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Human in the Loop: Decoding MPD Incidents Using Practical Human Factors

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Abstract

To err is human. The definition of error is not abstract, error is used as a catch-all term that encompasses the failures of planned actions to achieve their intended outcome. Conversely, the root cause of an error is up to debate and tied to an organization's and/or individual's viewpoint. The old view of Human Error is based on the philosophy that systems are inherently safer than humans and as such by minimizing human interactions and removing them from the loop; the result is a safer-less error-prone system. This inherently identifies humans as the root cause of most errors. The new view is based on the theory that human errors are unavoidable and are a symptom of a systemic problem and rarely the root cause. A focus on the human element is pivotal in the prevention of errors within any given system. The emergence of automated systems decreases individuals' interaction with progressively complex systems while increasing cognitive workloads. These critical processes can often lead to errors if Human Factors are not accounted for.

Most MPD operations include critical human-in-the-loop interactions that must be designed around human factors such as sensory overload, distractibility, input device deficiencies, communication failures, cognitive workloads, time pressure, and fatigue. Understanding the intricacies of Practical Human factors and its role in safe drilling operations will provide a path forward to mitigate errors and identify root causes when they occur.

Introduction

Human in the Loop: Decoding MPD Incidents Using Practical Human Factors will thoroughly examine the foundations of practical human factors and the challenges posed by pivotal human-in-the-loop interactions, particularly in complex automated systems related to Managed Pressure Drilling. Furthermore, by analyzing case studies through the lens of practical Human Factors, this paper aims to offer insight into effective mitigation strategies and root cause identification with the intended goal of safer drilling operations

Human Factors

Within the context of the Oil and Gas industry, human factors are a multi-disciplinary science that includes applications from psychology, biology, sociology, and engineering. The goal of Human factors (in any industry) is to improve safety and efficiency within the many complex environments an average worker or individual may encounter. The emphasis on analyzing and optimizing the interaction between individuals and their work environment is not unique to the oil and gas industry. Nowhere is this clearer, than in the aviation industry, whose contributions to the field of Human Factors cannot be understated. Within the aviation industry, a commonly referenced statistic is that roughly 70% of accidents are a result of human error, which leaves the remaining 30% tied to technical failures or faulty machinery. These failures rarely occur in isolation and can be typically traced back to inadequacies in design, maintenance, or improper utilization; all of which point back to a single person or group of individuals. Consequently, barring force majeure, the majority of incidents, if traced back far enough, it can ultimately be ascribed to a failure of the human element in the system. As such, understanding how a Human interacts within a given system at any given point becomes crucial to avoiding future accidents.

Shel Model

The aviation industry has developed a framework to break down the interactions a worker may encounter at any given moment; the SHEL Model. Developed in the 1940s for use in aviation and further expanded on in the 1970s, the SHEL MODEL by Elwyn Edwards, considers all elements of any given system that requires a human-machine interface with the goal of focusing on the interface between its components. SHEL is the acronym for the models four components:

Software/Procedures: Refers to the programs or processes imbued to hardware, to be utilized by liveware. In its simplest form, it's how hardware and liveware interact. This can be direct or non-procedural.

> **Direct**: Involves the use of procedures and/or software between two components of the SHEL MODEL. This includes all interactions that are part of job duties or are put in place as a result of a procedure relative to a specific task. Consider an MPD operator and Driller who are about to make a connection. Per procedure, the driller calls out "Pumps off" and waits to hear verbal confirmation from the MPD operator which in this case is repeating "pumps off". This signals to the driller the MPD operator are ready for connection and they may begin shutting down pumps. This interaction is direct – procedural.
>
> **Non-Procedural**: Refers to all other interactions that occur between components of the SHEL MODEL. Using the example above, after completing the connection and drilling resumes, the driller begins to talk to the MPD operator about the hurricane in the gulf and wants to know their opinion. This interaction is non-procedural.

Hardware: Refers to the physical components of a machine or process.

Environment: Refers to the set of circumstances, surroundings and conditions the system might find itself or interact in. The environment affects all components of the model as shown in the diagram.

Liveware: Considered the center of the SHEL model, liveware refers to the Human element in the system.

As displayed is Figure 01, the SHEL MODEL places the human at the center of the model with the environment surrounding all other components. This Liveware in focus can only interact to Hardware and other Liveware through Procedural/Software and Non- procedural means. This focus on the individual in question makes it possible to improve system performance by focusing their interactions and what can go right and wrong. These Interactions between liveware and other components of the SHEL model change in a variety of different ways dependent on the many different environmental variables that can occur, as well as changes to the other SHEL components.

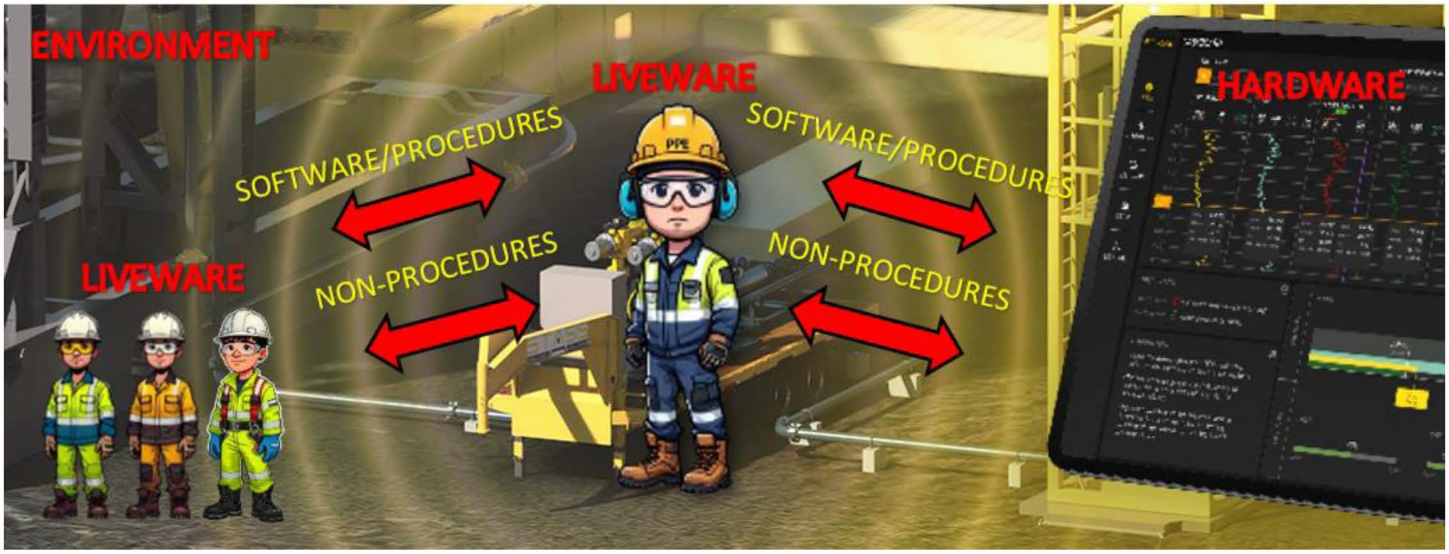

Figure 01—SHEL MODEL AS IT APPLIES TO DRILLING OPERATIONS

Consider how humans engage with their surroundings. At its core, human interaction involves perceiving stimuli from the environment and formulating responses accordingly. One would not be faulted in thinking that only allowing software and procedural interaction to occur, could improve the process. Simply attempting to maximize safety through the implementation of checks, rules, and procedures can and often result in a trade-off with efficiency, which in turn result in uneconomical projects. Often the non-procedural actions are what enable the process to be more robust and efficient, which in turn need to be documented and turned into procedural actions. The Liveware in the center are often the best in identifying how to streamline a complex process within the SHEL model, as well as the understanding of the SHEL model allows the process designer to make a more robust product.

Old vs. New View – Human Error

Traditionally, the old view suggests that human error is the primary cause of accidents, suggesting that systems are inherently safe and only malfunction as a direct result of human interference. This way of thinking attempts to enhance safety by eliminating the unpredictable variable in the equation, in other words, humans. The old way squarely places the blame on people and emphasizes strict adherence to procedures as the solution. Conversely, the new view, which attempts to consolidate normal accident theory with the science of human factors, regards error as merely a symptom of much deeper, potentially systemic issues. It acknowledges that systems are not intrinsically safe and very often contain inherent contradictions and competing goals that workers must navigate, such as safety and efficiency. This new view recognizes that to truly understand safety and risk in any given system, there exists a necessity to understand how it actually works, not how they perceive it works. From this standpoint, humans are, in fact, the indispensable part of the equation through their capability to adapt. How this is done at any given time or situation will depend on the Mental Model the individual in question has formed about the situation.

Mental Models

Mental Models, in the technical sense, is defined as the cognitive framework that individuals use to understand, interpret, and navigate the world around them, in essence shaping how they process information and make decisions. In other words, a Mental Model is how an individual perceives and understands what is happening around them. The individual then uses this Mental Model to make decisions on how to proceed. This underscores the importance of having the correct Mental Model when dealing with any given situation.

By extrapolating this concept within the framework of Human Factors and applied to MPD operations. In this context, it is imperative the Driller and MPD operator both have the same Mental Model of the MPD and drilling process. Any misalignment in their particular understanding may have undesired consequences, although this might prove challenging. Alignment of Models can be complex, as the driller in this scenario has to create a much larger Mental Model of all rig and downhole systems, whereas the MPD operator primarily needs to focus on the Mental Model of what is occurring downhole.

In drilling operations, HMIs are critical for the interpretation and alignment of the Mental Models for the users. Current HMIs or Rig EDRs provide users with a live interpretation of downhole data and as such become integral in the formation of the users' mental model. These HMIs, can vary between rig systems, and are infinitely customizable. The HMIs allow users to change orientation, color, range, variable bounds, etc., while all showing the same data. Although, to many users this is an ideal feature to have as it allows them to customize to their personal preference, it has the potential to create complications when it comes to alignment of Mental Models. To exemplify this, consider the example below in Figure 02, each of which show a flow in / flow out trend. Before continuing, look at these graphics, are some showing a loss and others a gain, or are they all showing the same trend?

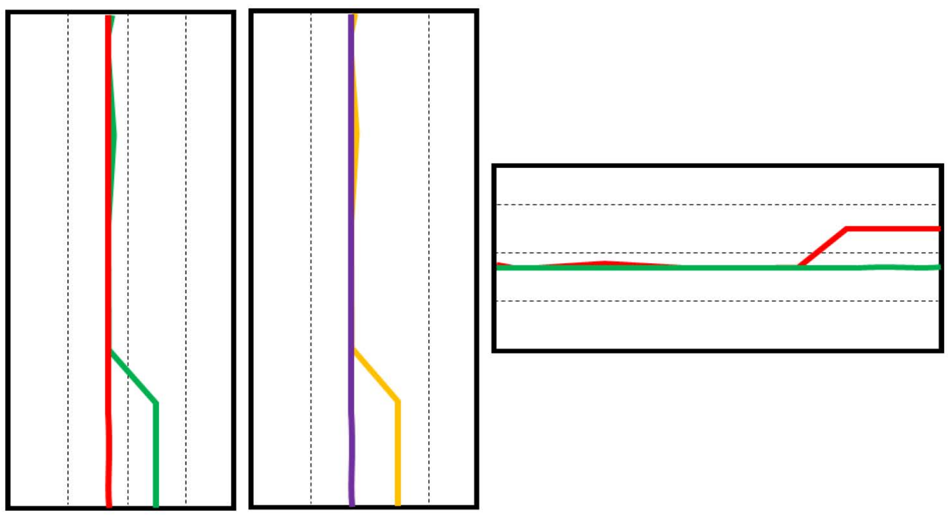

Figure 02—Trend lines

In this example, the first vertical graph on the left is meant to display a loss in the system after an increase in flow in, while the middle and horizontal graphs are showing a gain. Was it easy to arrive at this interpretation of the graphs at first glance? Of course not. Color variance between graphs as a result of individual customization has contributed to dissonance in their Mental Models when interpreting the data. Although this is a simple example, consider the reality of drilling operations, each rig, service provider, and individual have a specific customization, that can change from shift to shift and often with an individual utilizing multiple HMIs with different customizations. The complexity of building an agile Mental Model is compounded by the fact that these visualizations can have differing color schemes, timescales, bounds, visualizations, and sampling rates. In this complex scenario, any dissonance between the models may have catastrophic results. Thus, to that end, it's important to consider and understand all factors that may influence each individual's Mental Model.

Attention

In the context of human factors, attention refers to the cognitive process by which an individual will concentrate on specific information or stimuli while potentially ignoring others. This process utilizes mental resources available to humans to focus on tasks, detect signals, stimuli or alarms, and process pertinent data. As a result, how humans focus their attention, whether it be consciously or subconsciously becomes crucial for effective decision-making and performance in complex environments. Thus, understanding the different types of attention, their applications and their risks helps mitigate the potential for missing critical information or cues. In this context, attention can be categorized into three main types:

- **Selective Attention**
- **Sustained Attention**
- **Divided Attention**

Selective Attention

Selective attention is the cognitive process of focusing on a single specific task or aspect of information while at the same time ignoring other external stimuli. This process allows individuals to utilize their collective brain power to concentrate on the task at hand or relevant process at any given moment. This is possible thanks to the subconscious ability of the human mind to filter out distractions or what the brain perceives to be non-important stimuli relative to the task it is trying to accomplish. The implications of this mental process are quite clear. If the mind is engaged in selective attention, it could miss other stimuli that may signal something important. Drawbacks related to selective attention include:

- **Tunnel Vision**: By focusing intensely on one specific aspect, individuals may miss important information or changes in their environment that are leading indicators to something critical about to occur.
- **Reduced Situational Awareness**: Excessive focus can lead to a lack of awareness of the overall big picture, which in dynamic environment, where multiple tasks require selective attention may lead to incorrect decision occurring due to lack of overall information on subsequent tasks.
- **Task Switching Costs**: When people need to shift their attention to different tasks frequently, this change is attention can lead to decreased overall performance, a delayed response, efficiency or mental fatigue.

A documented example of this phenomenon is the gorilla experiment. Here, participants were asked to watch a short basketball video and count the number of passes made by a certain team. As the ball is passed around, a man in a gorilla suit walks right through the court. At the end of the clip, participants were asked if they saw something strange in the video, and less than <10% of applicants had noticed the gorilla. Once again, by asking participants to count a certain action in this dynamic environment, their brains focused on the task and missed the silly gorilla costume.

Sustained Attention

Although, at first glance, Sustained attention may seem like it manifests itself in a very similar manner to selective attention, they are quite different in how it affects the user. As opposed to selective attention, sustained attention is the ability to maintain consistent focus and concentration on a specific task or stimulus over extended periods. This cognitive process is crucial for activities that require prolonged mental effort and minimal distraction, such as monitoring data trends. As a result, Sustained attention engages the human mind by continuously processing information, detecting relevant signals, and ignoring irrelevant stimuli to attempt to continue its focus on the task at hand. Unfortunately, although there is lack of general consensus on the amount of time, studies suggest that the human mind is not particularly well equipped to maintain sustained attention for periods longer than 15 minutes. As a result, certain drawbacks may arise when dealing with task that require focus over long periods.

- **Neglect of Secondary Tasks**: Can result from prioritizing one task or piece of information. This can lead to unintentionally neglecting other responsibilities, which can lead to incomplete tasks or reduced performance.
- **Cognitive Fatigue**: Is defined as a state of mental exhaustion that occurs after engaging in demanding cognitive activities for extended periods of time. This can manifest itself as a feeling of mental tiredness, primarily resulting in reduced attention, slower cognitive processing, memory difficulties, and impaired decision-making. People who experience cognitive fatigue often find it challenging to maintain focus and are more susceptible to distractions. Cognitive fatigue primarily occurs from tasks that require sustained attention or are considered to be monotonous and repetitive. A high cognitive load, complex problem-solving, multitasking, and high stress dynamic environments can also contribute to this fatigue. If not accounted for, consequences of cognitive fatigue include decreased productivity, a higher error rate, and potentially lower motivation.

British psychologist Norman Mackworth explained this phenomenon with his novel studies during World War II. His studies focused on why sonar and airborne operators tended to miss weak signals that suggested the presence of enemy vessels/aircraft and why this would generally occur during the end of their shifts. The experiment revolved around participants who were tasked with sustaining attention on a radar/sonar, in effect simulating a war environment and tasking individuals to monitor signal detections much like the real-world example. Results in figure 03 indicated that after roughly 15-30 minutes, the accuracy of the signal detection declined by roughly 20-30% among participants and continued to decline as time on the task increased. Although initial findings may suggest participants were bored or under stimulated, thanks to the advent of brain imaging software, it was found that tasks that require sustained attention actually impose a large workload on the human mind. Thus, this creates a scenario where the human mind naturally begins to tire and as such performance is impacted. This effect can be further compounded by adding additional tasks on top of the task that requires sustained attention.

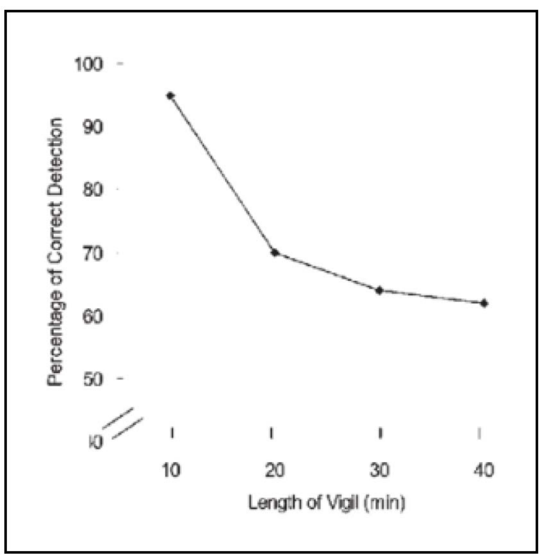

Figure 03—Vigilance Decrement Naval and RAF Results

An example of sustained attention is the monitoring of instantaneous data points such as gauges with no historical data trends accompanying them. Trying to monitor for historical variance will incur the same results as the above study, and be compounded if multiple gauges require the same style of monitoring.

Divided Attention

Contrary to selective and sustained attention, divided attention permits the human mind to fraction its focus to multiple items simultaneously, as opposed to a single task or item. Naturally, a very clear drawback to this is that humans are inherently terrible at multitasking. Although the human mind evolved the ability to divide focus (evolutionarily speaking, processing more information increases an individual's chance for survival), splitting an individual's attention may increase cognitive workloads and lead to higher possibilities of mistakes.

If not accounted for, divided attention can lead to:

- **Reduced Efficiency**: Tasks may take longer to complete due to the cognitive load of managing multiple activities simultaneously.
- **Increased Error Rate**: The likelihood of mistakes rises as attention is divided, potentially leading to incorrect data interpretation, improper equipment operation, etc.
- **Safety Risks**: Increased risk of accidents and injuries due to overlooked hazards or improper responses to critical situations.
- **Stress and Fatigue**: Constantly managing multiple tasks can lead to mental fatigue and stress, further impairing performance and decision-making abilities

For example, per the Texas department of Motor Vehicles: "Distracted driving continues to be a problem. In 2023, nearly one in six crashes on Texas roads were caused by a distracted driver in which 399 people died and 2,793 were seriously injured." Specifically, this example relates to texting and driving or phone use during the operation of vehicles overall. In this specific environment, where the individual is operating machinery in a dynamic environment, seconds or a fraction of seconds may mean the difference between life or death.

Mitigation Strategies – Chart

The different types of attention, selective, divided, and sustained, present a set of challenges when attempting to counter in high-stress environments. Mitigation strategies may overlap and operators may choose to use multiple approaches when it comes to prevention. Figure 04 discusses the most commonly agreed/used tactics and how they apply to each type of attention mitigation strategy.

CATEGORY	MITIGATION	DESCRIPTION	TYPE OF ATTENTION		
			SELECTIVE	SUSTAINED	DIVIDED
AUTOMATION	REAL TIME MONITORING SYSTEM	Utilize real-time monitoring systems to provide continuous feedback on drilling operations, highlighting anomalies or areas that require attention	X	X	X
	AUTOMATED ALERTS AND NOTIFICATIONS	Set up automated alerts and notifications for critical parameters such as pressure, temperature, and PVT to prompt immediate attention when needed. Wearable Technology may also be used in this endeavor.	X	X	X
	DATA VIZUALIZATION DASHBOARDS	Employ data visualization dashboards that consolidate various data streams into an easily interpretable format, helping to identify trends and potential issues quickly.	X	X	X
	AUTOMATION TECHNOLOGY	Leverage automation for routine tasks and utilize technology aids like real-time monitoring systems and data visualization tools to reduce manual mental workload	X	X	X
	PREDICTIVE MAINTENANCE TOOLS	Implement predictive maintenance tools that analyze equipment data to forecast potential failures.	X	X	X
	AUTOMATED REPORTING SYSTEMS	Implement automated reporting systems to compile and summarize data from various sources, ensuring comprehensive review and reducing the risk of missing critical information.	X	X	X
ORGANIZATIONIAL	TRAINING SIMULATIONS	Use training simulators to practice complex drilling scenarios, enhancing the ability to manage attention across multiple tasks and improving overall situational awareness.	X	X	X
	ROUTINE SAFETY DRILLS	Conduct regular safety drills to keep the team prepared for unexpected events and ensure comprehensive attention to all safety protocols.	X	X	X
	CHECKLISTS	Employ checklists to standardize procedures and ensure all steps are followed systematically, reducing the need to remember multiple tasks simultaneously. This is used extensively in the aviation industry		X	X
INDIVIDUAL	TIME MANAGEMENT	Implement time management tools and techniques to structure work periods and breaks, allowing focused attention on single tasks.			X
	TASK PRIORITIZATION	Use task prioritization techniques to focus on high-priority tasks first, reducing the cognitive load by handling one task at a time when possible.		X	X
	CLEAR COMUNICATION CHANNELS	Establish clear and efficient communication channels to minimize interruptions and ensure that essential information is conveyed concisely and effectively.	X	X	X

Figure 04—Attention Mitigation Strategies

Decision Making

Once a Mental Model has been created, one may find that there is an element of the situation which may require a decision to be made. At this stage of the cognitive process, humans become less aware of the remaining environment, and more focused on the task at hand. This refined Mental Model aids in the decision-making process, which can be approached through either a primitive/instinctive or evolved way of thinking. To put this decision-making approach in perspective, consider a person who just recently obtained their driver's license. At first it is very likely that this individual will consider and overthink every decision they might make behind the wheel. Since this may be considered a new experience for that individual, their mind is using a considerable amount of brain power to understand and accomplish the task at hand, this is the evolved way of thinking and is considered system two. That same individual, 10 years down the road will most likely not think about those same decision and just do as they drive. This process has now become "instinctive" and is considered system one. System one covers instinct, system two gives us our ability to adapt and learn new things. Both systems are not used exclusively and can operate at the same time. In high workload environments, system one might be used to get a quick response, but with time, system two would engage and override system one.

System One- Operates automatically and quickly, without effort or a sense of voluntary control. This System is rooted in our evolutionary history, enabling rapid decision-making in demanding situations. The automatic operation of System one can, in fact, generate surprisingly complex patterns of ideas, but cannot be applied when a thought-out series of calculated steps is required. System one is always active and allows humans to make rapid decisions when in a complex workload environment, and is usually described as the system of instinctive decision-making.

> **Skill Based (SB)** – Decisions are pre-programmed and automatic, such that the individual does not have to consciously engage with the problem in order to react to it. In essence, these skills are preprogrammed into the individual's cognitive and motor systems, enabling a quick response without having to consciously engage with the problem at hand. This automatic engagement arises from extensive training and repetition, which allows the individual to develop highly efficient pathways to specific actions or sequences of actions. When faced with a familiar scenario or task, the individual can easily access these programmed behaviors, implementing them with precision. Consider the following example, a Driller, who has been using MPD systems for a while, will have become accustomed to the cadence of the connection communication procedure, turning it into a skill- based decision. There is a high likelihood, that at the point prior to the pumps being brought offline, regardless if the MPD operator says hold or continue, the driller will continue to bring the pumps down. Even though the driller is trained to do the proper thing, the decision is made at the subconscious level, which is hard to control.

System Two- Makes us human, and is a more recent evolutionary development compared to system one. It harnesses the advanced processing capabilities of the cerebral cortex to facilitate rational decision-making. This system does not engage automatically and requires continuous cognitive exertion. Unlike system one, it is not possible to effectively solve complex problems in a parallel fashion while using system two. The inner strategist of system 2 empowers us to evaluate situations comprehensively, considering various factors, analyzing potential outcomes, and employing abstract reasoning to tackle intricate problems. With this higher cognitive workload, humans may be faced with several problems which require conscious effort. Rule and knowledge-based decisions fall under the system two realm.

> **Rule based (RB)** – Decisions are semi-automatic and require more conscious engagement than skill-based decisions. The rule- based level is often identified and associated with rules captured in the if, then format. These decisions serve as decision- making guidelines that dictate how a task should be performed based on specific conditions or criteria. For example, a trained Driller/MPD operator understands that a certain combination of drilling indicators can indicate a kick. They will be consciously aware of the pattern of warning indicators and because of their training will have a stored rule that says if this pattern is seen then react this way. The individual can employ this memorized rule to promptly react without the need to individually assess the meaning of each indicator, responding instead to their collective significance when encountered simultaneously.
>
> **Knowledge based (KB) -** Decisions occur when the individual finds no appropriate rule for determining what should be done in a specific circumstance. The only option is for the individual to examine their wealth of knowledge and attempt to understand what is going on. This cognitively demanding process requires selective attention to the issue at hand. If the issue is resolved using the knowledge-based method, it is highly probable that the initial pattern of stimulation will be harmonized to the final response, and the individual will generate a new Mental Model that will allow them to solve the issue at hand with the rule-based decision level if encountered again. In essence, this constitutes the process of learning; as experiences are accumulated, an increasing number of "rules" for generating patterned responses are also creating, allowing people to resolve issues more swiftly and accurately with the expansion of their experience.

System 1 & 2- Rule Based / Skill Based Case Study – Stasis Internal Field Escalation Report

During routine drilling operations, the mud motor recently failed and the decision was made to circulate several bottoms up and trip out. During the first circulation, a large gain was observed in the pits in tandem with gas seen at the Coriolis flow meter. The driller and MPD operator observed these kick indicators and shut the well in assuming it was a kick. After shutting in no pressure was observed at the rig choke. What happened? It was determined that during the circulation the derrick man was supposed to transferring fluids within the active system as is routine and accidently transferred fluids from a tank that was usually part of the active PVT, but was not at the time. The gas at the flow meter was later determined to be the connection gas that had just reached surface at the time of the transfer. This example highlights both system one and system two in action. The derrick man, who was used to that particular tank being part of the active, made this decision automatically as alerting was not required for transfers in the active, this is system one. The driller and MPD operator upon seeing kick indicators, employed system two, which within the predetermined rules of well control, this is system two.

Figure 05—System 1 & 2 Case Study

Error Management

The significance of individual decisions lies in the recognition that errors can manifest across all levels. Furthermore, there are distinct characteristics of the types of error that occur, the rates at which they occur, and the rates they are detected and corrected. While humans are performing tasks at the skill level, mistakes will inevitably occur. Skill based, Rule based, and Knowledge based decisions influence human behavior which will sometimes lead to incidents characterized by errors and violations. These factors can intertwine in unpredictable ways, sometimes resulting in actions that deviate from established standards or expectations. An error is defined as the failure of planned actions to achieve their desired goal. There are two ways this type of failure can happen:

- **Error 1**: Either the plan of action is wrong, where in this case, our actions are destined to fail from the beginning
- **Error 2**: The plan is correct but the execution fails, i.e. operator error.

Violation, in the context of human factors, is where the individual intentionally makes a conscious decision to not follow procedure. Although the word "violation" implies negligence, this may not always be the case, and as such can be divided into three categories; routine, situational, and exceptional.

Routine violations: Arise unconsciously and could be interpreted as bad habits that have passed unchecked and have developed into a process. They are habitual actions that have come to be accepted as normal operations and are often tolerated by society or governing bodies. Individuals will usually consider routine violations as low-risk to themselves and the task at hand. Routine violations tend to occur at the skill-based level of performance as they have become part of a person's automated routine.

Situational violations: Are deviations from procedures that are typically well intended and seen as "necessary" because of time pressure, lack of supervision, insufficient resources, or a negative work culture. Situational violations tend to occur at the rule-based level of performance, as people take actions believed necessary to get the job done.

Exceptional violations: Are the final response to the problem made with the best intentions. Exceptional violations are generally rare, and occur in emergency situations, or situations of equipment failure. They can be the result of a conscious decision to violate a plan or an instinctive reaction to the situation. Exceptional violations tend to occur at the knowledge-based level of performance as they are mostly occurring in novel and unfamiliar situations.

The crucial distinction between errors and violations lies in their nature: violations are deliberate actions, while errors are unintentional mistakes that occur without intent or awareness. A violation involves a conscious choice to stray from what is considered the correct or standard course of action, while an error can occur involuntarily, even when an individual is actively trying to avoid any potential mistakes. In the simplest of terms, human errors result from inadvertent actions or decisions, whereas violations involve purposeful shortcomings, and deliberately engaging in improper actions. The following concepts leverages this viewpoint with the to further strengthen and lower the likelihood of human error/violations. Furthermore, from this point onwards, this reading will use the term system to refer to a collection of interconnected components working together to achieve a common goal. In this sense, systems can be either on the micro level; i.e.- the Driller and MPD operator working together with the rig crew and rig systems to drill a well, or can be considered on the macro level; the operator who is supervising/drilling multiple rigs with multiple MPD systems.

Pilot/Co-Pilot Methodology

As previously stated in this reading, the old view of human factors views humans to be the most unreliable part of any given system. As a result, many industries, including Oil and Gas, have seen an increased push towards automating most if not all available systems found on a rig, including MPD systems. Although the intentions may be in the right place, as this push is understood to "enhance safety", when it comes to MPD operations these actions may create more problems than they solve. To understand why, let's once again look at the airline industry. Many people have asked themselves, in the year 2024, why aren't commercial airliners automated? Why is there still a need for not only a Pilot (Captain) but a co-pilot as well, when automation provides the key to eliminate one if not both human elements? The answer lies in how the industry approaches human factors and safety culture overall. This industry has stressed the importance of having both a pilot and co-pilot working in tandem in the cockpit as a direct result of several critical human factors considerations they have identified over the years through painstaking and often tragic trial and error. These findings are listed below:

- By having two pilots in the cockpit, it is generally understood that this enhances redundancy and error detection, significantly reducing the risk of human error. Both pilots may have varying degrees of expertise and knowledge and as a result by sharing responsibilities and cross-checking each other's actions, pilots can catch and correct mistakes that might otherwise go unnoticed, especially when they encounter a novel or knowledge-based problem.
- The shared nature of duties in the cockpit, that is to say the collaborative dynamics of a pilot and co-pilot facilitate effective workload management. This distribution of tasks between the two parties assists to reduce cognitive workloads, particularly during high-stress situations which require intense focus, aka selective attention. This allows for increased efficiency and handling of complex procedures or tasks, particularly when one individual may need to focus on a single task while the other maintains awareness of their surroundings or relevant deviations.
- Situational awareness has been shown to increase as a result of having two pilots, due to how people may perceive the same situation differently. Having two individuals working in tandem greatly increases the possibility of generating the correct mental model of the situation. The two pilots have the capability to maintain a broader awareness of the flight status, external conditions, and potential hazards, thus filling in the hole the other might have in their mental model.
- Communication between the Pilot and co-pilot now becomes essential to the correct functionality of the aircraft and as such protocols have been standardized to reduce the likelihood of miscommunication. Pilots and copilots are required to call out any and all actions before they take them and must receive verbal confirmation from the other individual. This communication confirmation prior to any change of flight parameters or actions permits the pilots to create mental models that are in sync with each other and reduces the likelihood of error due to one of the two being unaware of changes the other has made.

If these strategies seem familiar, it's because they are utilized in day-to-day drilling operations in one way or another, albeit not to the same degree. However, drilling operations, specifically as they relate to MPD can benefit greatly from adopting the Pilot/Co-Pilot methodology. That is to say, by approaching the driller's cabin in the same manner as a cockpit, the driller designated the Pilot and MPD operator would then take on the role as co-pilot. As MPD operations continue down the path of automation, its pivotal not to forget his interaction, as collaboration not just blind automation, has the opportunity to address multiple human factors concerns, such as error detection, workload management, situational awareness, human-machine interaction, and communication. These elements, if employed correctly, make the presence of both "pilots" indispensable in the cabin, despite advancements in automation. Furthermore, the inclusion of two individuals in a system or process creates a unique opportunity, wherein individuals can confirm or check each other's existing Biases whenever they might arise.

Traps In Mental Models

In Human Factors, Biases refers to a predisposition or preconceived notion that affects how the individual perceives their environment. This process can be conscious or unconscious and can influence the decision-making process. Biases often create mental shortcuts or rules of thumb that people use to simplify decision-making and problem-solving in a variety of environments. This often employs cognitive strategies that allow for quick judgments and faster responses, sometimes even with limited information or resources. A Bias can, in theory, help in reducing task or situational complexity and make decision-making more efficient. As such, they play a crucial role in human factors, influencing how workers interpret information and make decisions in dynamic and high-stakes environments such drilling operations in oil and gas. Unfortunately, Biases can also lead to errors in judgment, such as relying on familiarity or past experiences rather than extensive analysis of all available options. Due to the self-validating nature of Biases, they are difficult to self- correct as such, require other Liveware to counter. That is to say, the simplest way of countering a Bias, is to use the Pilot/Copilot approach discussed earlier. By employing at least two individuals when it comes to decision making the likelihood of one of the individuals challenging the others Bias increases significantly. However, not all Biases manifest or present themselves in the same manner, as such, it's important to understand the most common of these Biases, what they mean, how they may affect decision-making.

Confirmation Bias

Is defined as the tendency to interpret, favor, and recall information in a way that confirms one's preexisting beliefs or hypotheses. This is typically done at the expense of consideration for alternate possibilities or explanations to explain the current Mental Model.

Confirmation Bias Case Study - IOGP Well Control Incident Lesson Sharing #23-1

While running 14" casing, a consistent positive discrepancy between actual and theoretical steel displacement was observed. Numerous flow checks were performed at various depths, the results of which were concluded as static due to a decreasing trend in flow out. On several occasions the well was shut in, but no pressure build up was observed. With the casing at 10,203', the well was shut in following a pit gain and positive casing pressure build up to 80 psi. The well was controlled by displacing a 17.6 ppg pill to the riser, the well was opened, and the casing was run to depth managing losses and gains by bull heading the annulus and maintaining the riser cap. It was not possible to circulate without losses. A retrospective analysis showed that a cumulative influx of 153bbl had been taken over a number of days.

Figure 06—Confirmation Bias Case Study

As seen in the IOGP example above, the rig crews were swayed by a confirmation bias that the decreasing trend in flow out was a static flow check despite a cumulative pit gain of 153 bbl. This bias prevented the rig crew from recognizing the true state of the well, which ultimately resulted in a need to kill the well. Strategies to counter include:

Encourage Diverse Perspectives: Actively seek out and consider input from team members with different viewpoints or expertise who may challenge prevailing beliefs.

Use the Devil's Advocate Role: Assign someone the role of challenging assumptions and presenting alternative viewpoints during decision-making situations.

Overconfidence Bias

The Overconfidence Bias is defined as the tendency to overestimate one's own abilities, knowledge, or judgment. This can often lead to excessive risk-taking and unjustified confidence in decision-making. Therefore, potential oversights in hazard assessment may occur.

Overconfidence Bias Case Study – Supplementary Memorandum Submitted by Transocean

The memorandum of the Sedco 711 rig incident in the Bardolino field reports that the initial increase in flow out was mistakenly dismissed as a higher pump rate. As a result, the crew likely overlooked the early signs of an influx and missed the onset of the kick. This evidence suggests that the crew was overly confident in the existing well barriers during the completion process. This overconfidence resulted in the decision to disable the PVT monitoring system, dismiss the early indicators of the kick, and delay investigating the increased flow-out phenomena.

Figure 07—Overconfidence Bias Case Study

Counter strategies include:

Utilize Peer Review: Use peer review processes where colleagues critically evaluate decisions and assumptions to provide constructive feedback.

Training and Simulation: Provide ongoing training and simulation exercises that challenge assumptions and can enhance self- awareness and or potential limitations.

Plan Continuation Bias

Plan continuation bias (also known as perseveration) is the human tendency to continue with an initial plan of action once it has been formulated. This happens regardless of changing circumstances or evidence suggesting that the plan should be reevaluated or changed.

Plan Continuation Bias Case Study – Field Escalation Report 12/18/2023

During tripping operations, a pill was spotted at the desired depth and tripping resumed. The well was TD and the upcoming operation was a casing run, which called for displacement procedure utilizing casing OD/ID. This procedure was requested early on and approved by client representatives. Post pill spot, tripping operations resumed, The MPD operator and driller continued filling out trip sheets as per procedure. At this point, improper fill was identified. MPD personnel and client representative discussed well not taking proper fill and decided to trip back in to circulate the potential gas out. MPD personnel requested a new displacement procedure, utilizing the current tubular OD/ID. The client rep. did not want wait for the new procedure, and although advised to the contrary, decided to use the previously approved casing displacement schedule instead.

Figure 08—Plan Continuation Bias Case Study

The example above clearly demonstrates this bias in action. Although well conditions clearly called for a change of procedure, due to the fact the client representative already had an approved procedure their Mental Model of how events should play did not adjust to the real-world event that was occurring. Plan continuation Bias may be countered by using the following strategies:

Establish Decision Stops: Define specific decision points throughout the operation where the team must reassess the plan in the event of new information or unexpected events.

Use Checklists and Procedures: Implement checklists that include steps for reevaluating plans in response to unexpected changes or risks.

Resilience Engineering

Is a concept born of the New View of human error. In the simplest of terms, Resilience Engineering focuses on when things go right or according to plan. Per the IOGP, roughly 172 well-controlled incidents were reported through 2019 beginning after the Macondo tragedy. Although these statistics paint a grim picture, during this same time a much larger number of wells were completed successfully without incident. Where all of those wells perfect without incident? Did they not encounter any technical challenges or anything novel or unexpected? Of course not. The difference is the rig crews and operators were able to deal with the overwhelming majority of disturbances and situations without incident. This mindset tells us that there is valuable information to learn from the successes not just the faults. If we apply this logic to the earlier understanding of complex systems and environments, it's possible to see the value. Instead of expecting that every possible situation that a rig crew may encounter is covered procedurally, a resilient mindset underlines the fact that there may be situations where the rig crew or MPD operator may need to rely on the adaptive capabilities of the human in the loop or the liveware of the system. Given that these solutions generally involve trade-offs, especially in novel situations, it is important to make systems resilient. David Woods, author of the book "Resilience Engineering: Concepts and Precepts, suggests four properties of systems that can be used to assess their resilience. These are:

Buffering: How much disruption can a system handle without failing?

Flexibility vs. Stiffness: How does the system adapt or reconfigure itself during sustained periods of disruption?

Margin: How close are the operating limits to maximum system handling limits?

Tolerance: As max system limits are approached; how does the system behave? Does the system slowly degrade or does the system continue to operate normally until the system limit is reached?

By focusing on these properties, operators may asses a current system's resilience when compared to other potential outcomes or failures. When designing a new resilient system from scratch, the following questions must be asked:

- **How good is the system in anticipating potential requirements for the task it must complete?**
- **Does this system have practical monitoring capabilities?**
- **Does the system have the capability to respond to a breadth of different potential scenarios?**
- **Can the system learn from past experiences, albeit positive or negative?**

These concepts demonstrate the importance of having this mindset from the beginning of any given system or activity. Organizational influences matter, and Resilience Engineering attempts to leverage this influence in as many aspects as possible in any given system.

Safety Culture

Safety Culture, within any given organization, can be defined (depending on who is asked) in a variety of ways. In the simplest of terms, it can be defined as "how humans behave when they believe no one is looking". To further expand on this perspective, safety culture can be divided into two categories; Reactive Safety and Proactive Safety. The goal in any organization should be to transition from a reactive safety culture to a proactive one. Below are the defining characteristics of each category:

FACTOR	REACTIVE	PROACTIVE
HOW IS SAFETY DEFINED WITHIN THE ORGANIZATION?	Generally speaking, things go to plan and don't fail.	Generally speaking things go to plan.
HOW DOES THE ORGANIZATION VIEW HUMAN FACTORS IN RELATION TO SAFETY MANAGEMENT?	People are generally the cause of the problem and are a liability.	People are the reason systems have flexibility and are able to adapt to any given situation.
HOW DOES THE ORGANIZATION UNDERTAKE ACCIDENT INVESTIGATIONS?	Accidents are caused by failures and malfunctions. The investigation attempts to identify root cause.	Accidents happen. The investigation looks to understand why things usually go right as a basis to explain why it didn't this time around.
HOW DOES THE ORGANIZATION QUANTIFY RISK?	Once the root cause is identified, contributing factors are quantified.	Its impossible to remove all risk factors inherent to a system. Therefore it is beneficial to engineer resilient systems.

Figure 09—Proactive vs. Reactive Safety

If all individuals in a company are trained to do their job in a safe way and proactively watch for hazards, the company will approach a level of safety that is proactive level of safety. All elements of a safety culture must be actively encouraged and frequently demonstrated by supervisors if a proactive safety level is to be achieved. Leadership is crucial to a safety culture as well as implementing practical Human Factors in an organization.

Automation Management

As the world continues to modernize, the role of automated machines continues to grow. To that end, although automation implies little or no human interaction, due to the principles and concepts highlighted in this paper, it's important to understand that these machines do not exist in a vacuum and if and when they fail, still involve the human component. Was this automated task or machine right for the job? Was the automated machine designed with resilient principles in mind? Does the user or users of the automated machine understand its role in the system and how it works/fails? When discussing automation management, these are key questions that should be asked of any given system. Drilling/MPD operations may rely on one or more automated components working simultaneously at any given moment. As a result, the following key aspects should be considered:

Monitoring: When implementing automation, if the desire is to catch the attention of the Driller or MPD operator, there must be some sort of alarm(s) built into the system.

Risks:

- **Sensory Habituation**: Is a phenomenon wherein human senses become adjusted to their surroundings and may miss something critical due to this climatization. The individual becomes blind to outside stimuli and no longer "perceive it". This is best exemplified by the following; consider a person trying to fall asleep in a bedroom that is next to relatively consistent traffic noise. After some time, this individual might not notice the noise and start falling asleep, however, if a police car with sirens on were to pass by, the individual would once again "perceive the traffic". The sudden change in auditory cues draws their attention back, simply put; sensory habituation allows people to filter out continuous relatively unchanging stimuli which in turn frees up mental bandwidth and allows them to focus on other tasks until something changes and draws their attention back.

- **Sensory Overload**: Can occur when one or more of the body's senses experience overstimulation from the environment. This can happen due to a large amount of sensory input such as loud noises, bright lights, strong smells, or a high level of activity and movement. In this scenario, the brain struggles to process this information simultaneously, which can lead to being overwhelmed, stressed, or anxious. A large amount of audio, and visual cues overlaid one on another can overload the human mind and produce this undesired effect.
- **Sustained Attention**: Monitoring data trends for extended periods of time can lead to cognitive fatigue and neglect of secondary tasks. For more information, see the selective attention section of this reading.

Best Practice:

- Utilize a combination of alarms, both audio and visual, with different pitch and tone. This can assist the Driller / MPD operator in quickly realizing what the alarm is meant to signal. Furthermore, standardizing alarms across organizations can prevent misinterpretation in the event people move from one rig to another.
- Utilize sustained attention counter strategies listed in Figure 04.
- Routine training to create Skill Based decisions that allow for quick action when encountering certain alarms.

Automation Compensation: Refers to an automated system that has the capability to notice changes in its environment and adapt to the situation.

Risks:

- Although at first glance this might be viewed as a positive, it's important that the system alert the user of its state change. A well-designed system may recognize a hazard, such as a kick, and begin to respond automatically without input from the user. If the Driller or MPD operator is not informed of this state change they may make decisions believing the system is in another state which can induce an error in the current state.

Best Practice:

- Automated systems that can induce a state change should include confirmation messages meant to alert the user of a state change within the system. Furthermore, in particularly sensitive drilling areas, such as green field applications, as this state change may work best with user confirmation prior to making any changes. The idea here is an exploratory or HPHT well may encounter a novel situation the machine might misinterpret and make changes that further exacerbate the situation.

Skill Fade & Automation Dependency: In the world of automation, this refers to the phenomenon where a skill that used to be routine for an individual, typically learned through repetition and practice and replaced through an automated process or machine starts to degrade over time due to lack of practice.

Risks:

- Loss of Skill or rule-based knowledge due to lack of implementation.
- Potential to never develop in-depth knowledge of system functionality.

Best Practice:

- There are two primary methods to practice the skill set required for manual intervention in automated process, real-world and simulator experience. Often real-world experience is limited due to modern systems reliability. Leading to the only practical method to perform regular training is with simulators. The airline industry uses simulators to great effect, not only as a training tool but also as a consistent method of grading and standardizing procedures. Pilots are required to undertake certain key simulations within a given time period. Furthermore, these simulations require pilots to complete tasks using both the automated and manual systems to prevent skill fade.

Automation Complacency: Refers to the human tendency of trusting automation to complete the task it was designed to do without fail. Automation complacency typically occurs when one or more of the criteria below is present:

- When a human operator must monitor an automated system.
- The frequency in which incidents occur is low.
- The system is considered to be highly reliable.

Risks:

- Blindly trusting decisions made by automation even in scenarios where the individuals own judgment calls for a different course of action.
- Drawbacks found in sustained attention are also relevant in this section such as cognitive fatigue.

Best Practice:

- Generally speaking, automated operations involve all the criteria mentioned above and as a result trigger this phenomenon, particularly due to the high reliability of these systems. Unfortunately, studies in this area tend to have conflicting results and as a result it is generally accepted as the "price" of having high levels of automation. The best strategy is to only automate processes that always have the same outcome or predefined failure states.

Automation Surprises: refers to when a something occurs in the system that cannot be accounted for by the monitoring individual. Like a deer in headlights, humans don't generally react well when the machine they are supervising or using begins to react in a manner they cannot predict. If the user is asking themselves what the system doing or why did it do this, its likely this phenomenon has occurred.

Risks:

- An automated task or process making the wrong decision; whether it be due to a bug in the system or misinterpretation of its environment.
- The system enters a fault tree state previously undefined to the user, that the training does not exist for or has a low probability of occurring.

Best Practice:

- The only simple way to counter this is to provide sufficient training and understanding to the individuals working or monitoring the machine so they may have sufficient knowledge on how it operates and to understand if it's a system error or part of normal functionality. That's not to say the individuals must now become software engineers, it's a call to understand hoe the system will respond and when manual intervention is required.

To conclude, drilling and MPD operations overall are safer thanks to automation but an understanding of human machine interactions from a Humans Factors lens is critical for safe and efficient implementation of automation processes.

Human Factors Case Studies

The human factor in MPD has been implicated in the vast majority of MPD related incidents as is a common trait as in the aviation industry. This need for practical Human Factors can be illustrated by the now infamous Deepwater Horizon oil rig disaster in 2010. Although technical issues did in fact play a role, the event was exacerbated by a failure to address human factors adequately. Factors such as improper communication, decision-making errors, the desire to make up for time constraints, and improper mental models of the situation among key personnel contributed to this tragedy. Therefore, as an industry, the question should be asked, how can events like this be prevented from happening again in the future? The best way to accomplish this is to learn from other incidents which are highlighted below.

Distractibility Case Study – Factual Investigative Update – US Chemical Safety and Hazard Investigation Board

At 7:57 am, the driller opened the blowout preventer blind rams, then lowered a new bottom hole assembly into the wellbore. At 8:09 am, the drilling crew turned on the mud pumps, pumping mud through the BHA to test the equipment. Between 7:57 am and 8:35 am while testing the BHA, the mud pits gained 107 barrels of mud unnoticed. At 8:35 am, with testing complete, the driller lifted the BHA out of the wellbore. A drilling crew member observed mud flowing out of the flow line. At 8:36 am, after the bottom hole assembly was removed from the wellbore, mud blew upwards out of the well. The motor man and a floor hand, who were on the rig floor, entered the driller's shack. The gas and oil-based mud from the well subsequently ignited creating a large fire.

Figure 10—Distractibility Case Study

Distractibility: Operators may become distracted by non-essential tasks, communications, or environmental factors, diverting their attention from critical aspects of drilling operations. These distractions could jeopardize efficiency and compromise safety, leading to delayed responses to operational challenges.

Input Device Deficiencies Case Study – Significant Influx Taken During Managed Pressure Drilling Operations - IOGP, June 2021

A rapid increase in flow out was observed. Within 6 seconds, the flow out increased from the drilling rate of 1,600 gpm to in excess of 3,000 gpm. Within the MPD system set-up, the Coriolis meter raw data was evaluated by the system to determine "good" data versus "bad" data. However, when performing this data validation step the Coriolis meter flow out threshold settings considered values less than 0 gpm and greater than 3000 gpm to be "bad" data. In response to bad Coriolis meter data, the system would use for calculations and display a zero value. Due to this system response, the rig personnel were provided data indications that there was no flow out, when it actually exceeded 3,000 gpm, and the surface back pressure was observed to be increasing despite a fully opened choke. The initial diagnosis by the crew was a plugged choke. In addition to providing the rig team with incorrect data, the response of the MPD system to a zero flow out value resulted in the kick detection logic not generating an alarm that a kick had been detected. The flow increased to a value in excess of the upper range limit, i.e. 3,000 gpm, at which point a zero-flow value was returned, in less time than the kick detection trending period of 20 seconds. The MPD flow line tied into the rig flow line downstream of the rig's conventional flow detection system and the mud logging equipment.

Figure 11—Input Device Deficiencies Case Study

This incident illustrates the concept of distractibility in a high-pressure environment. The rig crew was focused on tripping back in the hole, testing the BHA and ensuring proper operation. During this time, a significant gain of 107 barrels of mud went unnoticed, indicating a lapse in monitoring critical well control parameters. The crew's attention was divided between operating the BOPs, mud pumps, handling and making up the BHA, which led to the oversight of the well flowing and the subsequent blowout. Five casualties resulted from this incident.

Input Device Deficiencies: Input device deficiencies, such as poorly designed interfaces, malfunctioning equipment, or improper installation of equipment can contribute to errors and violations by hindering the operator's ability to accurately input and interpret information.

In this case study, the Coriolis meter has a threshold categorizing values between 0 and 3000 GPM (gallons per minute) as good data and values outside of this range as bad data. This "bad" data led to a flawed response where the system reported zero flow when the well was actually flowing at a rate over 3000 GPM. The discrepancy led to rig personnel believing there was in fact no flow out which led to a misdiagnosis of a plugged choke. This misdiagnosis ended up delaying the response time of raising SBP to counter the flow increase.

Communication Failures: Communication failures are a significant risk in MPD operations, particularly when there are breakdowns in information exchange between rig team members or across different levels of company organization. Misunderstandings or partial communication can lead to incorrect assumptions and suboptimal decision-making.

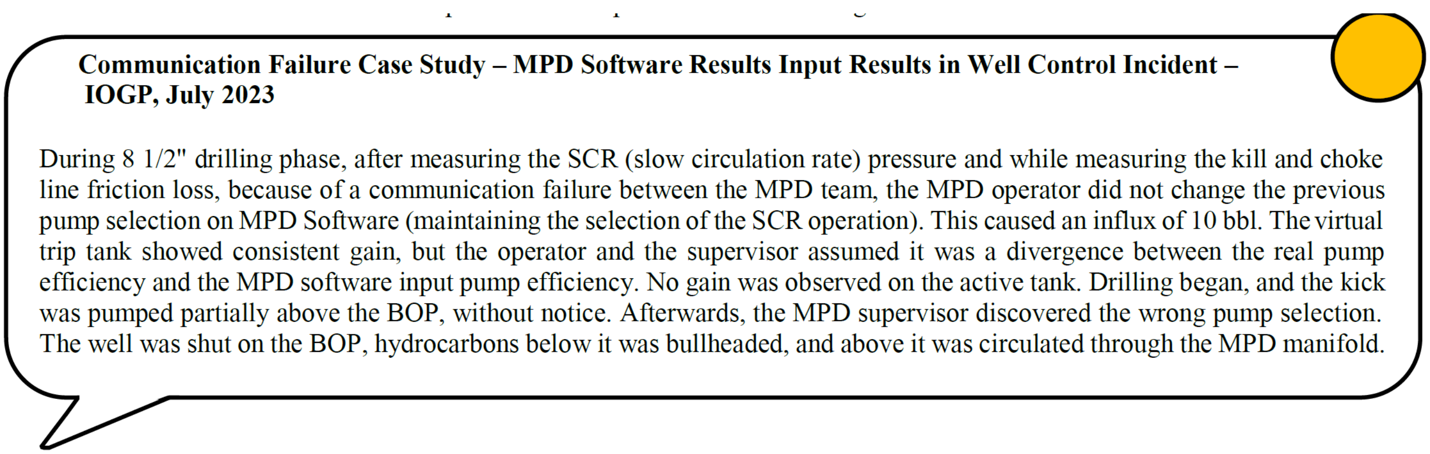

Figure 12—Communication Failure Case Study

The IOGP case study presents a communication failure between the MPD team members and rig crew. This oversight could have been prevented if there had been clear communication and coordination. Ultimately, the case study highlights the importance of effective communication, as failures in communication can lead to misunderstandings, overlooked operational issues, and potentially dangerous circumstances.

Fatigue: Fatigue due to long working hours, shift patterns, or insufficient rest, can significantly degrade operators' cognitive and physical abilities, increasing the likelihood of errors and violations. Fatigue can impair skill, rule, and knowledge-based functions such as attention, memory, decision-making, and problem-solving abilities. When operators reach a fatigued state, they may struggle to maintain enough focus, leading to reduced situational awareness. This can result in missed indicators, delayed responses to critical events, and increases the potential for poor judgment in decision-making processes or in knowledge-based scenarios. This reduced alertness can be particularly dangerous in high-risk drilling environments where swift and precise actions are necessary to mitigate hazards and prevent accidents. Excessive fatigue may create scenarios where an individual may consciously choose to take shortcuts to cope with exhaustion, without considering whether an error or violation has occurred. In short, in safety-critical environments, fatigue-induced risk-taking can lead to non-compliance with standard operating procedures, bypassing safety protocols, or neglecting proper equipment maintenance.

Fatigue Case Study – Investigation Report Refinery Explosion and Fire – BP Texas City, TX, March 2005

On March 23, 2005, an incident involving 15 fatalities and over 180 injured people occurred as a result of the operator allowing the tower to overfill. Post incident investigation, it was determined the day Board Operator at the BP Texas city refinery had been working 12-hour shifts, seven days a week, for 29 consecutive days. The operator's commute to and from work took between 30 and 45 minutes each way, providing him 10.5-11 hours off from work each day He reported that, due to these factors, he routinely got five to six hours of sleep per night, about 1.5 hours less than he slept during his normal work schedule. Losing 1.5 hours of sleep in a 24-hour period for 29 straight days, the Board Operator had accumulated a sleep debt of 43.5 hours. This evidence suggests that the operators' fatigue degraded his judgment and problem-solving skills, hindering his ability to determine that the tower was overfilling.

Figure 13—Fatigue Workloads Case Study

Misinterpreting Data: Can produce profound consequences in any setting or context. A misinterpretation of data can lead to flawed conclusions, which can undermine the integrity of operations, misguide strategies, and lead to incorrect diagnosis. Data which is not correctly interpreted can create safety hazards, operational inefficiencies, and damage reputations. To mitigate the risks of misinterpreting data, it is very important that investment is made in comprehensive training for any personnel that might be involved in that operation. Implementing data validation and verification, using advanced data analytics, and promoting accountability in the workplace can all help prevent the negative impacts of data misinterpretation.

Misinterpreting Data Case Study – Delayed Well Control Shut in During Auto Choke MPD -IOGP, May 2018

Drilling 8 ½" hole - high pressure caprock - with 15.2 ppg mud weight (MW) at 17,910'. Drilled with MPD with a MW of 15.2 ppg, surface back pressure is applied to get an equivalent mud weight (EMW) of 16.1 ppg on Bottom. MPD system is set up in detection mode with auto-choke enabled (choke will adjust itself if a discrepancy flow in/out is observed). Background gas 1-2% (pore pressure (PP) prognosed 16.1 –16.5 ppg EMW). While drilling at 17,910' MD, Driller flushed choke and kill lines with fresh 15.2 ppg mud. Coincidentally, a higher-pressure layer was crossed at the same moment. MPD Coriolis flow meter detected an increase in flow out. MPD automatically started closing choke to increase BHP and bring flow out equal to flow in. Surface back pressure increased up to 1120 psi. Flow in and flow was not equal. With MPD limit reached – the decision was taken to close the well on the BOP Annular preventer.

Figure 14—Misinterpreting Data Case Study

This IOGP case study demonstrates how a combination of factors and compounding data can be misinterpreted in high stress environments. The increase in flow out was explained away by the flush of the choke and kill lines – whereas in reality it was caused by a formation gain. The consequence was a delayed well shut-in.

Conclusion

To conclude, the data represented in Figure 15, provided by IOGP, highlights the most significant contributing factors that led to the reported well-control incidents captured in this study. As it stands, the largest contributing factor, with 71%, can be attributed to human factors, similar to the aviation industry. To the untrained eye, this graphic is a visual representation of the necessity for human factor training or development within the industry as most failures stemmed from an improper Human Factors approach with other factors such as barriers (67%), risk assessment (59%), and procedures (51%). However, by applying the concepts discussed in this paper, a different conclusion may be derived. 100% of incidents revolve around human factors as each one of the contributing factors above can be traced back to misaligned Mental Models, Attention deficits, improper Decision Making, lack of Error Management, neglect of Pilot/Co-pilot, improper Automation Management, or simply a bad Safety Culture. If viewed in this manner, these findings demonstrate that a holistic approach, prioritizing the human in the loop, among other critical elements, is essential for mitigating risks and building a resilient environment. As the industry continues to evolve, especially when it comes to MPD operations, maintaining a commitment to understanding and integrating the modern view of human factors will be indispensable in achieving efficient and safe operations in the years to come.

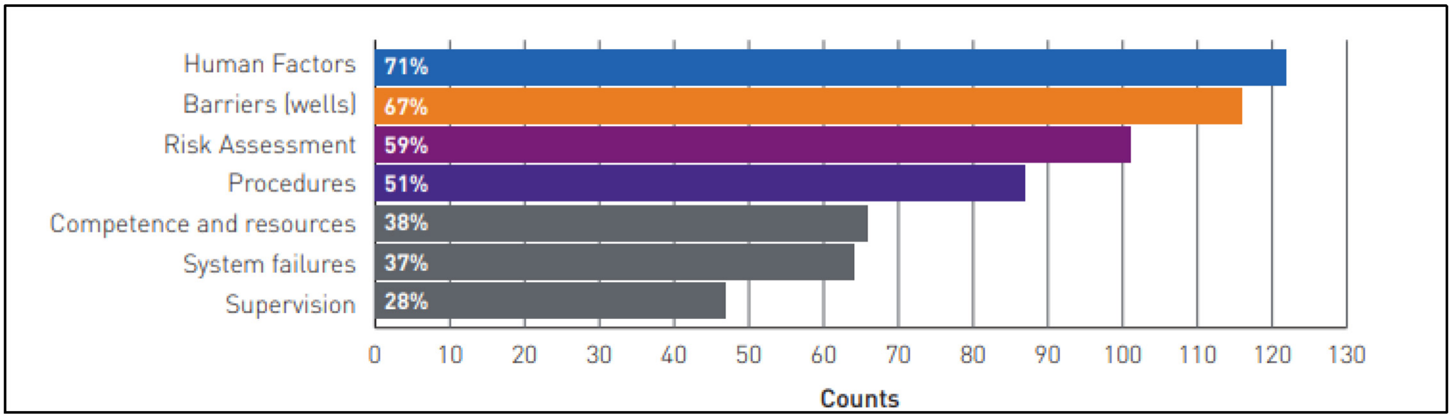

Figure 15—Review of Well Control Incidents per IOGP

Acronyms

BHA: Bottom Hole Assembly
BHP: Bottom Hole Pressure
BOP: Blow Out Preventer
MPD: Managed Pressure Drilling
MW: Mud Weight
PPG: Pound Per Gallon
PPGE: Pound Per Gallon Equivalent
PSI: Pound per Square Inch
SBP: Surface Back Pressure
HPHT: High Pressure High Temperature
BBL: Barrels
SCR: Slow Circulating Rates
PVT: Pit Volume Total

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