Summary Observations

The Drilling Systems Automation (DSA) Roadmap Summary Observations section provides an analysis of value opportunities together with a discussion on key topics that impact drilling industry progress adopting DSA.

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Development Team

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Introduction

The need for a drilling systems automation (DSA) roadmap are compelling. The well drilling and completion industries are highly fragmented and will require structure to enable the interoperability necessary to deliver functioning automated and autonomous systems. This roadmap can provide definition of opportunities that will allow suppliers to develop applicable value-generating products and services. A transformation of this scale requires a consensus across the drilling industry as to how drilling systems automation will develop in a way that attracts the needed levels of investment. Entry of non-oil and gas industry players will enable the drilling and completion industry to access alternative skills and advanced technologies that are necessary for accelerating successful adoption. Fear of change to implemented technologies and personnel roles is of concern but may be overcome by communicating the potential way forward. Communicating the business value that DSA can deliver is a key hurdle to its implementation. Currently, results have shown improvements in terms of rate of penetration that are 40% faster compared with human-controlled rotary drilling and attain mile-a-day building and steering wells performances.[1,2] However, the overall value proposition that is anticipated from these achievements remains unarticulated.

A recent offset industry example has demonstrated that when port container handling lift equipment was automated, with supervisory remote control, the entire wharf system became automated.[3] The effect was to increase productivity by 18%, reduce maintenance by 27%, and reduce fuel consumption and emissions by 22%. Similar knock-on value can occur in applying DSA to the benefit of operators, drilling contractors, service companies and original equipment manufacturers (OEMs).

Today's Drilling Automation Successes

Many automated systems that are primarily focused on drilling the borehole with less focus on parallel activities, have been successfully applied in drilling.
Examples include:

- Mud pump programed start up with VFD drives
- Rotary Steerable Systems
- Steering rocking systems
- A rate of penetration (ROP) focused automated driller
- A soft torque drill string vibration damping system
- MPD control systems
- Dynamic Positioning (DP)

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- Data processing for transmission
- Automated data processing and display in drilling advisors
- Drill-a-stand as a cyclic event in the drilling process
- Tripping drillstring into and out the wellbore
- Tripping casing into the wellbore.

Value Delivery from Performance Improvement Opportunity

Non-Productive Time & Invisible Lost Time

Two key elements of lost time in drilling operations include Non-Productive Time (NPT) and Invisible Lost Time (ILT). NPT is the reported time spent on activities that were unplanned and unnecessary in drilling the same well. This includes lost time from problems and down time from equipment failure. ILT is time lost due to inefficiency while drilling a well that is typically reported as Productive Time (PT) and therefore remains “invisible” in the record.[4]

Automation has the potential to positively influence both. To reduce NPT, automation can provide controls on operating envelopes and thus avoid problems. For example, automated controls on pumping and tripping accelerations and speeds may reduce the risk of borehole damage.[5] In terms of ILT, multiple opportunities exist for avoiding reliance on humans, who may or may not have been informed or understand best practices, by automating stand building off line to best practices programmed into the automation.

Opportunities can be gauged against potential performance levels in a number of ways (Figure 1). These include the best of the best (BOB) achieved within similar wells, the best in class (BIC) achieved through regional or comparable offset benchmarking, the technical limit (TL) generated by an aggressive drilling team seeking high potential opportunities to improve and maximum theoretical performance (MTP)

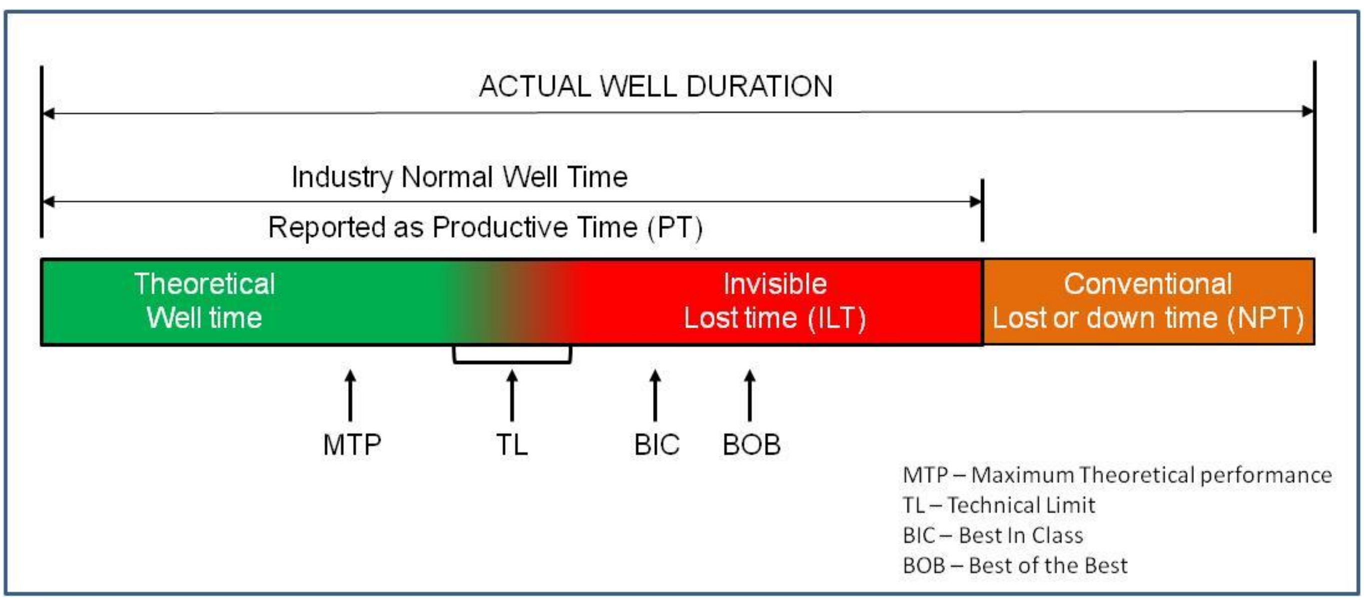

Figure 1: Measuring Performance Opportunity

established from a calculated potential performance.[4] Ultimately a fully developed and implemented DSA program offers the opportunity to exceed TL and achieve MTP.

Significant performance gains have been achieved through the adoption of advancing stages of automation in data acquisition and analysis for directional drilling, which has led to mile-a-day (5,280 ft per 24 hours) penetration rates in open borehole through the build and horizontal section.[2] This application has resulted also in a reduction of the number of personnel involved and elevated the directional driller to a supervisory role and has been accomplished by other supplier-operator combinations with similar results.

Direct Automation Value

Safety has been and will always remain a high priority for automation value, especially when it removes humans from heavy lifting, proximity to large moving objects, locations where dropped objects are a risk or from environmentally unfriendly locations. Many heavy industries, such as steel manufacturing, have removed personnel from these exposed locations through mechanization with automation. Some major oil companies have encouraged drilling contractors to make similar changes on drilling rigs. However, the lack of direct financial rewards has usually hindered development.

In some aspects of drilling and completing wells, process automation will directly deliver value. For example, certain activities require high data rate updates and continuous adjustment; this can quickly tire humans who can effectively be outperformed by automation, which is unaffected by repetitive task. Other aspects include envelope protection that is often applied to machinery. This system prevents human operators from changing control parameters, which may move the operation outside the predetermined safe operating envelop. For machinery envelope protection can simply be preventing over speeds, overloads and other similar attributes. In drilling operations, automated wellbore envelope protection is an impactful advantage of automation.

In locations where humans cannot control the operation due to access or latency and data rates that are inadequate for remote control, automation may also have a significant impact. Downhole tools fall into this domain and therefore may deliver value through internal (downhole) automation or high data rate-low latency telemetry (e.g., hard wire) to surface automation. DSA provides the opportunity for the engineered and planned processes to be digitally programmed into the operation, which avoids the impact of actions taken based on human interpretations and experience lacking in-depth engineering knowledge of the situation.

Mechanization combined with automation must be designed such that it is able to compete with the activity cycle time of the human control and manipulation process. Experience has shown that mechanization on drilling rigs operates at slower cycle times than an efficient, well trained and harmoniously operating drill crew. This creates a challenge to design mechanization around automation to gain the full benefits of the application of automation.

Some years ago, a manual dish washing was compared to an automated robot washing dishes and to a dish washing machine (Figure 2). The manual robot is slow and cumbersome; it emulates the motions of the human. The dish washing machine is a machine designed around automation and based on the intent of the operation, (i.e., to produce clean, dry dishes).

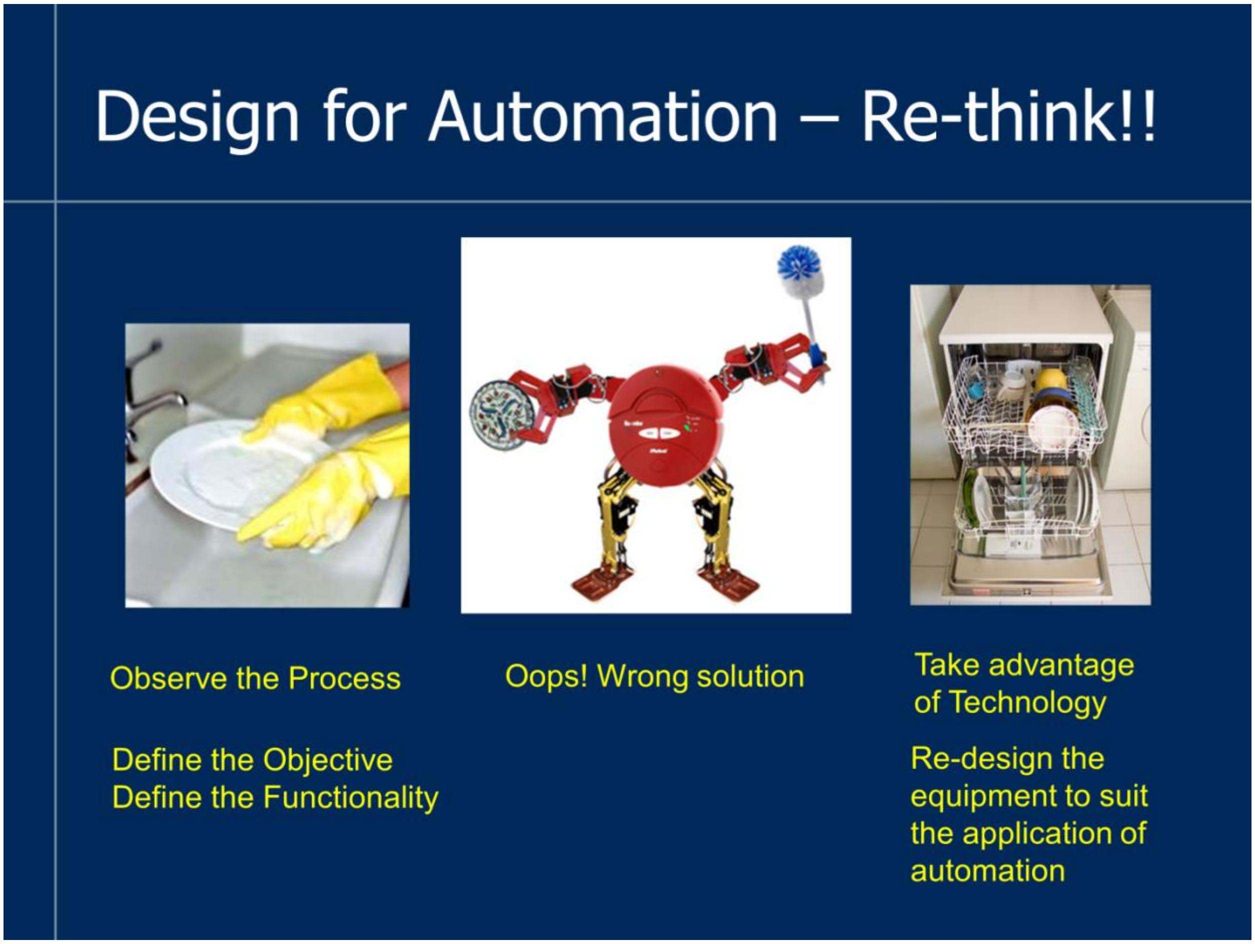

Figure 2: Example Comparing Automating Current Process versus Systems Engineered Solution (source: Walt Aldred; retired)

In fact, a dish washing machine is a re-engineered technology application solution that can be derived from the systems engineering approach. While the home style dishwasher may not be a lot quicker, the industrial dishwasher has a high rate of throughput and outperforms humans. Mechanization of drilling has usually followed the robot-with-the-mop approach and not a system engineered solution. DSA offers the opportunity for the drilling industry to use systems engineering and design mechanisms that manifest superior performance from holistic automation solutions.

Automation provides the opportunity for repetitive operations to be performed consistently. Reducing performance deviations from the mean, which occurs with many human operators, improves overall performance and lays the foundation for systematic and reproducible improvement. Consistency of performance leads to improvements in deterministic results of well drilling in terms of both schedule and cost. Deterministic results on well costs and schedule provide greater confidence for would-be investors. While this opportunity is fully available in repetitive drilling operations, in one-off exploration wells the opportunity is reduced, but should not be neglected because many repetitive operations are performed even in uncertain drilling environments.

Indirect Automation Value

In certain aspects of drilling and completing wells, automation of a non-critical path (offline or parallel) activity can enable that activity to be accomplished within the specified time. This ensures that these activities remain off the critical path and do not contribute to the overall operations sequence time.

Mechanization of some activities provides a foundation for automation; pipe make up offline is one example. If no humans are expected to interact with them, the size of mechanized systems required to perform these tasks can be reduced. At that point, automation becomes a requirement, with or without human supervisory control.

Mud mixing and make up is another activity that often consumes critical path time and should be accomplished in non-critical path time. Traditionally, this requires significant human intervention involving crews that may already be assigned to another critical path activity. Automating this process would ensure that it is completed while an offline activity and that it does not rely on additional crews or is not forced to await the current crew to avoid becoming an online, critical path activity.

Ultimately well-planned automation can level and then reduce crew workload. A level workload will reduce lost time caused by a lack of resources for peak workloads in the drilling cycle. Crew leveling through automation is a large opportunity in international operations in which the drilling crew performs most of the rig site work. In US land operations, smaller crews are on rigs and many operations are undertaken by extra service personnel called out for a particular activity that is not performed by the rig crew. This creates a de facto fluctuation in head count to match the required activity level. This does not exist internationally except in certain locations where this infrastructure has been developed.

The Automation Performance Opportunity Gap

The gap between current performance and Maximum Theoretical Performance is the opportunity for automation to add value in terms of performance from spud to total depth. [4] The opportunity for land rig automation exists in the cycle time from rig release to rig release because the impact of automation can directly and indirectly affect activity durations involved in rig moves on a single pad or between locations. Automation can be applied to the walking activity on a pad, yielding a faster and safer operation.

Mechanization designed around automation can yield a smaller and simpler-design device from both the systems engineering approach and the fact that there is no need to provide space for humans in the solution. The resulting reduced weights and dimensions also enable faster rig moves.

In the previous century, a large gap existed between current drilling performance (duration) and both Technical Limit and Maximum Theoretical Performance. High oil prices drove high activity levels that required companies to hire of personnel with limited experience for rig site crews. This was recognized as an opportunity for automation to capture the best (or near best) performance and apply it across a rig fleet to raise overall performance.

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The natural gas price collapse in the US caused operators, drilling contractors, service companies and OEMs to make significant improvements in performance to reduce well costs and to deliver production from the well sooner. This drive to improve well cycle time has been successful and has resulted in extraordinarily short well construction durations and has translated to shale oil drilling and resulted in similarly high-performance levels as those achieved in shale gas drilling.

Available data shows that the US drilling performance, in terms of overall feet per day (spud to TD), is about 5 times most global locations. One significant exception is offshore Thailand, where overall drilling rates are some of the highest in the world. This super performance has created a dilemma for automation implementers because the potential improvement to be gained by applying automation may be measured in hours rather than in many days.

This challenge requires a significant rethink of automation application to ensure that it can consistently deliver improved performance. One method for yielding value is to create fully re-engineered systems based on automation rather than automating current technology. Resulting designs must be as or more efficient than current manual semi-automated applications and not be overpriced compared with the cost savings they yield.

Another opportunity created by drilling automation adoption is reduced rig crew and safety expenses, which yield lower rig operating expenses through lower personnel and insurance costs. Application of automation to directional drilling is proving that fewer operators are required at the rig site compared with manual operations and that personnel activity is transferred to a higher supervisory level, which creates an uplift in capability with a reduction in manpower.

Value Delivery from Functionality and Quality Improvement

The value derived from automating drilling is not simply the potential to reduce crew and personnel costs and increase performance by reducing well construction cycle time, but also to deliver an improved product. In terms of a constructed well, an improved product is one that produces more dry oil or gas and requires less operating cost to maintain production. This is both a significant challenge and an opportunity for DSA because it creates a value opportunity gap in terms of well drilling times that may be much larger than that currently available in basins where drilling performance has achieved levels close to the MTP.

Automated directional drilling reacts to event inputs at a higher frequency than do humans in manual operations. Because these events are known to induce tortuosity, the automated system’s faster reaction time can result in a smoother wellbore, which leads to lower maintenance and intervention costs through less wear on artificial lift equipment and less liquid dropout in horizontal sections. These automated systems have advanced to include reactions to strategic components as well as immediate inputs, which include positions and trajectories relative to plan and to expected formation directional tendencies using current BHAs in next sections. Automation also provides a precise and reliable methodology to ensure all tactical decisions are taken within a strategic framework yielding higher value.

Transitioning from advisory well bore steering to automated geosteering offers operators an opportunity to access greater net pay and thus improved production. Further transitioning to a fully automated system through advanced analysis techniques, including machine learning (ML) and artificial intelligence (AI), is an opportunity for more value delivery.

Digitized well program

Digitized well programs are being developed by multiple vendors. Initially these digitized programs offered an opportunity to capture learnings and manage drilling (well construction) process updates, effectively avoiding a copy and paste methodology. A comprehensive methodology to digitize both well designs, including the Basis of Design (BOD) and the drilling programs, offers an opportunity to transfer many planned actions to an automated drilling system. This approach also needs a digitized schedule that is used to implement prescribed actions and track these actions for deviations against plan.

This application will become the equivalent of the manufacturing execution system, which drives many automated manufacturing processes including the manufacturing activity planning and monitoring. For one-off project wells, traditional project management schedules can be digitized, and potentially more advanced systems implemented that are driven by daily automated activity schedule updates based on daily reported status against plan.[6]

Unforeseen Value Delivery

Other industries have experienced additional value beyond the initially targeted value when the adoption of automation has achieved a holistic (full system) adoption.[3] Although implementers who are not yet seeing profits from their investments are pushing forward based on the belief that these unforeseen values do exist and will be rewarded, the oil and gas drilling industry has yet to articulate this future value.. This expectation of additional unforeseen value is not unreasonable and has been achieved in other industries.

Although they are unlikely to be manifested from sub system (system of interest) solutions developed in isolation of the total systems (systems architecture), unforeseen value can be manifested in many ways. This manifestation will require a holistic approach that covers all the systems of interest in well construction, which can be achieved through full interoperability at the sensor and machine level through an open industry approach or through a closed wholly owned integrator system.

The drilling industry will struggle to manifest the full opportunity in unforeseen value as is struggles to let go of old habits and perceptions of competitive advantage. It is likely that a well-funded wholly owned integrator system can step ahead of the islands of interoperability occurring between various parties who own the rig control infrastructure and the applications program interface.

Digital Twins

A Digital Twin has been defined as the virtual representation of a physical object or system across its life-cycle (design, build, operate) using historical and operational real-time data and other sources to enable understanding, learning, reasoning, and dynamically recalibrating for improved decision making.[7] It is a digital model used for purposes such as anomaly detection or asset management including forecasting.

Digital twins are beginning to be adopted by the drilling industry primarily for major drilling equipment in a similar manner being applied to jet engines and similar critical machinery in the aerospace industry. The application of digital twins is expanding to more complex assets with one example being the Port of Rotterdam. In mining, autonomous machinery, combined with remote operations, is reducing costs in large scale operations. [8] To deliver more value from these autonomous operations, digital twins of the mine are being developed that incorporate geological, engineering and asset information. The implementation of these digital twins requires an upgrade in applied sensor technologies which are becoming a low-cost implementation opportunity with the advent of the Internet of Things (IoT).

The drilling industry is beginning to adopt digital twins primarily for improved equipment maintenance and operability.[9] Digital twins that include the well construction model face specific challenges not typically found in manufactured equipment because the uncertainty of the sub surface environment is typically interpreted from primary or secondary sources.[10] The well construction digital twin incorporating subsurface, wellbore, rig and surface equipment, is emerging as a tool that can be integrated to DSA. The advances in mining digital twins with their more advanced application of autonomous machines and remote control can enlighten the well construction and DSA application.

Digital twins of comprehensive well construction systems will enable the outcome of an automated response to be better understood and even predicted. The application of digitals twins to well construction will continue to advance and will be coupled to the more holistic DSA applications.

Issues Impacting Uptake

Participation Roles

A fully automated drilling system will require an integrator to act as the equivalent to an orchestra conductor ensuring that all the participants (subsystems) perform their part according to the plan and schedule. Some operators have driven automation initiatives forward. However, they have not stepped fully into this role; two of these operators cut back their comprehensive automation programs focusing on data acquisition and processing and subsystem automation.

SPE DSATS successfully demonstrated their drill-a-stand protocol in 2011 at an SPE DSATS Symposium in Denver, Colorado. Subsequently, SPE DSATS suggested that the drilling contractor was best positioned to possess the data aggregator, which is a technology function, and to later become the integrator. For many years thereafter, drilling contractors showed little to no appetite for this proposed role.

Since 2017, drilling contractors have shown a very strong appetite to place themselves front and center in automated processes occurring on their rig. As this forward step by drilling contractors is occurring, the concept of a single aggregator at the rig site is changing to a split arrangement having a controls aggregator and an advisory aggregator. This tracks the Rio Tinto model for separating control and advisory systems.

Interoperability

Data sharing is becoming a hot topic of discussion and is of critical importance to DSA advancement. [11] Data from all aspects of drilling operations are a primary input to the cognitive cycle of acquire, assess, decide and act. The misalignment between a suppliers' scope and data supply from normal drilling contracts, and that which is required to automate processes according to the Systems Architecture, means that required data are not adequately shared in known attributes and quality.

Interoperability is a state in which all processes involved in constructing (drilling) a well can act interdependently without compromise. Interoperability provides the ability to plug and play multiple sourced sensors and processes. Industries have at first struggled then adopted interoperability standards to various degrees to reduce cost and delays in implementation.

Application of a set of standards in the drilling industry based on current standards employed in other industries under such organizations at IEEE, will reduce the cost to implement multi-faceted sensors and systems driving DSA. In 2019, the drilling industry has shown limited appetite to work cohesively to identify and adopt such standards.[12] Islands of success have occurred, such as the interoperability standards under the MCS-DCS Interface Standardization (MDIS) that enables a 10% cost reduction and an 80% cycle time reduction in hook up of subsea systems.[13]

This collaboration set out to streamline the Master Control System (MCS) and Distributed Control System (DCS) communications on topside systems by creating a standard interface, including a standard communication protocol. The MDIS network was formed with involvement from key industry players in the subsea controls area, topsides specialists and oil companies. Standardization of the interface was desired to simplify implementation of data communication links, whilst increasing data quality. The International Association of Oil and Gas Producers (IOGP) has demonstrated significant funding and delivery of common standards focused on reducing costs and cycle time for oil and gas project implementation.

Drilling rigs have control systems developed and supplied by a specific supplier. Some control system suppliers are also rig designers and others are specifically control systems, power and drive suppliers. DSA requires the development and installation of an application program layer (APL) over, and integrated with, the control system. These APLs are being developed as a direct one-for-one match with specific control systems, creating platforms for attaching process applications that are themselves islands and do not interoperate between these islands. For the foreseeable future, it is expected that these islands will be developed with their own- or third-party applications in competition with each other.

Data Accuracy and Quality

Some of the data in drilling do not meet accuracy requirements for normal drilling and pose a large challenge for the successful progression of DSA.[14] Although the uptake of specifications is a long duration process, efforts have been initiated to address the short fall in data quality.[15] The initial need for data quality is to improve the accuracy of parameters displayed to the driller for manual and joystick control drilling. This need increases as subsystems of interest are automated, such as directional steering, rate of penetration and drill-a-stand.

The need for data accuracy and quality is also rising with the growth of drilling data analytics. Along with this is the necessity to provide data about the data, which describes attributes that may be used to qualify the data attributes, such as location of measurement, calibration, etc. These attributes usually are described as metadata (e.g., the data attached to a digital photograph that is available for all viewers to see). Methods of processing data are advancing with adoption of global analytical approaches; consistent data can be used to identify deviations when they occur. However, systematical errors in the data may not be observed without sensor calibration metadata, as has been demonstrated in borehole surveying.

Another approach to data characterization is the use of semantics which provide ontology of the data that describe both attributes and relationships.[16]

Consistency of data is an attribute that can be tracked in real time by automated systems that provide alerts when changes or deviations from expected or modelled trends occur.

Verification and validation is employed in many advanced industries that use systems engineering methodologies to verify and validate that the output of a sensor or system meets the needs of the user through the cycle of design, manufacture, operate and maintain.[17] An initiative launched from the DSA Roadmap and approved as a joint industry project (JIP) has struggled to raise funds to undertake the scope of work necessary to produce a proof of concept that shows the benefits of verification and validation on data quality from a selected sensor or system.[18] Verification and validation methodology of sensors and systems is expected to ultimately be adopted as has occurred in other high technology, highly automated industries (e.g., commercial aviation).

Return on Investment

In public industry forums, speakers from numerous suppliers implementing automated drilling systems have stated that they are not making financial returns on their investments. They are investing in automation applications and implementing them because they believe these are key technology developments for the future of drilling and view them as competitive advantage. Industry leaders are more often voicing their concern that the dated drilling business model (i.e., traditional dayrate) is inappropriate for rewarding investments in DSA because its value currently flows primarily to the operator.[19]

Business Model Impact

A change of business model from the traditional day rate payments to one in which investments in automation that produce benefits are rewarded, could accelerate the uptake of automation. Some changes have occurred as operators begin to offer forms of incentive payments and as the number of lump sum turnkey style contracts undertaken by integrated project management (IPM) companies expand. Changes in the business model attempted in the 1990s are resurfacing.[20,21] However, a comprehensive transformation that can drive technology adoptions is not obviously underway. [22, 23]

Currently, it is unlikely that major operators will embark on a comprehensive re-evaluation of their business models. The supply chain-led approach in major oil companies commoditizing technology and minimizing pricing seems here to stay. The independent operators drilling department-led approach to contracting services will continue to select and deliver those solutions that improve performance (i.e., reduce well cycle time) and those that also deliver improved well functionality and quality.

Way Forward

Predicting the future in a deterministic manner is equivalent to seeking “fool’s gold.” The future is uncertain and looking forward requires an open mind to both predetermined outcomes and uncertain outcomes based on the current state and the trajectory of the business and technology applications within the business. This is an overview of some key expectations in the progression of DSA based on the outlook developed in the preceding sections of this report by the multitude of experts who collaborated under the steering committee leadership to produce it. Inevitably, some of the content of this outlook will prove to be wrong as the future unfolds. It is intended that this DSA Roadmap report is updated by experts every two years, in accordance with the Sandia National Laboratories process, to accommodate actual developments into the current state and project their impact on the revised future state.

Technology is Ready

Automation technology for drilling systems automation is ready for adoption and application. Well construction integrators with the vision of ultimate value and the will to implement can and will create needed solutions. Unfortunately, the rate of adoption is not driven by technology capability but by inadequate business models, misconceptions of competitive advantage, lack of understanding of interoperability and how automation will manifest gains for the industry. Companies with broad reach to build platforms that deliver wells with all their own services will probably dominate the development until the industry identifies and recognizes true sensor and equipment level interoperability as a value enhancer and cost saver and then takes many years to select and define the enabling standards.

Holistic Solutions will Deliver Greatest Value

Current DSA solutions tend to be sub system focused. These are making progress but lack the ability to perceive their interdependent role within the complex construct of well construction and its many technology specialties and participating companies. A comprehension of all the parts of well construction as intimately interconnected will enable more productive applications at both the sub subsystem level and the overall system level.

The reference architecture offers an industry standard solution which can provide a common basis to underlie value generation from interdependent systems of interest (subsystems). Other industries, more advanced in their application of automated system than is the drilling industry, have demonstrated that greater value has been realized than was estimated from the sum of the parts.[3] Single entities developing a fully digitized in-house solution or fully cooperative groups with interoperability capabilities will be the first to access this compounded value.

Predetermineds

Information technology (IT)—process and storage of electronic data at the enterprise level—and Operational Technology (OT)—monitor events, process and make adjustments at the operations level is progressing rapidly in many areas. Computational power (Moore's Law), Internet of things (IoT)—devices able to interact with computer networks, edge analytics, cloud-based computing, increased communications speeds and bandwidth are also growing rapidly. Data acquisition and analytics is moving up the maturity curve as basic analytics gives way to predictive analytics and then optimization through applications of machine learning (ML)—computer systems that can learn and artificial intelligence (AI)—computer incorporating human reasoning. This technology advancement provides the opportunity for large amounts of data to be acquired, processed and acted upon quickly.

Sensors and processed data in drilling systems have evolved slowly from some very basic technologies. Some measurements are made far removed from the attribute they purport to display (e.g., weight-on-bit). Some are manually measured intermittently (e.g., mud density and viscosity) still and many have unknown accuracies and qualities that have been proven suspect. Recognition of these issues is increasing although there is not a consistently strong drive to develop and implement real improvements. These legacy systems are not adequate for implementation of reliable automated systems. This industry inability to articulate the value and invest in the right sensor systems leaves the data sensing component of automation highly handicapped.

Graphical outputs, such as the squiggly lines that were the sole option of the geolograph with its potentiometer-driven pens on a drum recorder, have remained the norm despite improved graphics interfaces that could be designed for greater operator situational awareness. Digital displays are often 'photographs' of older mechanical displays (e.g., Bourdon tube gauges). New data displays have often been added onto current data displays creating a large and varied interface for human operators; these displays are far behind the displays developed for private and commercial aircraft which rely on clear communication for situational awareness. The industry lacks the appetite to apply known human machine interface methodologies to clean up and improve the machine–situation communication to the human operator.

The industry perception that controlling access to data and to the machine controls is founded on a long and deep history off proprietary attitudes. A change in this perception to one that views the applications of standards that enable data exchange and interoperability is unlikely to be significantly advanced in application. The view that data ought to be shared is just emerging from some industry leading organizations which could drive change. The industry will struggle with data sharing and interoperability at the sensor–machine level for many years forward.

Two groups of equipment and machines are primary drivers of the operations for drilling wells: the surface machinery, which is typically provided as components of the rig's systems, and the downhole equipment, which is sometimes provided as a system (e.g., a bit with steerable bottom hole assembly combination) or are provided from a combination of suppliers. Sensors and closed control loops have advanced significantly with the introduction of autonomous rotary steerable systems. Surface systems have advanced with the application of alternating current (AC) variable frequency drives (VFD) and created an environment for significant adoption of automation.

Surface control systems are not common across all rigs and there are specific control systems that are either supplied by equipment manufacturers or developed and implemented by drilling contractors. Key automation applications to the rig machinery have been applied through application layers that match to the control systems creating islands of interoperability. This situation is expected to remain for many years as drilling contractors control this space and the applications that run on their rigs.

Uncertainties

Telemetry up and down the borehole during drilling is a key enabler of alternative solutions for DSA. Originally commercialized as a mud pulse system which have become common in usage with its limited data rate and high latency, it later competed with a hard wire system that significantly increased data rate and reduced latency. The latter was first attempted as an R&D project in the early 1980's as the Shell Oil hardwire system. Intervening is the electronic magnetic (EM) telemetry that transmits through the formation and was developed from the technology that activated the early subterranean nuclear bombs (wireless to avoid radiation leaks).

Acoustic telemetry has become successful in situations where there is no circulating fluid medium for mud pulse (e.g., completions) after proving successful in air hammer drilling. The unsuccessful Shell Oil system was conductive-based and struggled to retain connectivity between drill pipes. The currently commercialized hard wire system uses induction between the pipe to overcome this defect. Later systems are becoming available with multi-aerial Wi-Fi transmission between pipes and new conductive systems that offer higher data rates and power down capabilities. Reliable high date rate telemetry systems from down hole to surface and vice versa can gain a significant position in the drilling industry subject to the value extracted from them over the cost and reliability they are perceived to deliver. Advanced closed loop downhole automated tools beyond just the rotary steerable tool can lengthen the applicable life for mud pulse telemetry systems as the low data rate will not be an encumbrance to the adoption of automation. The uptake of high data rate hard wire telemetry systems in replacing robust low-cost mud pules and EM systems is uncertain.

Multiple drilling process applications are being developed by both small independent teams and major industry players. These applications (apps) analyze data and deliver controlled directions to humans initially as advisory mode and thereafter directly to machinery in closed loop computational control.

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Although many of them have not been verified or validated, opportunities do exist for these apps to deliver significantly improved performance. Lack of uniform verification and validation opens up users to potential risks for both increased performance opportunity and competent control of the complex drilling processes especially when these apps are not transparent to the interconnected world of drilling systems. Applications offered from vendors in an ad hoc manner could deliver strong performance gains or could result in unintended consequences on performance, equipment and well integrity, which could lead to major financial losses.

Primary drilling equipment has been designed to fulfill the demands of manual or joystick-controlled drilling. The opportunity exists to redesign major equipment modules that respond better to automated control. Very few manufacturers are pursuing this aim with most relying on automating currently installed assets. Asset obsolesce is an issue for the oil and gas drilling industry as owners are reluctant to look at replacements as extracting value from current assets with the contractual business models compensate the status quo.

Two camps are anticipated—one that uses the current, installed physical assets to develop and control their own platform for DSA, and one that offers technology leading designs created around automaton. Although after many years the value of the automated based designs will move to the forefront of new technology adoptions, as of now, the latter will struggle to penetrate the market. The unknown is the time it will take for this transition to occur.

The department of defense demanded adoption of a common systems architecture to ensure interoperability of various platforms in land, sea and air domains from multiple vendors operating under duress. This offers an opportunity for the drilling industry to appreciate the reduced cost and increased value such an approach can deliver.

Under current management styles, it is unlikely that the proposed Reference Architecture and all sub structures will be adopted in the near term. It is probable that this situation will be viewed as a value add after value is lost through the current process, which focuses on competitive advantage rather than the whole business. In order to remain competitive as an industry in an energy competitive world, the reference architecture may be adopted by the industry after 2025.

The traditional drilling business model based on time and materials payments is not conducive to driving technology application. The use of incentive payment schemes is increasing, and lump sum style integrated project management contracts have surpassed 10% of global rig activity. Drilling is a service type environment in which the end user and well owner, or operator, is overviewing the well construction process without acting as a general contractor.[14] Drilling systems automation requires an integrator to structure the relationships and interconnectivity of all parties involved.

Operators appear unlikely to step fully into this role, leaving an opening for drilling contractors to take on more control and responsibility for drilling the well. The rig control system with an application program layer built over it provides contractors with the tool to manage the drilling systems automation application. If operators were to step into the role of general contractor and become the integrator, they would require full interoperability down to the sensor and equipment level. If the operators allow the drilling contractors and, maybe IPM companies, to assume the general contractor and thus integrator role, the systems will remain closed below the application program layer. The oil and gas drilling industry has struggled to transition business models and it is unlikely that any structured transition will occur. It is likely that ad hoc changes become adopted leaving the outcome in the future uncertain.

The perceived future is not intended to be definitive but to show the expectations as the predetermineds and uncertainties manifest themselves into the future of the drilling industry. This DSA Roadmap has concerned itself with developing and describing many best practices. However, the actual implementation will be governed by forces outside this DSA Roadmap team.

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