature eliminates concerns about transmission reliability through an electric line, associated accessories such as sinker weights and the point at which the wire is connected to the toolstring. But the mechanical demands on the insulation-wire bond remain significant; the wire deployed using standard slickline equipment must withstand the rigors of spooling on and off the drum, running around sheaves and through pressure-control equipment. It must also endure an often punishing downhole environment, and when it emerges from the well through the stuffing box, it is exposed to instantaneous decompression from wellhead to atmospheric pressure.

In 2009, those hurdles had been overcome and the first commercial jobs were performed successfully in Africa, France, Italy and Indonesia. Since that time, various applications within digital slickline services have been performed in France, Indonesia, China, the US and Saudi Arabia.

The core of the LIVE toolstring includes the computer baseboard management controller (BMC) that handles the telemetry downhole; delivers surface readouts of shock, line tension, deviation and movement in real time; and confirms the success of operations such as perforating (below). Surface equipment includes a slickline unit furnished with a computer and transceiver, pressure control equipment and the...

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[^] Surface confirmation of detonation. Multiple measurements displayed at the surface show the instantaneous effects of the firing of perforating guns just before 03:29:00. The shock curve (red) indicates a negative acceleration of more than 100 gns. At the same time, head tension (purple) increases from approximately 80 lbf [356 N] to more than 120 lbf [534 N] and pressure (blue) drops from 1,364 psi [9.4 MPa] to about 1,220 psi [8.4 MPa]. Tool movement is apparent on the CCL curve (green) immediately after gun detonation as the tool moves in the tubing, creating voltage across the CCL coil. Oscillation of the cable and gun after detonation is reflected in both the head tension and pressure curves. After the guns are fired, a decrease in temperature (orange) indicates cooler fluid is entering the tubing from the annulus. These indicators are independent verifications that the gun has been detonated on command.
digital line. Optional core downhole equipment includes a depth correlation cartridge, which delivers real-time CCL and GR measurements to provide depth accuracy during any slickline service; a digital pressure-temperature gauge may also be added for downhole measurements.

LIVE digital slickline services are divided into the typical intervention service classifications: mechanical, remedial and measurement. The mechanical LIVE Act digital slickline services include conventional tools deployed as they would be on a standard slickline. Remedial services include LIVE Set setting services, which are nonexplosive, hydraulically set plug and retainer services; LIVE Seal sealing services, which use nonelastomeric sealing for monobore completions; and LIVE Perf perforating, punch and pipe cutting services. The measurement segment of the service is the LIVE PL comprehensive suite of production logging tools. These services are run in conjunction with the core and optional tools and with real-time measurement and control.

In addition, LIVE services expand on traditional capabilities and requirements by adding the digital D-Jar downhole adjustable jar, which can be commanded to repeatedly activate and deliver a specific force downhole. When using traditional hydraulic or mechanical jars, operators rely on their experience and a weight indicator to determine jar action downhole. The D-Jar tool, in contrast, provides control and efficiency to jarring operations without requiring trips to the surface to adjust the impact force. It does so through repeated upward jarring using elasticity of the cable to store energy while the jarring action is delivered via the electrically triggered mechanical firing function. Downhole tension and shock are measured and monitored at the surface during operation, which allows an optimized jarring force without unnecessary stress on the toolstring or jarring of components. Engineers set jarring force by adjusting cable tension, which can be reset when and as often as necessary.

The digital controlled release (DCR) tool is another LIVE tool that may be added to any digital slickline operation. In the event the toolstring becomes stuck downhole and cannot be freed, conventional slickline options include using a cutter bar to sever the wire as close to the toolstring as possible. The resulting fishing job may require numerous runs to gather, cut and retrieve any wire that remains in the well, sometimes followed by attempts using a braided wireline to latch onto and retrieve the stuck tool. This can be problematic if wire remains on top of the object being retrieved or the fishing neck has been damaged. Often, it requires numerous attempts to determine the nature and amount of the debris that is on top of the stuck tool and to then remove it before the stuck tool can be latched onto and retrieved. In contrast, the DCR tool provides a controlled separation of the toolstring assembly at or near the tool head, which instead of leaving wire behind, leaves only a defined internal and external fishing neck profile (above).


9. Punchers are perforating devices designed to penetrate the inner tubing string without damaging the surrounding casing.
D-Set electrohydraulic setting tool. The D-Set electrohydraulic unit contains three principal components: a high-temperature lithium battery, an electronics package and a hydraulic power unit (HPU). The lithium battery provides power. The electronics package converts the DC battery output to three-phase alternating current for the HPU’s electric motor and commands the hydraulic circuit. The battery and electronics package are isolated by means of a pressure barrier from the HPU. The HPU, which consists of the electric motor, microhydraulic pump and a solenoid valve is 54 mm [2.1 in.] in diameter by 510 mm [20.1 in.] in length. A smaller 43-mm [1.7-in.] diameter pump can generate nearly 6 tons [60 kN] of force. Within the HPU, the brushless electric motor is coupled to a fixed-displacement, microhydraulic axial piston pump (not shown). The motor is run at high speed for low-torque requirements, such as tool stroke, and switches to low speed for high-torque needs such as setting a tool or shearing a setting stud. Hydraulic pump output is routed to the tool’s mechanical section (not shown) through surface-controlled solenoids.

Setting without profiles. With a GeoLock mandrel, tools may be set in smooth tubulars having no internal setting profiles. When the tool is in the running position, the slips and seal elements (inset, bottom) are retracted, which minimizes the mandrel’s outside diameter and allows it to pass through tubing. Once the tool has been run to the desired depth, it is set using a LIVE D-Set digital setting tool or explosive setting tool to compress the tool, forcing cones to travel beneath the slips and seals. This expands the seals (inset, top) against the tubing wall. The mandrel may be retrieved using an electric or hydraulic tool that latches and returns the cones, seals and slips to their original positions.

Unlike traditional locking mandrels, the LIVE Seal GeoLock digital sealing service uses a non-rubber kinematic sealing mechanism that does not deform when the tool is set (left). It can thus be used in the presence of gas and at high temperatures and pressures for prolonged periods—circumstances that often lead to failure of extruded rubber seals—and can be easily retrieved with standard slickline pulling tools. The anchoring and sealing devices maximize the mandrel’s internal flow area and, when retracted, reduce the mandrel OD while running in and out of the hole.

The GeoLock mandrel is run with the D-Set setting tool and a sequence consisting of centralizing, anchoring and sealing. Engineers can monitor the procedure from surface using a time plot of the complete sealing sequence. The tool and mandrel use a calibrated shear disk instead of a shear pin, which ensures a fully open flush tube with no internal restrictions once the tool is set.

Digital slickline also includes LIVE Perf perforating services. With these services, operators can confidently and safely cut pipe for recovery, punch tubing and perforate at specified depths. The service employs the D-Trig digital activation device,
The LIVE PL service offers an alternative to the larger electric line unit and delivers more accurate depth correlation than is possible with memory tools; in addition, the service sends logging data to the surface in real time while simultaneously storing it in memory.

Additionally, when engineers perform transient buildup tests with digital slickline, they can monitor downhole pressure and temperature in real time and detect when the well has reached maximum bottomhole pressure (BHP). Obtaining this information in real time can reduce shut-in times. Data can therefore be used efficiently for reservoir monitoring, updating models and diagnosing certain individual well conditions such as the existence and location of water sources.

Two for One
Combining real-time downhole measurements with traditional slickline creates numerous benefits. For example, one operator discovered inherited wellbore schematics were in error. Had engineers chosen to shoot tubing perforations as originally planned, based on depths displayed on the schematic and without a CCL and GR for correlation, they would have tried and failed to puncture a blast joint located where the well schematic showed the target tubing joint. In this case, changes were made immediately as the job was progressing based on real-time GR and CCL data seen on the surface, allowing engineers to carry out the operation without additional time and, more importantly, without error.

Digital trigger. The D-Trig device is controlled by redundant dual microprocessors and incorporates multiple fail-safe systems. A signal sent from surface is received by the tool, which generates a pulse to fire the detonator of the cutter or explosive tool (not shown). The device includes a battery that can fire either third-party exploding bridgewire detonators or Schlumberger Secure detonators. A separate smaller battery is mounted in the baseboard management controller (not shown) to power the electronics within the electronics cartridge. This design allows for a safety fuse to be placed between the firing battery and detonator (not shown) and adds a level of security to operations. In addition, a safety sub is placed between the detonator and the D-Trig tool and includes a safety pressure switch that automatically grounds the detonator when the device is at atmospheric pressure. The D-Trig device shown is electrically plugged into the detonator using a single spring monopin box connection.
In addition to risk management, efficiency and precision advantages, LIVE digital slickline services also enable engineers to perform certain types of jobs—operations that once required use of traditional slickline and electric line with a unit and a crew for each—with a single digital slickline unit and crew. For example, engineers often use both conventional electric line units with surface readouts to gather real-time measurements, and a slickline unit to perform mechanical operations on the same well. When performing such interventions in each of four producing zones, engineers traditionally first use a slickline unit to prepare the well for logging by running gauge rings, installing plugs and shifting sliding sleeves. They then run production logs using a separate electric line unit. This movement of equipment and personnel can lead to complicated logistics, high costs, increased potential risks and lengthy operating time. Because LIVE digital slickline services can perform the full scope of work, the single unit and crew cuts logistics and manpower requirements by half and reduces risks while saving significant overall rig time (above).

ATP Oil & Gas Corporation engineers seeking to capitalize on these efficiencies selected DSL services for a recompletion operation at Eugene Island Block 71, offshore Louisiana, USA. The zone isolation and recompletion operation was performed from the deck of a jackup vessel by first setting a through-tubing cast iron bridge plug and dumping 50 ft [15 m] of cement in 2%-in. tubing to shut off a depleted lower zone at 12,790 to 12,875 ft [3,880 to 3,924 m].

Once the lower zone was plugged, the operator planned to perforate a shallower interval at 12,668 to 12,678 ft [3,861 to 3,864 m] using six shots-per-foot perforating guns (next page). Because the shallower target sand was thin, depth precision and accuracy were critical and could be achieved efficiently and in real time through the use of CCL and GR, an option formerly available only with electric line. Because other parts of the operation, such as dump bailing the cement, required slickline tools, two crews would have been required to perform numerous rigging operations and equipment moves on the deck of the vessel. Using the LIVE depth correlation package with the LIVE Perf services, a single unit and crew accomplished the plug back and perforation operations. Total cost as a result of time saved was US$ 80,000 below the original authorization for expenditure.

In this instance, the operator realized savings by reducing the time required to mobilize and move electric line and slickline units on and off the well and around the deck and by eliminating the standby costs associated with a second crew. In other cases, there may be additional savings because space and weight requirements are reduced when only one unit is deployed, allowing the operator to hire a less expensive lift vessel with reduced deck capacity. In some instances, because of the slickline equipment’s relatively small footprint and light weight, an operator may be able to place the unit directly on the deck of a platform too small to accommodate larger, heavier electric line equipment. This may eliminate the cost of a service vessel entirely, resulting in significant savings.

Cost reduction as a function of time can quickly multiply depending on environment. For example, in relatively shallow waters, interventions may be performed from the deck of lift boats for which the day rate ranges from about US$ 4,000 to as much US$ 40,000 as a function of water-depth capabilities and deck space. However, savings can skyrocket when work is slated for water beyond lift boat depth capabilities, which is about 60 m [200 ft], in relatively calm waters such as offshore West Africa and in the Gulf of Mexico. The cutoff depth is even shallower in areas of typically rougher waters such as the North Sea.

In deeper waters, an operator may use a semi-submersible or dynamically positioned drilling unit whose costs are much higher than jackup vessels. And in deep and ultradeep water, operators must use specially designed deepwater drilling units. The day rate for these giant units is around US$ 1 million. Saving a few days or even a few hours to perform slickline and electric line work can quickly yield significant savings.

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^ Single-unit logging operation. Typically, operators use a slickline unit to prepare a well for logging by first performing gauge ring runs, installing plugs and locking out the surface-controlled subsurface safety valve (SSV). They then use an electric line unit to acquire production log data. For one typical operation requiring a static pressure gradient, drawdown and shut-in pressure and temperature survey for each producing zone, the operator scheduled the program to take 168 hours using slickline and electric line independently. By using DSL services to perform both conventional slickline and electric line surface readout operations, the operator saved more than 10 hours and eliminated an extra crew and logging unit.
In the deepwater Green Canyon area of the Gulf of Mexico, Nexen Petroleum USA leased the deepwater rig Ocean Saratoga to plug and abandon (P&A) a well in about 900 ft [275 m] of water, about 100 mi [160 km] off the Louisiana coast. Typically, this phase of the P&A operation would have required preparatory work on slickline, followed by tubing punching and tubing cutting, which require accurate depth correlation using electric line. Nexen engineers turned to digital slickline to perform all P&A operations using a single slickline unit. Their objective for this high-cost environment was considerable savings through operational efficiencies—such as fewer rig-up and rig-down operations.

Digital slickline was used successfully for depth correlation and the subsequent tubing punching operation at 10,030 ft [3,057 m]. Tool shock measurements displayed at the surface in real time clearly indicated the successful firing of the puncher. The operator benefited from the value of a smooth, depth-correlated puncher operation, and as a result, realized significant savings in this high-cost environment. Some of these savings were achieved because the operator was not forced to pay standby costs for two crews when unforeseen delays idled the rig for several days.

Executing such interventions with digital slickline instead of electric line also reduces risk because its pressure control equipment is less complex. During pressure control events, if it becomes necessary to cut the line, it is easier to cut slickline than thicker electric line that may be across the wellhead.

A Very Large Niche
As operating environments become increasingly more challenging in places such as the Gulf of Mexico and the North Sea, operators are actively seeking ways to control costs. Digital slickline, which offers the robust simplicity of slickline while maintaining the versatility of electric line, is poised to play a significant role in that quest. Its suitability for P&A operations will no doubt draw particular attention as aging wells in the North Sea and the Gulf of Mexico drive a push by regulators for large-scale platform decommissioning.

Engineers are likely to adopt digital slickline technology as part of a well’s completion strategy. It maintains the basic simplicity and familiarity of slickline and is thus far less intrusive than other recent innovations such as intelligent completions or monobore wells, whose complexity sparked years of resistance from an industry as concerned with the cost of failure as with potential benefits. A failure of an intelligent well or a monobore installation may result in loss of an entire wellbore and almost certainly in the loss of many thousands of dollars spent in repair costs and delayed production. In contrast, the worst-case scenario of a digital slickline operation failure is lost time while an electric line unit is brought in to finish the job.

In a post-Macondo world, operators are eager to seize any safety advantage, which means the benefits of digital slickline may be more than cost and time savings. Because digital slickline often allows a single crew with a single unit to provide services that once required two units and crews, it can significantly ease personnel and equipment movement logistics and thereby enhance safety and reduce environmental risk. This may be especially important in remote locations where transportation is difficult and offshore, where space, weight and environmental considerations are paramount.

There are also some simple but important and practical advantages to choosing digital slickline over electric line for certain offshore operations. For example, several industry efforts to develop riserless intervention techniques on subsea wells are ongoing. Slickline may have an edge over wireline in this application because it is very difficult to manage a grease seal during subsea riserless operations. In this environment, the slickline-style stuffing box used in conjunction with digital slickline could prove to be one of the critical components that brings deepwater riserless intervention into the mainstream. This technology upgrade is long overdue for a service that has been used since the turn of the last century; digital slickline services may soon move from technology trial status to best practice. —RvF