Drilling Automation/Augmentation Technical Pain Points & User Stories

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# Introduction

Purpose: to collect a list of thoughts, experiences, ideas, etc. about improvement opportunities (so called user stories) in drilling augmentation – digitalization and automation. It is not to prioritize those items or to assign action items. This list will be kept publicly available on https://dsabok.org. The “customer” for the list is any organization, group, company, individual, etc. who would like to become inspired about building a solution. This is a Sisyphean task.

Caveat emptor: The list is a non-exhaustive, work in progress which is made available as information that may contain inaccuracies, be out of date, contain typographical errors or may not be applicable to user’s (customer’s) needs or circumstances. The contributors are not liable for any errors or omissions.

Publication: A snapshot of the document is made publicly available on <https://dsabok.org>. It is updated regularly as new additions/modifications are gathered.

Rules: Share your thoughts, experiences, ideas, etc. It is okay to have different thoughts, experiences, ideas, etc. (and it is okay to disagree), just add into the document an “Opposing view” or “Comment”. This can be done by directly editing the master document that is stored on a web accessible repository. Please contact info@dsabok.org.

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# Definition of a User Story

A user story is an informal, natural language description of one or more desired features or capabilities of a software system. It is told from the perspective of the person who desires the new capability. Parts are usually: <type of user>, <desired feature>, <reason why>.

# User Stories

## USER STORY: Real-Time Drilling Dynamics Flags

While drilling, event flags and dynamics-related data indicate the dynamic behavior of the downhole drilling system. For example, green (all okay), yellow (caution) and red (detrimental). Alternatively, a spider or radar plot could be used. These flags are derived from either downhole or surface data and indicate the presence of behavior such as stick-slip, whirl, bending, bounce, HFTO, severe axial, lateral and tangential vibrations. Obviously, the fidelity (certainty) of the indication is a function of the measurement, processing and measurement location, and the usability of the event flags to mitigate an event depends on standardization in the industry.

## USER STORY: Kick Detection

Kick detection is often broken into two phases, early kick detection and consequences (formation flow). However, in many circumstances, the actual transition from drilling with an overbalance to drilling with an underbalance is progressive over time. In these cases, signals may indicate the higher probability of a kick occurring if encountering a zone of higher fluid transmissivity. This gives time for the drilling contractor to react, for example by raising the mud weight.

## USER STORY: Rig activity Codes- rig states

The drilling contractor indicates the activity of the rig over time, for the daily drilling report, using rig activity codes as defined by the IADC DDR Plus. Service companies use higher fidelity activity codes, for activity-based KPI’s (for example, for measuring connection times). In automation, the triggering of applications may depend on the change in rig activity. In this last case, the resolution and certainty of measuring the change of rig state is important.

## USER STORY: Process activity Codes

Similar to the rig codes, but looking at the various process that execute on a given rig activity, these can change based on what is happening with equipment and wellbore without any change in the rig activity. The triggering of applications may also depend on this and the associated risk matrix.

## USER STORY: Time Stamping

There are multiple measurement and processing systems on surface at the wellsite, and remotely, all with independent time clocks. To reduce uncertainty in surface time measurement and processing there should be only one master clock in the system, and all reference clocks should synchronize to that clock.

## USER STORY: Asynchronous timestamping

Building upon the Time Stamping user story, In some operations there is no control loop. It is an Asynchronous stream of commands. This can lead to issues with controlling the rate of execution on these. Having asynchronous time stamping would remove the need for adaptive rate algorithms that estimate timing and execution in this scenario

## USER STORY: Sensor Risk Index

Not all sensors measure the physical property of a process, and all sensors suffer from degradation of accuracy. Having the ability to adequately asses the quality of a certain measurement based on intended use for a given situation (Flow rate from gas cut mud) and the level of uncertainty based on last calibration would be useful in enabling algorithms to account for this.

## USER STORY: Depth Measurement

The measurement of “measured depth” (MD) is quite uncertain. It is an inferred value typically based on the length of pipe in the string and the height of the hoist above the rotary table. However, the length of pipe changes depending on temperature and loads, and the height of the top drive may be inaccurately measured. The true vertical depth (TVD) is based on the estimated MD, and the MD and TVD are used in many derived values.

## USER Story: Bit/Tool Depth Measurement

The determination of bit depth is a key source of error for most data streams. This problem is linked to the depth measurement of the hole. The user wants to receive a corrected bit depth which considers drill string mechanics to know where the bit is located in the hole?

## USER STORY: Merging downhole and surface data in real-time

There is considerable uncertainty in merging downhole data with surface data. There are time delays in the acquisition of downhole data (measurement, processing, transmission, decoding) that have to be applied to the surface time stamp to derive the correct merging time. In addition, the downhole clock will drift with respect to the surface clock. Aligning downhole and surface time stamps will allow the merging of downhole and surface data sets with confidence.

## USER STORY: Data Quality Issue Alarms

The user wants to receive alarms if the data quality of data streams and other process relevant data is outside a defined set of quality parameters. The data stream responsible shall be informed and a mitigation workflow including an escalation process initiated.

## USER STORY: Standardized Drill String Component List

The user wants to have a quality assured list of drill string components/tools which are in the hole with all relevant information included.

## USER STORY: Standardized Surface Drilling System Equipment List

The user wants to have access to a standardized equipment list which covers relevant properties of equipment used on the surface (rig components etc.).

## USER STORY: Standardized Inventory List

The user wants to central repository where a standardized inventory of equipment and materials available (including consumables) on the rig site can be pulled by all the parties involved.

## USER STORY: Data Filtering and Manipulation Audit Trail

The user wants to have a trail of all the data treatment, e.g. filtering steps which took place from the original sensor signal to the point where the data is pulled. This would help to understand how data has been filtered or manipulated from the source further downstream.

## USER STORY: Time and Depth Based Measurements

Sampling typically occurs based on time (time-based). Conversion to depth-based measurements is quite undefined. It may simply use an associate time for each equal increment of depth, and use interpolation to find time, depth pair. It may use an associated depth with each equal increments of time, and again interpolate to find the time, depth pairs. Alternatively, it may take the closest depth to a specific time, or … The lack of standardization leads to many questions on the relationship between time and depth-based measurements.

## USER STORY: DDR Operation Codes

The DDR operation codes are still widely used and cannot be replaced by real-time activity detection yet. The operations codes are the cornerstone of all operation analytics and benchmark in drilling. It is not possible to discuss ILT and NPT analyses without those codes. But they are subjective, prone to errors and hard to verify they correct start/end time and depths. There are many different ontologies (and granularities) which turns even harder to compare wells from different companies, and sometimes, within the same company.

## USER STORY: Data cross-reference

One of the biggest hurdles to share, collaborate and re-used drilling data is on cross reference between databases, inside organization and inter-organizations. In order to increase data flow between systems there is a need to address cross reference, such as unique/uniform well name; explicit metadata for units and date format; datum used for measurements; Geo-data format used (projection, UTM); and similar items. Without this, the industry will continue to build data silos, isolated applications and cumbersome data sharing.

## USER STORY: Along-Hole Depth Quality assurance and Uncertainty from WPTS

It is some time unclear what depth reference is used, the so-called Zero depth point (ZDP). This concerns both the curvilinear abscissa, often referred as the along hole depth (AHD) or measured depth (MD), and the true vertical depth. Sometime the ZDP is defined as the ground level: this can reveal to be problematic over time for instance, when there is subsidence or with drilling operations in desertic region where sand dunes move constantly. Utilizing a reference that is rig specific, e.g. rotary table elevation (RTE), can also be problematic as some wells may be drilled with one RTE, while others may be drilled with another RTE therefore causing problems when estimating collision potentials.

## USER STORY: Rounding of numerical depth values

Tabulations of well survey data is typically to 2 decimal places when the uncertainty, at deeper depths, is in whole meters / feet and multiples thereof. This is misleading to the end user and subsurface modelling (especially cross correlation of pressures) suffers badly. A common representation of uncertainty on shared TVD data is needed to ensure end users take into account the real uncertainty.

## USER STORY: Well placement Planned vs. actual by WPTS

Planning a large DLS build to horizontal drain section, 2D well. Geological model reservoir top, thickness and dip angle are not constrained due to early field development stage. Well placement survey program for a planned well includes QAQC processes for *managing* :

* surface platform
* slot location,
* horizontal, vertical reference and water depth or ground level
* depth QAQC tracking process
* EOU drawn at 2sigma 95% confidence level

Geo-model reservoir top and bottom defined as points taken from the seismic 3D model

Primary TVD uncertainty method to intersect target was to use LWD response from geological marker beds prior to starting build and landing the well out

***No geodata vertical (TVD) uncertainty is defined in the drilling program to incorporate DD reported drilling uncertainty***

Reservoir contact sensitivity, uncertainty and production performance / quality done on the plan center line not the outside Vertical Dimension to the ellipsoid of uncertainty edges for the signed off drilling program complete with low tier vertical correction

Realistic angle of incidence, relation to the reservoir contact engineering analysis not possible due to lack of incorporation of well uncertainty magnitudes shallower and deeper than the planned well bore. Without quantifying geological and drilling uncertainty there is significant risk of the well not intersecting the planned target sweet spot.

## USER STORY: Failure to follow Well Position Quality Controls and Manage Error Sources can lead to a well collision by WPTS

Controls and control types used to prevent those errors. It is a routine approach to establish and maintain those controls with no bad outcome. See Appendix for scenarios.

## USER STORY: Process / Equipment Alarms.

The user wants to receive alarms on processes and equipment relevant to the operation being undertaken and the alarm screen to change in a standard manner to accommodate this.

## USER STORY: Well Quality definition

The end user desires a quality well for their subsequent use during production and maintenance (OPEX). There is no (common) definition of a measurable quality wellbore.

## USER STORY: Calibration of deadline anchor hook-load

During the commissioning of the draw-works, the hook-load from the dead-line anchor is calibrated by weighing known amounts of barite sacks. The correction factors are put directly into the PLC code and afterward nobody has any knowledge of this correction table. The problem is that some of the measurements have been made when lifting the known amount of barite sacks and others have been when lowering other amounts of barite sacks. The result is an inconsistent correction table deeply embedded in the drilling control that nobody can be made aware of its existence unless someone, someday, open the source code and wanders what this table is for?!

## USER STORY: mud pump flowrate in

The drilling control system on a rig shows the flowrate in measured by a Coriolis flowmeter. An app connected to the drilling control system through an “open” interface receives an unspecified flow-rate in. It happens that it is the one calculated based on the pump rate from the stroke counter and the pump efficiency. The app is supposed to detect pack-offs and take proactive actions. During an operation, there is a pack-off while starting the mud pumps. The driller notices immediately based on the Coriolis flowmeter measurement, while the app does not react because the flowrate has not yet increased according to the stroke counter.

## USER STORY: Pit temperature sensor measuring air temperature instead of mud temperature

A drilling automation app controls the axial velocity of the drill-string to protect the well against swab and surge. While circulating the hole clean, the mud is transferred to the reserve pit which is not equipped with a temperature sensor. The app continues to receive the temperature from the active pit, but now it is the air temperature that is measured and not the mud temperature. As the temperature has decreased by more than 30°C, the app finds that the mud density has increased, therefore allowing to pull out of hole with a much larger axial velocity than what is tolerable by the well.

## USER STORY: External influences on the mud density sensor in the mixing unit

A drilling automation app controls the maximum allowable flowrate. It utilizes the mud density measured in the mud mixing unit for its calculations of hydrostatic and hydrodynamic downhole pressures. However, occasionally, the mud density sensor provides values that are substantially lower than expected. Yet the reported values could be actual values and cannot be simply disregarded as outliers. After investigation, it appears that the deviations of the mud density measurements always happen while performing X-ray inspection on the lower decks.

## USER STORY: Additional pumping with the cement pump while drilling

While drilling the 12 ¼-in section of an ERD, it is found that there is not enough flow to clean the hole. It is therefore decided to use the cement pump to provide an additional flow. The cement pump is not integrated in the drilling control system. Any apps that is connected to the drilling control system receives an erroneous flowrate which only accounts for the mud pumps and not the additional flow provided by the cement pump.

## USER STORY: Automatic kick detection and booster pumping in the marine riser

An automatic kick detection app gives systematically false alarms each time booster pumping is used to clean the marine riser. This is simply because the booster pump is not included in the signals provided to external apps by the open interface of the drilling control system.

## USER STORY: Multiple collision criteria

An operator has taken responsibility of an existing field that has been developed for many decades. The operator does not trust the measurements made by the previous operator of the wellbore position. The new operator desires to utilize two different collision criteria: one for older wells and one the wells that are new drilled.

## USER STORY: Repetition of real-time signals

A service company has been asked to increase the refresh rate of its real-time signals from 0.2Hz to 1Hz. Instead of acquiring new signals every second, the same signal is repeated every second for 5s. Consequently, any app that calculates accelerations will have consider that there is no “movement” for 4s and a sudden acceleration over 1s.

## USER STORY: Downlinking to the RSS by flow diversion

An app connected to the open interface of a drilling control system monitors the flowrate and the pump pressure. When utilizing an RSS, the pump pressure “oscillates” for a few minutes, while the flowrate reported by the drilling control system seems to be steady. The reason is simply that downlinking to the RSS is made using flow-diversion and the commands to the flow-diverter are not made available through the open interface of the drilling control system.

## USER STORY: Downhole pressure measured in the BHA compared to downhole pressure measured by ASMs

A drilling operation makes use of high-speed telemetry and several ASMs. When comparing the downhole pressure measured by the PWD in the BHA and the downhole pressure measured by the ASMs, there is large difference in dynamic response: the downhole pressure from the PWD does not show any of the micro pack-offs that are visible on the ASMs measurements. The reason is that the PWD provides average values over a much longer time window than the time window used by the ASMs.

## USER STORY: Synthetic signals vs Actual Measurements

A dynamic sub measures axial acceleration and 3 tangential accelerations at 120° from each other’s. It also provides a synthetic radial acceleration based on the tangential accelerations and the rotational speed measured with a gyro. It is important to know that the radial acceleration is synthetic and not measured as the synthetic value will not be able to account for lateral displacement effects and therefore that synthetic signal cannot be used to reconstruct the pipe lateral movement.

## USER STORY: Practical accuracy compared to given accuracy of downhole pressure measurements

A downhole pressure sensor has a given accuracy (possible bias compared to a true value) and precision (statistical discrepancies of multiple measurements). In practice, pressure is transmitted to the sensor through a small piston-like element. Small solid particles may jam the displacement of the piston resulting in a much large inaccuracy than the theoretical one given by the manufacturer.

## USER STORY: Side effect of daylight saving on real-time logged data

A real-time drilling data acquisition system timestamps recorded data using the local day-time clock. If the local daylight-saving procedure change clock in spring and autumn, there are inconsistencies in the continuity of the timestamps.

## USER STORY: change of hook-load measurement configuration in the middle of an operation

During a drilling operation, the driller decides to change the configuration of the hook-load measurement, from using the two load cells at the top of the top-drive, to using only of the two. The change causes a permanent deviation of the hook-load measurements which can be misinterpreted by an app that monitors overpulls and set-down weights.

## USER STORY: False zero of the standpipe pressure

The standpipe pressure is influenced by the mud column in the standpipe and therefore always reports a pressure even when the mud pumps are turned off as long as there is mud in the standpipe. On a rig, the mud pump PLC has been modified to apply a false zero such that the SPP is approx. zero when not pumping. As a consequence, the SPP is negative when the standpipe is drained out or when the fluid density is lighter than the one that has been used to define the false zero.

## USER STORY: Discrepancy between pump rate command and measured pump rate

A drilling control system sends a mud pump rate command based on the request from an app. This mud pump rate command is translated by the mud pump PLC into a motor speed which is applied by the VFD drive on the AC motor of the mud pumps. i.e. a rotational velocity of the magnetic field generated by the stator of the AC motor. But the actual mud pump speed is the one the rotor which is always smaller than the one of the rotating magnetic field generated by the stator. As a consequence, the obtained mud pump speed is always lower than the one requested. The difference between the two depends on the pump pressure (in fact the torque on the AC motor).

## USER STORY: In situ tortuosity from continuous inclination and azimuth

When using an RSS, the continuous inclination and azimuth is sent by mud pulse telemetry. This information is used to calculate the local micro-tortuosity. In the same BHA, there is a high frequency/high precision accelerometer and magnetometer recording data in memory, but position at the top of the BHA. When comparing the two set of measurements, it appears that the micro-tortuosity calculated from continuous inclination and azimuth is much larger than the one from the memory data. A plausible explanation for the discrepancy is that the continuous incl and azimuth is measured inside the RSS which is subject to much more sag effects than the memory-based instrument placed at the top of the BHA.

## USER STORY: calculation of inclination from a dynamic sub

A dynamic sub has three tangential accelerometers and one axial accelerometer. Under uniform rotation, the amplitude of the tangential accelerometers shall be related to the local inclination. However, none of accelerometer measurements are compatible with the same inclination because the accuracy of accelerometers. One wants to use sensor fusion to extract a plausible local inclination.

## USER STORY: Fann 35 measurements at high temperature

Once a day, the mud engineer performs Fann35 measurements of the mud at 20, 50 and 80 °C. However, at 80 °C, there is substantial evaporation of the fluids and therefore the measurements are not representative of the real rheological behavior.

## USER STORY: Fann 35 measurements of a thixotropic and weighted fluid

To measure the rheological behavior of a thixotropic fluid, it is important to wait sufficiently between each change of speed of the rheometer. But, if the fluid is weighted, then at high shear rates, there is a risk that the high gravity solids will settle in the cup during the waiting period. As a consequence, further measurements are made with a fluid that is actually different from the original one. These two aspects are conflictual, and it is practically impossible to correctly measure the rheological behavior of a thixotropic, weighted fluid with a mechanical rheometer that does not have a large number of possibilities for the measurement speeds.

## USER STORY: Fluid rheological behavior when drilling reactive shales

When drilling reactive shales, the mud gets continuously contaminated. The mud engineer is very busy managing the quality of the mud and therefore has not much time to send mud reports. Therefore, any applications that depend on these mud reports will not get this information in a timely fashion while it is the moment for which the mud rheological behavior changes the most.

## USER STORY: Unclear temperature conditions for mud density

In many mud reports, the temperature conditions of the mud density are absent or unclear. This is a source of uncertainty when performing hydrostatic and hydrodynamic pressure calculations.

## USER STORY: Unclear source of the fluid sample

In many mud reports, it is unclear whether the mud sample has been taken from the pit or the flowline. Also, if some samples are taken from the pits and others from the flow-line, they are not necessarily comparable, especially while drilling reactive formations or when cuttings may dissolve in the drilling fluid like for instance in a chalk reservoir.

## USER STORY: Unclear measurement of the mud density when utilizing loss circulation material

When loss circulation materials (LCM) are used, it is often unclear whether the mud density has been measured with the LCM or after being filtered. This can impact both hydrostatic and hydrodynamic pressure calculations.

## USER STORY: Rheological measurement of drilling fluids with LCM

When utilizing a Fann 35 rheometer, the drilling fluid is filtered to remove LCM. Therefore, the measured rheological behavior is not the one of the fluid that is pumped into the well. Solid particles in suspension influence the rheological behavior and therefore calculating pressure losses based on the filtered fluid will lead to biases on pressure drop estimations.

## USER STORY: Effect of Thixotropy on Pipe Rheometers

When utilizing a pipe rheometer with thixotropic fluids, any change of pipe diameter causes a change in the shear history of the fluid and therefore influences the measured pressure drop over a certain distance. If this is not accounted for, then the measured rheological behavior is biased, which in turn impact estimations of pressure drops.

## USER STORY: WOB Calibration

The surface WOB (SWOB) is deducted from the subtraction of the free-rotating weight (FRW) to the hook-load. The driller needs to “zero the WOB” prior to tagging the bottom. If he does so before the flow has reached steady state conditions, then the FRW may not had reached yet a nominal value since it depends on the pressure losses along the hydraulic circuit. Similarly, if the flow rate is changed while drilling, the zero WOB is falsified. In addition, it is really an FRW if the drill-string was fully rotating, which is not necessarily the case when utilizing a low top-drive speed as there may be static to kinetic friction induced stick-slips. An erroneous SWOB can influence mechanical specific energy (MSE) calculations.

## USER STORY: pick-up/slack-off friction test executed without removing torque on the top-drive

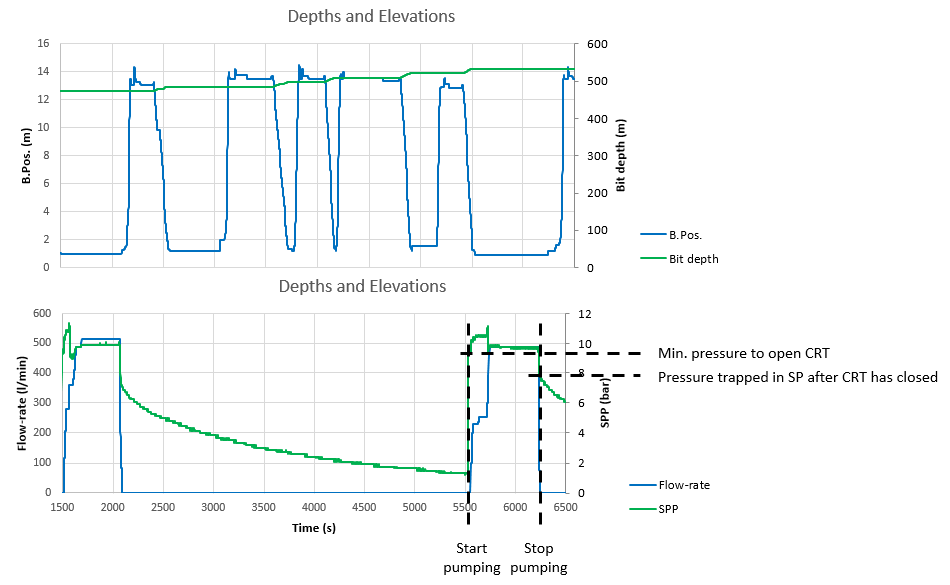
After drilling a stand in a deviated well, when the top-drive is stopped, there is still a torque on the top-drive. This remnant torque is caused by static friction along the drill-string keeping the drill-string to be twisted. If the driller performs a pick-up/slack-off procedure to measure the pick-up weight (PUW) and slack-off weight (SOW), without removing the torque on the top-drive then the drill-string untwist while moving axially and therefore the measured PUW and SOW are not the one of pure drag but a combination of axial and rotational movements. There is a function on the drilling control system to untwist the drill-string, usually called “Zero top-drive torque”. However, whether the “zero torque” has been used or not is not necessarily passed. This has an influence when filling information on hook-load “roadmaps” (also called “Hockey Sticks”).

## USER STORY: Influence of the mud hose and umbilical on the hook-load

When the travelling block is high in the derrick, the pull exerted by the mud hose and umbilical is larger than when the block is closed to the drill-floor. This influences the measured hook-load when it is not measured directly by an instrumented saver-sub or iBOP. As a consequence, there are biases in hook-loads and consequently on SWOB depending on the block elevation when the hook-load is measured at the deadline anchor, at the top of the top-drive or at the crown blocks.

## USER STORY: System State Interpretation: Casing Running Tool

When running in hole a casing string with a casing running tool, it is necessary to have some pump pressure to open the tool even though one just fill the string (no circulation) and after the casing running tool is disconnected, the SPP remains high even though there is no connection with the string (see Figure 1). Without knowing that a casing running tool is used, many automation systems would be fooled.



*Figure 1: When utilizing a CRT while running in hole with a casing string, a minimum pressure is necessary to open the CRT valve. The observed SPP could be misinterpreted as if circulation has been established while drilling fluid is only filled at the top of the casing string.*

## USER STORY: System State Interpretation: booster pumping in the marine riser

When drilling from a floater with limited flowrate, e.g. reservoir section, there may not be enough fluid velocity in the marine riser to lift the cuttings. Booster pump may be used to add sufficient flow through the riser. However, lack of information shared with other system of booster may cause troubles to drilling automation functions, such as kick detection, downhole pressure estimation, hole cleaning management,…

## USER STORY: System State Interpretation: dropping ball to open under-reamer

After chasing a ball to open an under-reamer, the SPP and the surface torque will increase as the under-reamer is activated. This can be misinterpreted by automatic functions as a pack-off or an over-torque.

## USER STORY: System State Interpretation: dropping ball to open circulation sub

After the ball has landed in the circulation sub, the flow is diverted to the annulus. The pump pressure decreases substantially. This can be misinterpreted as a pipe washout or a twist-off by some automation functions.

## USER STORY: System State interpretation: displacing fluid

If no specific information is made available to drilling automation functions, the displacement of in situ with a new mud can be misinterpreted, e.g. abnormal change of hook-load, pump pressure, torque).

## USER STORY: System State Interpretation: adding an “unconventional” pump to increase cuttings transport

To improve cuttings transport, it is decided to utilize the cement pump in addition to the mud pumps while drilling a long section. If the automation functions are not been made aware that the cement pump is used in addition to the mud pumps then these functions may be useless or even dangerous.

## USER STORY: System State interpretation: downlinking with a flow diverter

When downlinking with a flow-diverter principle, the pump rate remains constant and yet the flow inside the string is modulated. This can be completely misinterpreted by an automation function.

## USER STORY: System State interpretation: heave compensation

An automation function, e.g. hoisting velocity control, may have totally different operating values, if the heave compensation is turned on or off. These values could also be refined if active heave compensation is used instead of passive one.

## USER STORY: System State interpretation: stick-slip mitigation

An automation function, e.g. a smart ROP manager, may behave differently if it knows that stick-slip mitigation is turned on or off. It may even want to control the activation of the stick-slip mitigation or some of the parameters of the stick-slip controller.

## USER STORY: System State Interpretation: in-slips

In some conditions, e.g. when the hook-load is low, it may be difficult for an automation function to know if the string is in-slips or not. This can lead to misinterpretation and possible disastrous consequences.

## USER STORY: System state interpretation: wet trip and mud bucket

When pulling out of hole wet, the mud bucket may be used to ensure collecting the mud and having correct mud volumes. However, if the mud bucket is not used, then an automation system may misinterpret the measured pit volumes.

## USER STORY: automatic sequence: ROP performance estimator

An auto-ROP function would like to perform short sweeps of rotational speed, WOB, flowrate to check the ROP gain factors and the proximity to the founder point.

## USER STORY: automatic sequence: fill pipe during tripping (both with drill-string, casing string and liner)

An automatic function wants to control the mud pumps to fill the pipe during tripping of drill-string, casing string or liners. It observes the pump pressure and the return flow to check if filling is achieved. This can be complicated in a dual-gradient context as return flow may start before the string is filled. The hook-load is also monitored to check if the weight increase is as expected, however in deviated well, this may not be a good indicator as friction along the string may cause drag forces that imped weight transfer.

## USER STORY: automatic sequence: running in hole with closed BOP

During a kick, it may be necessary to run in hole in order to circulate the kick out of the well. When the BOP is closed, there is a need to have a coordinated control of the rig choke opening and the hoisting system in order to keep the downhole pressure as stable as possible.

## USER STORY: safeguarding: maximum hoisting speed and acceleration

An automation system may want to limit the hoisting speed and acceleration to decrease the risk for swabbing. This value may depend on gel duration if there is no circulation, or flowrate and rotational speed if circulation is established.

## USER STORY: safeguarding: maximum lowering speed and acceleration

An automation system may want to limit the lowering speed and acceleration to decrease the risk for surging. This value may depend on gel duration if there is no circulation, or flowrate and rotational speed if circulation is established.

## USER STORY: safeguarding: maximum speed when large elements passing through restrictions

An automation system may want to limit the speed when a large element will pass through a restriction, e.g. BHA passing through a milled-window.

## USER STORY: safeguarding: limiting certain actions to avoid activating inadvertently downhole elements

Some downhole elements may be inadvertently activated if some accelerations or speeds are applied to the string, e.g. breaking pins of whipstock. Therefore, an automation function may want to pass limits for the relevant machines.

## USER STORY: safeguarding: maximum flowrate

An automation system may want to limit the flowrate to limit the risk of fracturing or washing out the open hole formation. This value may depend on rotational speed and string velocity.

## USER STORY: safeguarding: minimum flowrate

An automation system may want to limit the minimum flowrate to avoid getting in trouble with cuttings transport. This value may depend on rotational speed.

## USER STORY: safeguarding: minimum top-drive speed

An automation system may want to limit the minimum top-drive speed to ensure proper cuttings transport or avoid stick-slip. This value may depend on WOB/ROP…

## USER STORY: safeguarding: hole collapse or cuttings avalanche during flow check

When performing a flow check, the hole may collapse or cuttings that were maintained in position by the previous may be destabilized and fall on the drill-string. If rotation was maintained during the flow-check, torque will become erratic with an increase tendency. It is then necessary to restart pumping as quickly as possible to increase the downhole pressure or assist in stabilizing the cuttings bed.

## USER STORY: Fault Detection, Isolation and Recovery: Overpull

When moving the string upward in automatic mode, the operation shall stop immediately when the hook-load overpass a given threshold (overpull limit). Note that the threshold may need to be different before the string has started to move than afterward (for instance because of the necessary force to get out of differential sticking). In fact, it would be even better if it moved in the opposite direction when the overpull has been detected.

## USER STORY: Fault Detection, Isolation and Recovery: Set-down weight

When moving the string downward in automatic mode, the operation shall stop immediately when the hook-load drops below a threshold (set-down weight limit). Note that the threshold may need to be different before the string has started to move than afterward (for instance because of the necessary force to get out of differential sticking). In fact, it would be even better if it moved in the opposite direction when the set-down weight has been detected. Also note that set-down weight limit does not apply when tagging bottom.

## USER STORY: Fault Detection, Isolation and Recovery: over torque

When rotating the string in automatic mode, the top-drive shall stop immediately when the top-drive torque exceeds a value that corresponds to a stuck pipe situation. Note that the threshold may depend on whether the bit is on bottom or not.

## USER STORY: Fault Detection, Isolation and Recovery: pack-off/bridging

When pumping with an automatic function, the flow should be automatically controlled in case a pack-off is detected (typically based on the SPP, but in some future it could also be based on downhole pressure transmitted with high speed telemetry with low latency). Note that the flowrate should be maintained as long as possible, but a safe level compared to the fracturing pressure limit of the open hole formation, as this is the only way to get out of the pack-off situation. Also, the auto-driller shall be turned off and if possible, the drill-string should be lifted off bottom if we were drilling. Note that there is additional complexity to this function under pump acceleration.

## USER STORY: Fault Detection, Isolation and Recovery: auto-driller and hard stringer

When the bit starts to get out of a hard stringer, the WOB is often very high and there is a risk of damaging the bit as some of the cutters are penetrating softer formation. Drilling interbedded formations shall be accompanied by parameters to manage the transitions from high to soft formation rocks.

## USER STORY: Fault Detection, Isolation and Recover: protection under FIT, LOT and XLOT

It is desired to take control of the cement pump while running an FIT, LOT or XLOT, if the formation fractures prematurely.

## USER STORY: Safe Mode Management: loss of communication with a specific machine

An automation function would like to specify what to do to put the system in a safe mode, in case communication with one of the drilling machines is lost. The safe mode procedure may be different depending on the context, e.g. tripping, drilling, etc.

## USER STORY: Safe Mode Management: loss of communication with the interoperability layer

An automation function would like to specify what to do to put the system in a safe mode, in case communication with the interoperability layer is lost. The safe mode procedure may be different depending on the context.

## USER STORY: Safe Mode Management: logging in the SCADA system in case of miscommunication

It is important that miscommunication with the interoperability layer are logged in the RigOps SCADA system.

## USER STORY: break Circulation

As the provider of an application that has the potential to enhance the consistency of the drilling process, I would like the ability to request that the operating system performs a “Break Circulation” (Start Circulation) action.

The Break Circulation action request will include:

* Target flow rate
* Flow ramp rate
* RPM limit (optional)
* Set ramp style (full fidelity profile, target only, Exponential etc)
* “Soft” standpipe pressure limit

## USER STORY: Turn on Rotation

As the provider of an application that has the potential to enhance the consistency of the drilling process, I would like the ability to request that the operating system performs a “Turn on Rotation” action.

The Turn on Rotation action request will include:

* Target rotational speed
* Rotational rap rate (max rotational speed acceleration)
* “Soft” max top drive torque limit

## USER STORY: Go on Bottom

As the provider of an application that has the potential to enhance the consistency of the drilling process, I would like the ability to request that the operating system performs a “Go on Bottom” action.

The Go on Bottom action request will include:

* WOB re-set
* Hook-load reference set point (or the operating system to use to calculate WOB)
* Move blocks to a desired position
* Max block velocity
* Max block acceleration
* Max block deceleration
* Target block position
* Enable and set the auto driller
* Enable auto-driller
* ROP set point
* WOB set point
* Potentially auto-driller gain settings
* Drill-stop point (block position the auto-driller must stop drilling)

## USER STORY: Set auto-driller

As the provider of an application that has the potential to enhance the consistency of the drilling process, I would like the ability to request that the operating system performs a “set auto-driller” action.

The set auto driller action request will include:

* Enable and set the auto driller
* Enable auto-driller
* ROP set point
* WOB set point
* Potentially auto-driller gain settings
* Drill-stop point (block position the auto-driller must stop drilling)

## USER STORY: Drill ahead Setpoints

Setpoints to manage drilling founder and limiting optimization as you drill ahead. Combines multiple models into orchestrated founding limits setpoints and target (similar to auto driller #88, but not the same , could be combined)

* WOB (Set point and/or limit)
* RPM (Target and/or limit)
* FLOW RATE (Set point and/or limit)
* ROP(Limit and/or Target)
* DRILL Start and Stop Transition states flags
* Mode (Auto, Advisory , Off)

## USER STORY: Send flow downlink on bottom

As the provider of an application that has the potential to automate the directional drilling process, I would like the ability to request that the operating system performs a “Send flow downlink on bottom” action.

The “Send flow downlink on bottom” action will include:

* Downlink command
* High and low flow rates
* Timings for each flow rate interval
* Flow ramp rate
* “Soft” standpipe pressure limit

## USER STORY: Send flow downlink off bottom

As the provider of an application that has the potential to automate the directional drilling process, I would like the ability to request that the operating system performs a “Send flow downlink off bottom” action.

The “Send flow downlink off bottom” action will include:

* Downlink command
* High and low flow rates
* Timings for each flow rate interval
* Flow ramp rate
* “Soft” standpipe pressure limit

## USER STORY: Take upward friction test

As the provider of an application that has the potential to enhance the consistency of the drilling process I would like the ability to request that the operating system performs a “Take upward friction test” action (to obtain a pickup weight).

The “Take upward friction test” action will include:

* Target block velocity
* Max block acceleration
* Target top drive rotational speed
* Target flow rate
* “Soft” hook-load limit (avoid excessive overpull)
* Friction test stop point (block position)

Note: the interface spec would also need to determine how the operating system should respond if the overpull limit is hit (i.e. stop pulling, return control to Driller ..?)

The friction test can be continued with a downward test.

There may also be a rotation off bottom step

## USER STORY: Ream up and down

As the provider of an application that has the potential to enhance the consistency of the drilling process, I would like the ability to request that the operating system performs a “Ream up and down” action.

The “Ream up and down” action will include:

* Target block velocity
* Max block acceleration
* Target top drive rotational speed
* Target flow rate
* “Soft” hook-load limits (avoid excessive overpull and slack off)
* “Soft” standpipe pressure limit
* “Soft” surface torque limit
* Ream up and down start and stop points (block positions)

## USER STORY: Drill Stand Verification

Operations to initialize drilling operations

1. Verify required rig control system on-line and communicating
2. Verify pumps off
3. Verify rotation is off
4. Verify bit is off bottom
5. Verify HD < (BD + stand length), i.e. that bit is close enough to bottom that is possible to drill with the current stand.
6. Check that hook load is sensible
7. Notify System that Stand is Ready to Commence
8. Check for System OK
9. Advance to next phase of drilling stand

## USER STORY: Stabilize circulation

Pump(s) are holding desired rate(s). Standpipe pressure is normal.

1. Start time out period
2. Monitor Pump Rates, Flow Out rate, and Pump Pressure
3. Check for time out if readings are good, else fail out
4. If time out, end Case successfully. Else repeat steps 2-4 5

## USER STORY: Auto Driller stopped come off bottom

Operations to transition control from the auto-driller and position the bit off bottom

1. WOB threshold achieved and drill off complete
2. Rotation has been reduced to 60 – 80% of original setpoint\
3. Vibration is minimal
4. Torque, borehole pressures, and hook-load values are sensible
5. Pump flow is reduced, and pump pressures are sensible
6. Connection Procedure determines hole cleaning (back reaming and circulating sweep)
7. Bit has been raised off bottom to target established by the Connection Procedure

## USER STORY: Set Tripping Profile Limits

Set Max Velocity profile for stand to avoid Swabbing issues in wellbore

1. Tripping transition state request
2. Tripping profile style
3. Setpoint Limits
4. Max Velocity
5. Max Acceleration
6. Max Deceleration
7. Full fidelity Velocity profile
8. Mud Idle Time
9. In Slips/Out of Slips status (optional)
10. Tripping Transition flags (ex. about to pull pipe)

## USER STORY: Lagged Data Merging

During a drilling operation, data can be received into the control systems and data stores significantly after the recording of the data, for example mud pulse data or even more delayed from a downhole memory recording. The user wants a standard way of getting lagged data into the real time data stores, then updated other systems and data stores.

## USER STORY: Alarm Management Terminology

Many individuals involved in a drilling operation use the term “alarm” for both alarms and warnings as defined in ANSI/ISA 18.2 – 2016 Management of Alarm System for the Process Industries. For a user, everyone using the same meaning of the words alarm and warning would greatly simplify operational management.

## USER STORY: Relief Well and Wellbore Uncertainty

During a blow-out situation, it may be necessary to drill a relief well. The wellbore position uncertainty of the well to kill may be quite large if the initial location was not measured precisely and if the surveying program did not focus on an accurate wellbore positioning. Therefore, the success of the relief well may be impacted by these initial uncertainty issues related to the well to be killed.

## USER STORY: Influence of Local geomagnetic field on wellbore uncertainty

In some region, the formation rocks have magnetic properties that may influence azimuth readings and therefore increase the lateral biases on the well bore position. This may result in borehole collisions or missing the geological target.

## USER STORY: Impact of time dependence of the global magnetic field on wellbore uncertainty

The global magnetic field is time dependent. Errors in estimating the global magnetic field at the moment of the drilling operation may introduce important biases on the lateral position of the borehole with possible negative consequences on the risk for inter well collisions or reaching the geological target.

## USER STORY: Impact of biases and scale errors on gyros and accelerometers for wellbore uncertainty and drill-string vibrations

Gyros and accelerometers measurement may be subject to a systematic bias and scaling errors. When there are no other calibration sources like a magnetometer or multiple sensors mounted at different angles, these sources of error can impact the interpretation of the inclination but also drill-string vibration measurements.

## USER STORY: Impact of actual hole diameter on BHA Sag

If the borehole is enlarged, the BHA may sag differently than expected therefore leading to errors in BHA Sag correction terms for the calculation of the wellbore position. Enlarged borehole size also impact drilling hydraulic calculations and cement jobs.

## USER STORY: Impact of survey station depth distance on wellbore position uncertainty and tortuosity

The use of longer distance between survey stations impacts wellbore position uncertainty. For example, drilling with quadruples is not equivalent to drilling with triples. Also, it has been seen that directional work performed between two survey stations may introduce substantial tortuosity in the borehole trajectory that is not reflected by at the survey stations, but which is visible through continuous inclination and azimuth measurements. The additional tortuosity may impact weight transmission to the bit, increase the risk of buckling and lock up situations, or simply induces larger drill-string vibration conditions.

## USER STORY: Wellbore collision caused by overseen existing well

A typical cause for wellbore collision is simply that an existing wellpath has not been considered during the scanning.

## USER STORY: Wrong measurement of casing joint length

A drilling crew measured the casing joint lengths. However, they included the length of the pins therefore resulting in setting the casing off by 30m. These last 30m of formation were not isolated by the casing and therefore when the next section has been displaced to a new mud density, the formation collapsed.

## USER STORY: top hole uncertainty and the importance of borehole size

On the top-hole part, the borehole size is important for considering wellbore collisions. At greater depths, this is less important because the wellbore position uncertainty is much larger than the borehole size.

## USER STORY: incorrect of position of the wellhead

Utilizing an incorrect wellhead position may impact borehole collision risks. This is of greater importance when there are multiple sites concerned in the anticollision scan.

## USER STORY: Caging risk

Poor positioning of previously drilled wells may result in difficulties utilizing remaining slots.

## USER STORY: High incidence angles between wells during anti-collision scan

Poorly implemented anti-collision scan may oversee potential collisions when two well intersect at high incidence angles and when the scanning interval is too long.

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# Appendix

## Appendix for 22. USER STORY: Failure to follow Well Position Quality Controls and Manage Error Sources can lead to a well collision by WPTS

**Hypothetical Scenario**

Three wells planned with drilling programs for a 36 slot platform

* 10ft slot spacing
* 30” conductors
* Inside slots picked to drill out first
* All slots contain a plan to target to conserve the drilling window below each slot

**Well 1 (1 of 3)**

Planned kick off from 30” conductor shoe

Conductors were driven deeper than planned and not gyro surveyed

Assumption conductors vertical, (not surveyed after driven)

MWD surveys 450’ interval no surveys and BAD MWD surveys out of the shoe for 200’ not 50’ as planned

Survey program specification not met

Difficulty drilling with motor BHA to plan with planned flow rate

Assumption collision can not occur

Confusion of multiple survey programs sent to rig adding to complacency (it was going to change anyways)

Collision avoidance travelling cylinders plots were not produced as planned

Internal operator, DD and survey review performed – decision to drill ahead section and use contingency – drop gyro at TD if needed..

Review of Well 01 operation

* *Team unfamiliar with AC method required*
* *Congested field with development planning*
* *Training and Coaching lacking*
* *Low to no team experience in drilling close proximity collision avoidance wells*

*Plan was signed by operator and DD supplier*

* *No challenge to change of survey program and no TC plots available to plot proximity*
* *No mention of collision avoidance issue in correspondences between town and rig*
* *No STOP Drilling, No MOC raised*
* *Decision to keep to plan, follow Inc / Azi as best as possible*

No Team escalation or decision to stop drilling.

**RESULT:**

**Well 1 was poorly positioned, poorly defined in well directional survey software**

***Well 2***

Conductors were driven deeper than planned and not gyro surveyed

Assumption conductors were all vertical, (not surveyed after driven)

Planned kick off from 30” conductor shoe

New Survey program specification used

Assumption collision can not occur

Instruction to run GWD to take conductor surveys running in hole and continue GWD until feree of magnetic interference switching to reporting MWD as definitive

Modified flow rates with improved BHA tool face

Internal operator, DD and survey review performed –

Travelling cylinders plot contained crossing tolerance lines for offset wells (Well 1 of 3 and planned well 3 of 3)

Decision to drill ahead no MOC performed as Travelling cylinders plot TOLERANCE LINES NOT CROSSED

No Team escalation or decision to stop drilling.

* *No mention of collision avoidance issue in correspondences between town and rig*
* *No STOP Drilling, No MOC raised*
* *Team unfamiliar with AC method*
* *Congested field with development planning*
* *Training and Coaching lacking*
* *Low to no team experience in drilling close proximity collision avoidance wells*

**RESULT:**

**Well 2 was poorly positioned, poorly defined in well directional survey software**

**Well 3**

Well 3 plan expedited due to change in batch drilling

Well 3 plan crossed tolerance line

* Well 1 is closer than planned (conductor gyro surveyed and surface MWD surveys define drilled well)
* Team need to save the slot (Well 3)

Anti-collision situation escalated and communicated

Assumption conductors were all vertical

* Team unfamiliar with AC method / Congested field with development planning
* Training and Coaching lacking

Anti-collision method deemed “busy work”

Projection crossed tolerance line

Well 3 plan collision tolerance increased

Plan signed off by Operator and Supplier

Planned kick off from 30” conductor shoe

Well 3 DD Projection crosses tolerance line

Drilled ahead – MOC limits for controlled drilling 1st stand out of 30” shoe

Cement Returns Trace reported at surface

Drilled ahead – MOC limits for controlled drilling first half of second stand

Cement Returns 20% reported at surface

Drilled ahead – MOC limits for controlled drilling second full stand

Cement Returns 90% reported at surface

Stopped Drilling Due to Well 1 close proximity

**RESULT:**

**Well 3 collided with Well 1**

**Well 1, 2 and 3 were poorly positioned, poorly defined in well directional survey software**

**In Summary**

*Quality controls mostly admin controls which rely on individuals to be highly trained and work without operations bias*

*Competency excellence is difficult to obtain, needs leadership and courage to STOP the job*

**Cause(s)**

*Over bearing operational pressure to drill ahead when STOP the job / stop drilling when failing the collision avoidance drill ahead conditions*

# Definitions of User Story and Use Case

* User Story
  + a user story is an informal, natural language description of one or more desired features or capabilities of a software system. It is told from the perspective of the person who desires the new capability. Parts are usually: <type of user>, <desired feature>, <reason why>.
* Use Case
  + a use case is a methodology used to identify, clarify and organize system requirements. It’s a textual description that captures the user to system interaction. Parts are <actor>, <goal>, <actions to realize goal>