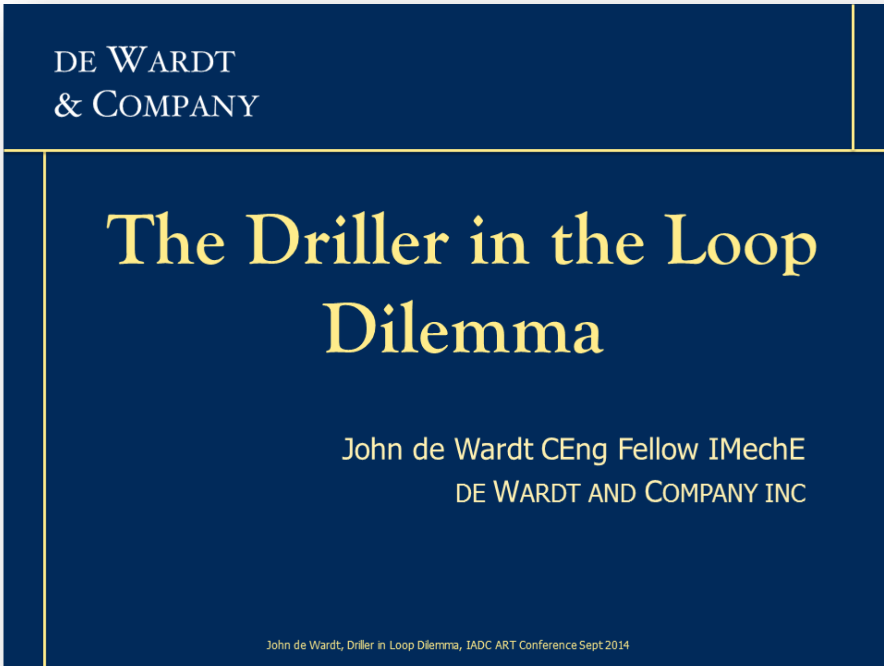
Driller in the Loop Dilemma



I would like to thank the International Association of Drilling Contractors for selecting my presentation of this exciting and timely subject at their IADC Advanced Rig Technology Conference, Galveston, September 16, 2014.

Introducing John de Wardt CEng, Fellow IMechE

John de Wardt is an independent global oil and gas management consultant specializing in Strategic Planning, Lean Manufacturing, Lean Drilling and Value Delivery Systems.

John's 38 years of work experience in 31 countries includes operations, engineering, contracts and management roles with ICI, Shell, Forasol/Foramer and Halliburton. He founded his consulting practice in 1994 and has a client list of 65 companies.

John has published over 30 SPE / IADC papers and industry articles many of which describe leading edge innovations in drilling. He has been a committee member on the SPE / IADC Drilling Conference for 20+ years and was the Program Chairman of the SPE Drilling Systems Automation Technical Section 2010 – 13. John leads the industry initiative to develop a Drilling Systems Automation Roadmap affiliated with IADC, SPE and AUVSI. He can be contacted to discuss this work at john@dewardt.com

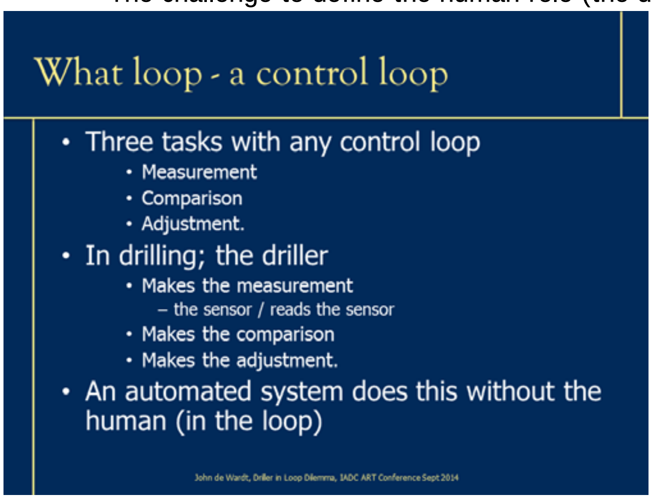
Outline

The role of the driller in the loop has become part of the conversation on Drilling Systems Automation as advances are made to apply automation technology to drilling operations. A dilemma is defined as a problem offering two possibilities, neither of which is practically acceptable. This particular dilemma tends to set proponents of automation apart on an either or attitude to the driller's role. As this presentation explains, the answer to this dilemma is neither simply one of two possibilities nor singly dimensioned. There is much learning from experts in automation application and from application experience in other industries that provide methods for effective solutions to defining the driller role in Drilling Systems Automation.

The resolution is explained in this presentation building upon expertise and models from industrial applications of automation and Human Factors engineering.

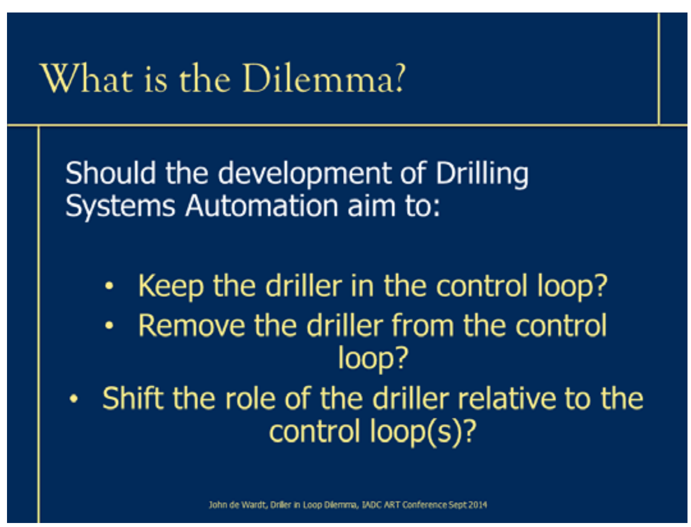
Introduction

The challenge to define the human role (the driller) in automation requires an understanding of the loop that is being challenged. Each control loop, whether human or automated, has a sequence that it follows. This sequence covers 3 tasks: measure, compare and adjust. Traditionally drilling has required that the driller views gauges that display measurements while also observing various inputs through sensory perception (sight, sound, feeling, etc.) combining both to control the process. An automated system requires sufficient sensors of a required accuracy to define the measurement in order to make the comparison and then apply the adjustment to achieve the desired measurement by the control loop. These automated systems operate, at the basic control loop level, continuously and without interference except when the operator resets the desired measurement for the camparison. A home heating / airconditioning thermostat is a simple example of this.



The Dilemma

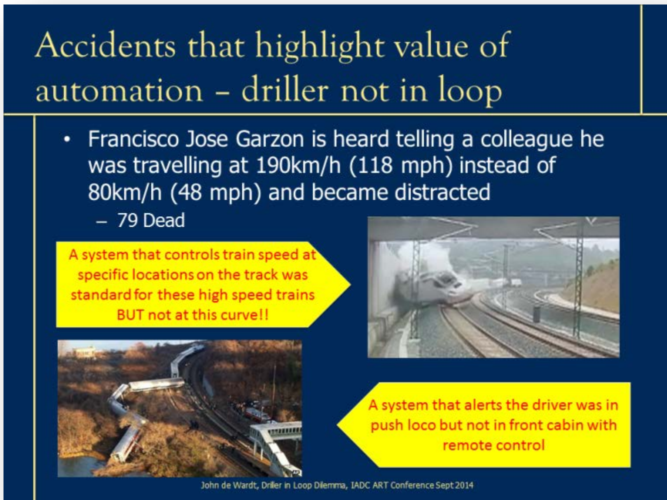
There are multiple solutions to the dilemma raised by asking if the driller should be kept in the control loop. One simple answer is to avoid automation and keep the driller firmly in the loop observing the comparisons between current reading and desired readings and making the adjustments necessary to close this gap. The other extreme is to anticipate that drilling operations can be "outsourced" to an autonomous system that has been programmed with high levels of logic which enable it to successfully act autonomously. In reality, the third option of shifting the role of the driller relative to the many control loops that exist in operating and controlling various



pieces of surface and subsurface drilling equipment is the more relevant question. Also, the “driller” in the terms of this question is not simply the driller “on the brake” but the driller and the entourage of experts from the operator, drilling contractor and service companies that support the driller in executing the well drilling program. The challenge of this query is inherently complicated however it is solvable through the judicious use of expertise and knowledge that has not traditionally resided within drilling operations.

Accidents and Extreme Operations Highlight the Potential Value of Automation

Unfortunately for 79 lost souls, the driver of a high speed train in Spain was distracted and exceeded the speed limit, by over 100%, through a very tight corner. The effect was that the train left the tracks resulting in a major crash. The railroad system incorporated control systems that inhibited the high speed train from exceeding speed limits in critical sections of the track – except this one corner. If the system had been installed here, the train would have automatically slowed to the correct speed in spite of any distractions of the human operator.

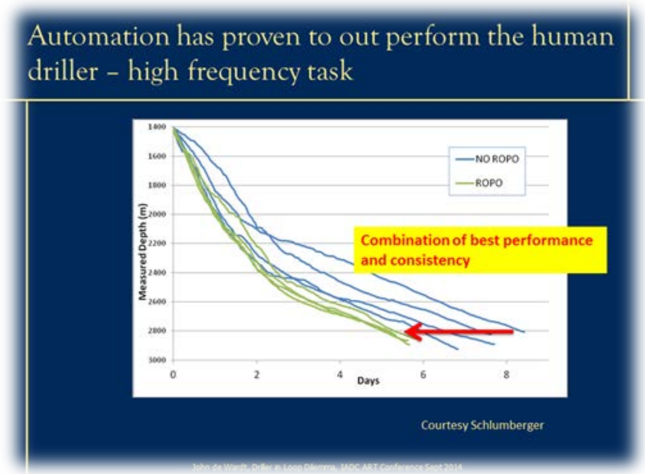


A similar accident occurred in New York with a commuter train where the over speed alarm was not audible to the engineer driving the train.

These unfortunate accidents demonstrate that humans do not always provide continuous vigilance on operating parameters over long durations; an attribute at which automated systems usually excel. Known automation technologies could have prevented both of these accidents had they been implemented in the systems operating these trains.

In August 2013, a fully autonomous drone flew from Norfolk Virginia sixty miles offshore and landed on an aircraft carrier. Notably, an aircraft carrier landing is one of the most difficult in an aviator’s repertoire. Video released across the news wires shows that the aircraft carrier crew were standing in their normal locations prepared to interact with a landing aircraft that on this day had no human in the cockpit and no human operating the drone via remote control system. Obviously, this is an application of automation that is at the extreme end of the current spectrum yet it confirms that, given the right impetus, extraordinary feats can be achieved by autonomous systems. It leaves a real challenge to the oil and gas drilling industry: can we match the need, the support and the expertise to achieve similar levels of autonomous activity?

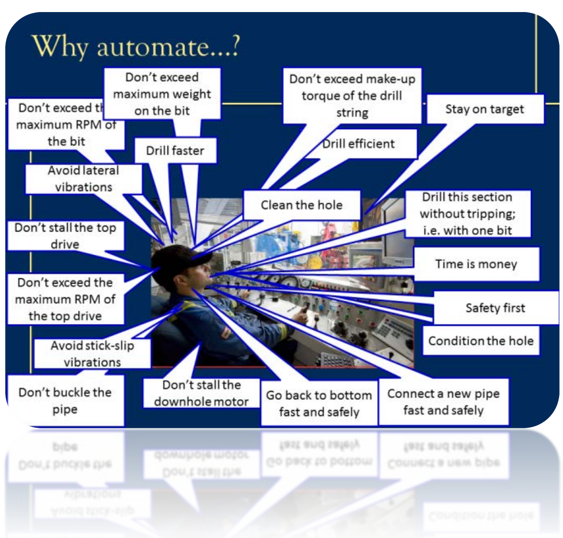
As an industry we have proven the benefits of removing the driller form the loop. The example shown here is of a Rate of Penetration Optimization (ROPO) system published at various conferences and workshops. Essentially, the ROPO system employs advanced algorithms that continuously define the most appropriate drilling parameters (WOB / RPM) to achieve the highest rate of penetration (ROP). The system detects changes in drilling / rock interaction and provides the required response – an advanced form of a continuous drill of test. In some cases, the required response is not intuitive to a human as it requires a regression and an advance in another vector of parameters. The experience published by the developers of this system, in various forums, is that the human will react to instructions from the system for a period of time and then, essentially, give up following the rapid changes dictated. Subsequently, it was proven that the system will out drill a human driller by 40% in ROP terms when the system directly controls the drawworks (rate of feed to weight on bit) and top drive (rotary speed).

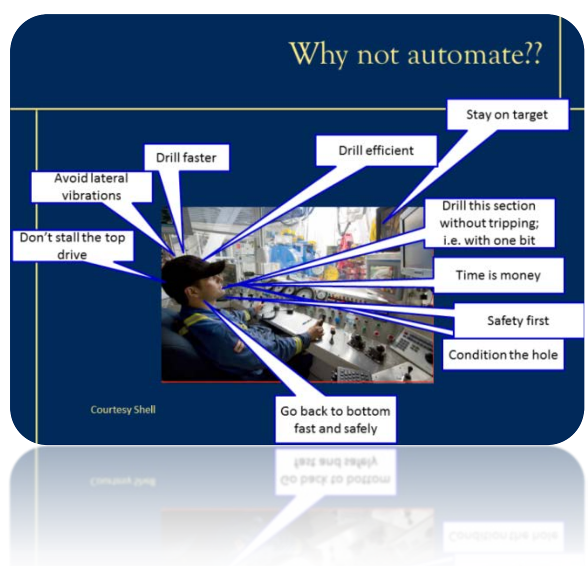


This application while a small aspect of the overall drilling operation proves that correctly applied automation delivers benefits and relieves the human in the loop (driller) of tedious and repetitive tasks.

Why Automate – The Perennial Question

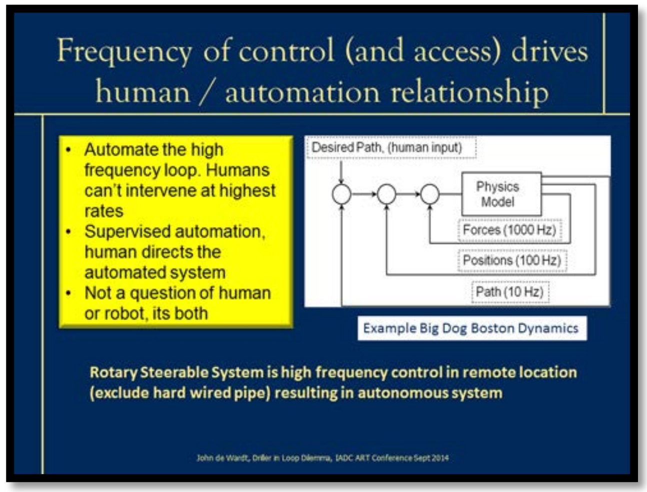
The workload on the driller has grown over recent years as many attributes have been recognized as impacting the performance of drilling, including such things as the stability of the well bore and other factors that affect the overall cost of a well. This load has been added in an ill-defined manner. The instrumentation provided to the driller has remained in a format based on traditional operations from the past and has not been expertly adapted to display the responsibilities he is now expected to take. These diagrams (courtesy of Shell) essentially pictorially demonstrate the multitude of requirements imposed on the driller and how some could be removed through automation. Drilling technology has advanced to enable easier operation of drilling machinery and downhole tools however this depiction points out that the demands on maintaining the best parameters, in many aspects, has not been compensated by advanced systems application.





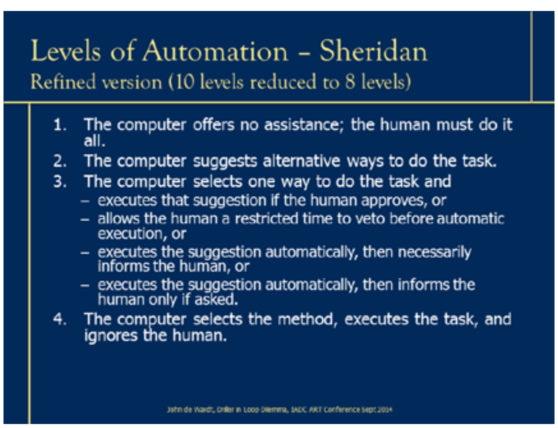
Automation can be readily and quickly applied to reduce this manual work load. The first steps are to remove operations that an automated system can perform for the driller with a better result. Currently, there are many "control" systems installed on drilling rigs from the rig manufacture and from the service companies which often are not properly tuned to the actual drilling operation. These systems can be advanced to provide easy access to drilling engineers to set the parameters such that the driller is able to focus on the human tasks and not to worry about the non-human tasks and their potentially detrimental effect on his drilling operations.

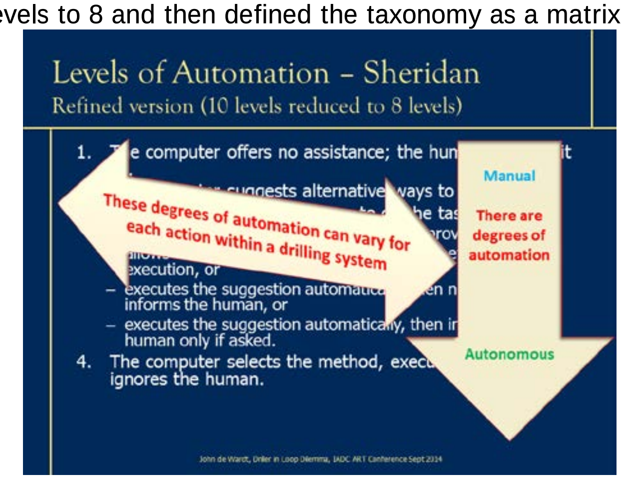
Non-oilfield industries have recognized that high frequency responses are better controlled through automation than through a human. This provides a clear impetus to take automation to the driller to enable him to perform his thought process in the lower frequency loops. Boston Dynamics provide a clear example of this hierarchy of frequency that defines the role of the human in the loop. Their product is an autonomous vehicle (Big Dog) that walks behind a soldier carrying a heavy load of resources in extremely difficult and uncertain environmental conditions. The description of the hierarchy of feedback loops employed in Big Dog provides an example of effective automation and human interface. The high frequency feedback required to maintain system stability is undertaken autonomously, the highest level of feedback (low frequency) that provides supervision to the system is undertaken by humans. Between these extremes are defined steps of autonomy and human integration.



Levels of Automation Define Human / Automation Interaction

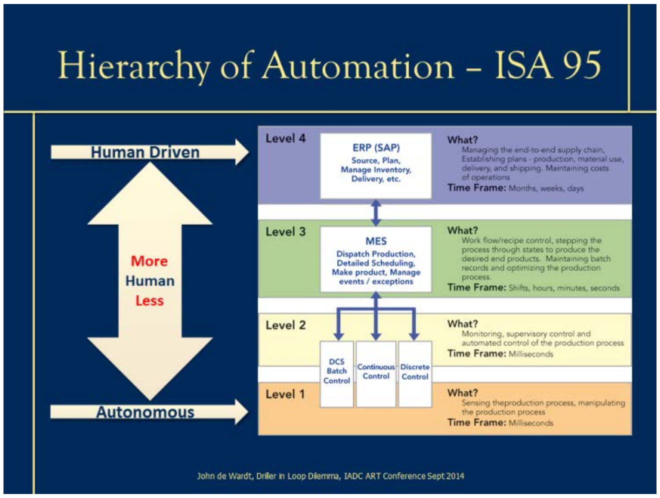
Sheridan and Verplank published the original work on levels of automation in 1978; they suggested 10 levels where at the basic level a human operator acts without assistance all the way up till the tenth level where the automation takes full control. This ground work was further developed by Endsley and Kaber by adding four different action stages; monitoring the process, generating an option, selecting an option and implementing. Later, 2006, Sheridan modified the levels to 8 and then defined the taxonomy as a matrix of these 8 levels and 4 action stages (see later). The levels of automation definition provide insight into the relationship between the human operator (driller) and the various automated systems within the drilling operation. They clearly define the full range from manual to autonomous operations and observe that these graduations vary across a complex system such that multiple levels are





employed. These ranges will also transition from human control toward autonomous as automation is implemented. Understanding these stages provides a methodology to define the staircase toward autonomous operations and the role the human will play in various elements as the staircase progresses.

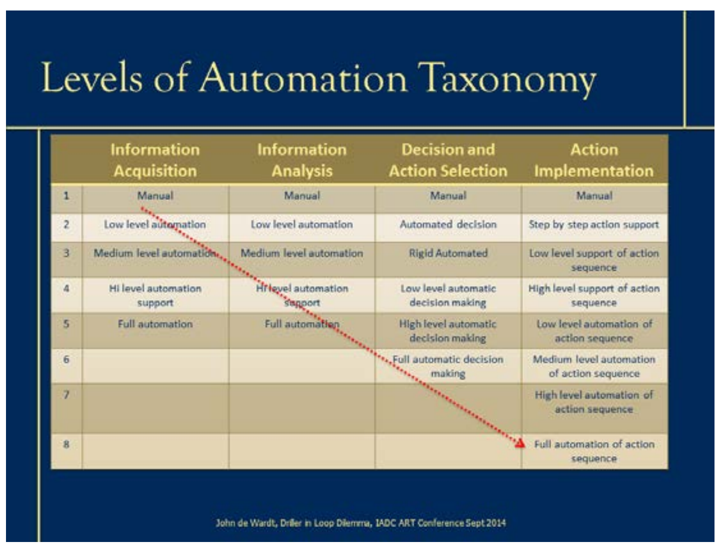
Further definition to the human / automation interaction is provided by the Purdue Enterprise Reference Architecture (PERA) that models the enterprise in multiple layers showing how automation can vertically integrate with business planning and operation control. This model was adopted by the international standard for developing an automated interface between enterprise and control system which is now referred to as ISA 95. This provides a consistent terminology for suppliers and customers as they develop a hierarchy of automation. This ISA 95 has been adopted by industries applying automation and, in the case of manufacturing, developed further to illuminate how process control is intertwined into the hierarchy. Manufacturing provides an important analogy for the application of automation hierarchy in drilling systems automation, particularly in multiple well operations such as shale gas / oil drilling.



Fear of Automation is Inhibiting Progress

The drilling industry has a significantly negative view of drilling systems automation. This is inhibiting progress of this technology application. Some reasons for this negative view include that an automation system is assumed to contain flaws, these automated systems are unable to handle the uncertainties inherent in the drilling environment and that automation simply shuts down leaving the operator with a very difficult task to recover control.

Interestingly, the process under which humans sense the status and take action is similar to the process under which automation processes information and takes action. This is reflected in the range of automation defined by action stages – information acquisition, information analysis, decision & action selection and action implementation. This matrix provides a valuable insight into the transition from manual to fully automated levels of control.



We can, as an industry, learn from a number of guiding principles developed and applied in other industries. These include:

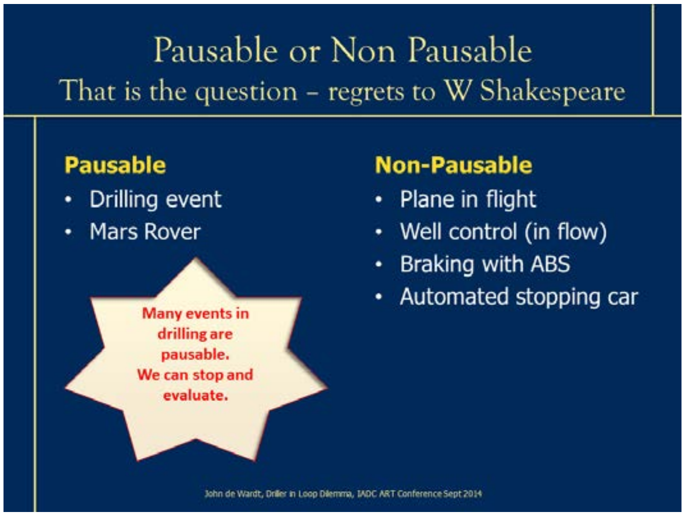
- An automated system cannot have one ‘overall’ level of automation as such. In other words, a statement about a level of automation for a system always refers to a specific function being supported.
- One automated system can support more than one function, each having a different level of automation.
- The description of each automation level follows the reasoning that automation is addressed in relation to human performance, i.e. the automation being analyzed is not just a technical improvement but has an impact on how the human is supported in his/her task accomplishment.

This shows how a multidimensional solution can be applied to automation in drilling systems.

We are now seeing the application of techniques to improve human performance in terms of process control. One such development is the application of “chronic unease” (a methodology that focusses on a preoccupation with failure) as a tool to improve situation awareness. This is a proven methodology in other industries and has benefits. However, there are other techniques that are available for application to the automation / human interface that reduce risk of adverse events which have not been addressed by the chronic unease methodology. In the words of a Human Factors expert (Amanda DiFiore, Quinetiq, December 2013) “you must design the system in such a way that workload is well-controlled. One way to do this is with adaptive automation. The level of system automation is contingent upon the workload and level of awareness of the operator.” Adaptive automation is a mechanism where both the user and the system can initiate changes in the level of automation.

Distinguishing Abnormal Events

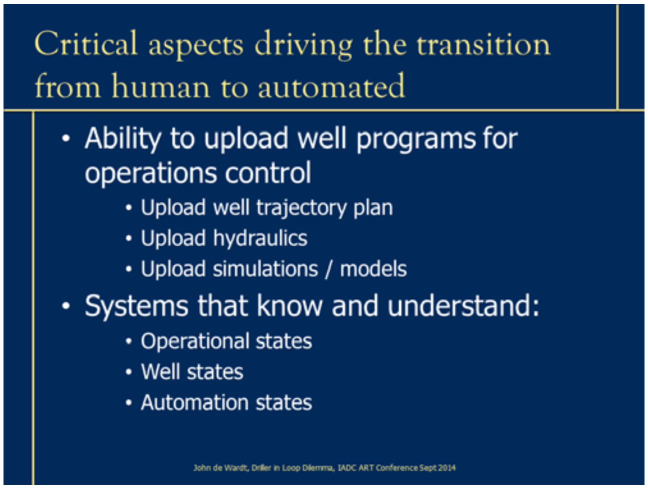
Aviation pays particular attention to the detail of what happens when an automated system fails or hands off to the pilot in an abrupt manner. This is a critical issue in that industry since flight is truly a “non-pausable” event. Analogies of the aviation learning, experience and methods have been proffered to the drilling industry. However, in our industry we have many “pausable” events in which the automation system can simply “park” the operation into a prescribed safe mode. The analogy that represents this is the aerospace industry where the huge time delays in communication with autonomous craft requires the craft to adopt a holding position (in flight or on a new planet) and await instruction for the subsequent autonomous event. Drilling automation can adopt the ability to pause operations in a safe manner until the human re-directs the operation.



Well control is the key event in drilling operations that can rapidly become “non-pausable” leading to the need to integrate the human response with the control system such that the well is competently controlled. This particular aspect of automation is a dilemma since the sensors that measure well flow are often rudimentary and inadequate for a control system application. If the sensors are upgraded to true flow measurements in and out, such as Coriolis meters, the automated systems can provide more timely control over well flow and alert the driller before the situation deteriorates into one in which extreme measures are required. If current sensors remain in place, the driller will be required to observe a well control event and intervene, leaving automation in the dark.

Transition from Human to Automated Drilling

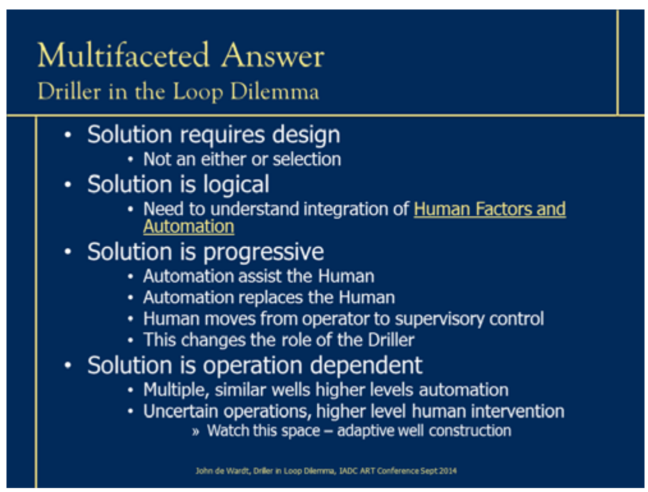
Drilling programs have traditionally been issued as written (typed) documents that are read (sometimes and not always in detail) by the site personnel drilling the well. Often the details and nuances are not transferred to those operating the drilling machinery and equipment as this takes a significant effort including the use of interactive DWOP's and pre-spud meetings. The advancement of physical calculations of the drilling process that are written into the drilling program provides an opportunity to upload these plans into the drilling machines directly relieving the humans in the loop. For example, it is increasingly apparent that the desired well trajectory can be uploaded into the drilling machinery and downhole steering tools with knowledge based algorithms that allow the machinery to steer within the most efficient and effective corridors. Similarly, the desired hydraulic effects on the well bore can be programmed into a control system that defines the ramp up of mud pumps, the acceleration of drilling strings during tripping and other effects that impact the quality of the borehole. Mud pumps are usually preprogrammed to a factory default setting that many crews do not adjust to well bore conditions; then add in the ramp up rate of the mud flow with movement of the drillstring and an automated programmable solution soon seems to have obvious advantages. In a further advancement, simulations and models can be used to observe how the drilling operation is being undertaken and whether to provide advice to correct actions that negatively impact total value or even to intervene to limit these impacts.



Knowing the state of the drilling system is a must for taking action; the human driller is continuously aware of the operational state from his / her own actions. The well state may or may not be known as it changes with the combined effect of the driller input and the conditions within the subsurface formations. Once automation is introduced, the control being exerted by humans, control system or modeling logic must be known so that the human or the automation system can take the next correct action. This adds a new dimension to the knowledge of states in a drilling operation. In short, the operational state is known by the human and needs to be assessed in a defined manner by automation; the well state is uncertain in normal drilling operations and can be better defined through the judicious application of models and predictive systems combined with improved sensors in terms of their measurement capability and their application to drilling. The state of automation is a definition and communication between the system and the driller such that the driller is always aware of the automation role and the human role.

The driller in the loop dilemma can best be addressed in a multifaceted response. Knowledge exists from the application of automation in other industries that provides methodology to solve this dilemma:

- Human and automation interaction can and will be designed – hopefully this is not impacted by poorly developed business relationships and payment schemes.
- The knowledge contained in experts in Human Factors and Automation can define a staged solution – unfortunately the drilling industry has failed to recognize this expertise as a key competency.



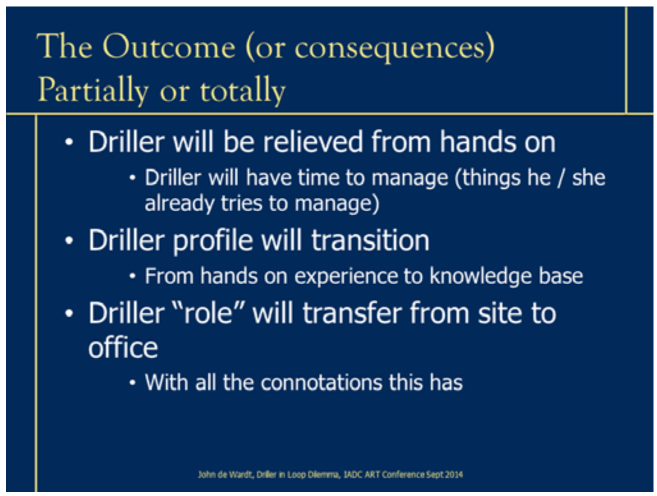
- The progressive application of automation will create a transition in the well understood and defined hierarchy of human interdependency with automation – currently the drilling industry is far behind in recognizing this transition and may struggle to undertake it effectively.
- The solution will require recognition that the drilling industry will be divergent in its application of Drilling Systems Automation. This spectrum is characterized by the multiple well operations of shale drillers in the USA who seek the next level of value enhancement and high cost operations in highly uncertain environments (where the potential exists to develop adaptive well construction) such as deep offshore.

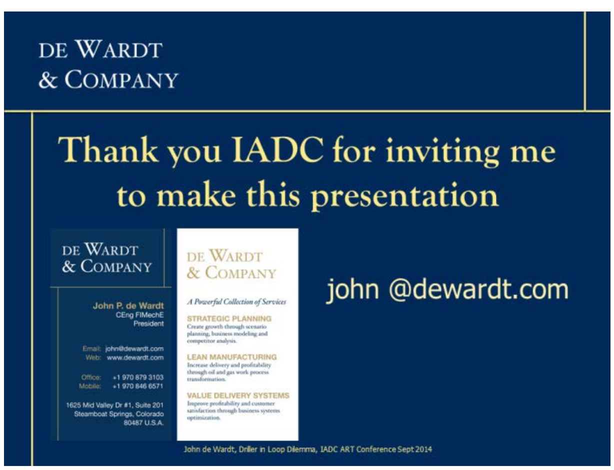
Choices will be made and the human automation interaction will be defined by these choices.

The Driller and Automation Future

There are some key outcomes that will occur as a result of the introduction of automation:

- The driller will be relieved of routine operations that require fast manipulative response. This includes not only the rig driller but also the other drillers who support the rig driller through their operational services.
- The profile of the driller will transition from a competency developed through manual experience rising up the career ladder, to one of a knowledge based person who probably has a higher education and skills related to data interpretation from sensors and an understanding of automation.
- In the future, multiple wells could be drilled by autonomous drilling machines which will be controlled from remote centers where a combination of control and analysis will be input to the sequence of operations. This “driller” will monitor and direct these systems that are autonomous and inter-combined taking back control when the operational parameters fall outside the automation envelope.





Thank you for reading this presentation made possible by IADC. john@dewardt.com