The Human Factor: Process Safety and Culture

TECHNICAL REPORT

Society of Petroleum Engineers

SPE Technical Report

The Human Factor:
Process Safety and Culture

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1.0 Introduction

1.1 Objectives

In July 2012 the Society of Petroleum Engineers (SPE) held a two-day summit on human factors to create a common understanding of the strategic challenges for the oil and gas E&P industry, to identify what is known and unknown in the field, and to explore possible actions to accomplish the needed change indicated by the U.S. National Commission on the Deepwater Horizon Oil Spill and Offshore Drilling report.[1]

This Technical Report is based on discussions and conclusions at the summit and is intended to provide guidance on the human factors risks in E&P operations and what can be done to reduce those risks and increase safety.

The changes required in the industry involve moving to an organizational culture in which process safety is as well managed as personal safety is currently managed in the industry. In civil aviation, a series of major accidents led to the introduction, mandatory requirement and acceptance of human factors methodologies called Crew Resource Management (CRM). Similarly, the nuclear power industry identified and acted upon the concept of its safety culture after a small number of major incidents. The challenge is whether the E&P industry can achieve a similar breakthrough by confronting the human factor as an issue in process safety both onshore and offshore.

1.2 Process and Scope

A steering group of subject matter experts (SME's) developed the summit agenda. Participants in the summit were nominated by the steering group as SMEs with experience and knowledge needed to achieve the objectives of the summit or applied to attend and were accepted by a steering group as SMEs. The final composition of about 70 participants represented a broad cross-section of the industry, with individuals from oil and gas major operators, national oil companies, smaller operators, major contractors, regulators, universities and consulting organizations.

In preparation for the summit, a steering committee developed the following list of six topics to act as a springboard for discussion:

1. **Defining the Scope of Human Factors** -- What is human factors in the context of Process Safety? Summit participants identified ten risk areas that need to be addressed. Three of these were considered priorities that underpin the others. Three others were considered "low hanging fruit" that would be relatively, easier to develop.
2. **Safety Culture** -- The safety culture of organizations is often proposed as the problem and development of a culture of process safety as the solution. But these concepts need to be made accessible to the wider industry. Despite the many advantages a safety culture brings, it cannot easily be regulated; organizations have to do it themselves if they want the benefits.
3. **Training and Certification** -- Solutions proposed often involve more training and rigorous certification. Both technical and nontechnical skills are important

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[1] *Deep Water: The Gulf Oil Disaster and the Future of Offshore Drilling*," Report of the US Commission on the BP *Deepwater Horizon* Oil Spill, 11 January 2011, Page 215, http://www.gpo.gov/fdsys/pkg/GPO-OILCOMMISSION/content-detail.html

requirements for safe operations. The industry can look to other sectors, such as aviation, nuclear power and defence for good examples of skills required.

4. **Operational Control of Work** -- A new approach to management may bring in many of the human factors requirements. Operational Control of Work is an idea that goes beyond management of change (MOC) to capture the strategic and then tactical deviations that, by small-scale alterations, have been found to underlie many incidents.
5. **Decision-Making** -- Decision-making and the assessment and communication of risk lie at the core of safety management. Yet the summit identified a lack of knowledge in the industry about this vital topic. There is a wide body of established knowledge that is highly relevant but little known in the oil and gas sector.
6. **Information Technology (IT)** – IT faces many challenges regarding what information to present to individuals and teams. Moreover, it is often unclear in its support, appearing to be confrontational or confusing.

2.0 Human Factors Risks in the E&P Industry

In the context of process safety, the term "human factors" refers broadly to factors that can lead to the loss of standards of consistently reliable human performance that are relied on as part of an organization's defenses against process safety incidents.[2]

The summit identified ten human factors risks that need to be addressed in oil and gas E&P operations:

1. Leadership and Culture
2. Perception of Risk and Decision-Making
3. Communication of Risk
4. Human Factors in Design
5. Individual and Team Capacity
6. Collaborative and Distributed Team Working
7. Commercial and Contractual Environment
8. Workload Transition
9. Assurance of Safety-Critical Human Activities
10. Investigation and Learning from Incidents

While these risk areas are not independent, they are presented separately here to emphasize their individual significance and because there are differences in the actions that need to be taken and among the stakeholders that need to be engaged in addressing each one.

This list recognizes that the factors that can interfere with consistently reliable human performance under real-time operational pressures extend beyond the immediate operational situation. They include (1) the attitudes, competencies, skills and behaviors of front-line operators, their immediate supervisors and management who are engaged in activities with direct and immediate potential for major accidents; (2) the degree and quality of "back-office" support, including the organizational structures and commercial relationships that shape and provide technical services to support front-line operational

[2] This definition should not be confused with definitions of "human factors" as a professional scientific discipline. The definition used here refers to the factors that need to be managed and controlled to reduce the potential for major incidents, not the technical disciplines that bring specialist knowledge, skills and techniques to mitigating these risks.

teams in their real-time decisions and actions; (3) the design, maintenance and support of the equipment and technologies (both hardware and software) used by those performing safety-critical activities; and (4) the commercial, organizational and operational processes, decisions and arrangements that may date months or years before operations began but still have a direct bearing on front-line operations.

The order of the list of human factors risks does not imply any priority. Each is briefly discussed in Sections 2.1 to 2.10.

Summit participants, however, identified three issues as those organizations could feasibly prioritize immediately.

- Leadership and Culture
- Perception of Risk and Decision-Making
- Individual and Team Capacity

These three issues underpin the others in that without an effective base in these, progress on the others is unlikely to be achieved. They are discussed in more detail in Sections 3, 4 and 5.

2.1 Leadership and Culture

Creating and maintaining a safety culture that includes shared values, attitudes, beliefs and expectations that emphasize the critical importance of safety across an organization is dependent on leadership. The decisions, actions, and statements made by leaders, the reward and incentive structures that leaders implement, the way leaders behave and interact with people throughout the organization, and the decisions and actions they take to balance safety against commercial imperatives, directly determine the attitude to safety within an organization.

Operators and regulators who adopt an attitude that compliance to regulations and procedures will automatically lead to safety and ignore the key role played by leadership in setting and reinforcing norms and motivations are unlikely to create a culture that provides the necessary foundation for strong process safety assurance.

2.2 Perception of Risk and Decision-Making

Awareness and assessment of risk (and decisions made based on those assessments) occur at all levels of an organization. They are made in the "back-office" removed from the consequence of the assessments and decisions, with no direct exposure to hazards or risk to their own safety and by operational staff with direct exposure to hazards where their own safety is directly at risk. Such assessments are virtually always made in the presence of uncertainty. The Key Performance Indicators (KPIs) that senior managers select are indicators of how they perceive the risks and demonstrate their commitment to managing them.

A great deal is known from scientific research about the psychology of how irrationality and cognitive biases lead to poor risk assessment and decision-making. Practical and simple solutions can be created to counter these biases, with significant improvements in decision-making. This knowledge, while widely available, is not generally being applied within the oil and gas industry.

2.3 Communication of Risk

Assessment of risk and decisions about the prioritization of risk are made throughout oil and gas operations and across companies. Assessments made at senior levels, often long before operations begin, can be especially significant in setting expectations about risk that pervade operational decision-making. These assessments, and the way they are worded and explained, can have a powerful influence on how individuals perceive the risk associated with their work. When boards and executives concentrate on personal Lost Time Injuries (LTIs) in preference to process KPIs for major accident hazard controls, they lead their organizations toward prioritizing individual and occupational risk over major process disaster risk.

Particularly critical is sensitivity to "weak signals" that risks have increased. Everyone involved in safety-critical operations needs to not only be mindful and sensitive to such weak signals that risks may be increasing, but also have the willingness and ability to communicate their assessment of the change in risk profile to their immediate leaders.

Effective communication of risk, and continuous re-appraisal and shared awareness of risk throughout an organization can be achieved by developing a culture of "chronic unease" that encourages a high awareness and sensitivity to risk and minimizes the potential for complacency.

2.4 Human Factors in Design

Incident investigations often identify deficiencies in the design or implementation of the interface between people and technology as contributing to loss of reliable human performance. This is sometimes referred to as "design-induced human error." Critical systems need to be designed to recognize the possibility of human error, with such resilience and robustness that human errors, when they occur, are likely to be caught before they can lead to serious consequences.

There is much that can be learned in improving human factors engineering in design in the oil and gas industry from industries such as aviation, nuclear power and defence. The oil and gas industry, however, has a number of specific challenges that can make it difficult to apply design process and standards that have worked well in other industries. Processes and standards are being developed that are specifically customized to the needs of the global oil and gas industry.[3]

2.5 Individual and Team Capacity

Individual and team capacity means ensuring that people expected to perform safety-critical activities are fully capable of doing so. The foundation of process safety is the availability, capability, capacity and attitude of both individuals and teams to do what is expected of them.

Team members need to possess both the technical and interpersonal skills that allow teams to work together effectively in the interests of safety. They also need to have the resources, means and authority to communicate in a timely manner as needed.

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[3] See for example "*Human Factors Engineering in Projects*", Report 454, August, 2011, Oil and Gas Producers Association (OGP), available as a download on OGP website.

Those in team leader positions need to have the interpersonal skills to effectively draw on the knowledge and experience of everyone on the team who may have a contribution to make to safe operations, without allowing differences in personality or authority to inhibit communication or prevent sharing of critical knowledge or information.

2.6 Collaborative and Distributed Team Working

Oil and gas operations rely on communication and collaboration between different groups of people, often located in different locations and working on different scales in terms of the time between their input and the potential for an incident. Assurance of human performance on safety-critical activities, particularly in real-time operations, depends on highly effective, often real-time, collaboration and communication across these distributed teams.

Control of the risk to human performance begins with each team's awareness of the contribution the team makes to front-line operational safety. Team members need to know what is required of them and the risk and potential consequences if they do not provide the support required. Intentional effort and established mechanisms (technological, organizational, procedural, legal and commercial) is required to support and encourage effective distributed team operations.

2.7 Commercial and Contractual Environment

Oil and gas operations are carried out in a complex commercial and contractual environment. Ventures can involve many partners, all with different priorities, cultures, ways of working and legal responsibilities. These factors can lead to inconsistencies and conflicts in risk assessment and decision-making, breakdowns in communication of safety-related information, and increased risks to the ability of people to perform safety-critical activities effectively.

Adequate control of these issues requires each stakeholder to be aware of the contribution he/she makes to ensuring safety-critical human performance and to commit to support of activities designed to reduce risk. It also requires a clear focus and line of sight by the operating partner on assurance of safety-critical human activities.

2.8 Workload Transition[4]

"Workload transition" refers to situations when people are expected to transition quickly from "normal" operations (typically stable situations with a relatively low workload) to "abnormal" or emergency situations, with extremely high workload and significant challenges, particularly mental ones.

Proper planning and preparation needs to recognize the critical role that human factors can play in ensuring successful transition into these emergency response situations.

2.9 Assurance of Safety-Critical Human Activities

The use of automation in oil and gas operations has increased dramatically over recent decades. However, the global industry still depends on people at all levels of operations

[4] The term "Workload Transition" to refer to this issue is borrowed from a project carried out by the US National Research Council on behalf of the US Army and published by the National Academy Press in 1993 as "*Workload Transition: Implications for Individual and Team performance*" under the editorship of Beverley Huey and Christopher Wickens.

to perform activities that are fundamental and critical to safe and environmentally sustainable operations and will continue to do so for the foreseeable future. Reliance on human behavior and performance can be either direct (such as performing a valve line-up correctly, responding to alarms, or detecting and diagnosing causes of abnormality) or indirect (such as inspection or maintenance of safety-critical elements).

2.10 Investigating and Learning from Incidents

Researchers, human factors professionals and others with a professional interest in human performance and major incidents across many sectors believe that real learning from incidents has been hindered by a tendency to "blame the human," or to treat "human error" as an acceptable final explanation of why an incident occurred.

Despite the best efforts of many companies, the development of a range of investigation tools and techniques to support identification of underlying human and organizational causes, and routinely investigating incidents to properly understand the reasons why human performance fails, going "beyond human error" is still relatively uncommon in many industries, including the oil and gas industry.

The key is to pursue a deeper understanding of why "human error" occurred, and especially the organizational/cultural factors that "set up" the human for failure.

3.0 Leadership and Culture

Recent analyses of major process accidents, including NASA's Challenger, Columbia and Hubble accidents; BP's Texas City accident; and the banking crisis, have implicated the culture of those organizations. Looking further back, including Piper Alpha, reveals many accidents in which high-hazard activities were allowed to happen even though people knew they could have done better. Because nothing had actually gone wrong in the past, the high-hazard activities were accepted as the norm. In addition, many recent high-hazard well control events occurred with operating staff choosing to ignore, or accept as nonthreatening, danger signs they had been trained to observe. Such acceptance, even when people know things can be done better, is essentially cultural.

The safety culture challenge is creating and maintaining an organizational culture that no longer allows things to happen when, in hindsight, it is clear that something should have been done and everyone knew it. Establishing such a culture begins at the top of the organization, but the distance from executives at the top to the hazards is often great and involves multiple decisions by individuals at many levels throughout the organization. This distance also means that executives' beliefs about the safety culture of their organization may not always correlate with what is happening on the ground.

3.1 Definition of Process Safety Culture

Safety culture has been defined in many ways, but the definitions are usually too abstract for the oilfield, which makes discussion difficult. Organizational culture can be defined either in abstract terms of values, beliefs and attitudes, or more practically in terms of "how we do things around here."

A culture reflects attitudes in an organization that are cooperatively shared by all stakeholders, including both workforce and management. A culture of safety is one where people do things with safety as a priority and believe that high levels of safety performance are feasible and desirable.

A process safety culture requires much more than just attention to personal safety activities. It requires the existence of organizational behaviors, a level of continuous awareness of the dangers associated with even the most straightforward of activities, and the ability to properly assess alternatives in the face of conflicting goals and inadequate information.

The five-step Oil and Gas Producers Association (OGP) ladder[5] describes how a safety culture may range from Pathological – or hardly interested in safety at all – up to Proactive and Generative, where both beliefs and behaviors are strongly supportive of safety. A crucial point is that people may want and support safety, but not believe that it is completely achievable in the face of production and profit pressures. More advanced cultures, such as the proactive and generative, are typically less vulnerable and therefore more resilient, especially when processes do not proceed as expected.

3.2 Measurement of Safety Culture

Measurement tools for safety culture often refer more to personal than process safety attributes. In personal safety, the dangers are salient and the mechanisms of accidents and their prevention fairly obvious. Properly conducted hazard analyses, measurement of change (MOC) procedures, etc. required by a safety case or a process safety management system can uncover the salient dangers, identify possible accident mechanisms and specify ways in which they can be prevented or reduced.

Process safety is different, often hidden in the engineering and the initial design and acceptance decisions, removed in time and space from the actions at the time of a potential specific incident. A problem can exist in the interaction of personal and process safety, where specific behaviors or actions are required to prevent an incident or to minimize the potential for the incident to develop into an accident. Stopping the work is relatively easy, and usually of limited consequence for production, when the problem is personal or occupational safety. Process safety stop-work issues, in contrast, may require expensive delays and interventions. There can be competing objectives when process problems are identified, often conflicting with major commercial and production goals. Advanced process safety cultures understand the possible conflicts, face them early on, and determine the decisions as much as possible in advance, rather than waiting for incidents to actually occur.

Examples of approaches to measuring safety culture include the OGP's five-step culture model and field experience such as the California State Lands Commission 15-year experience using an interview process derived from a 1997 Safety Assessment of Management Systems (SAMS) Joint Industry Project[6] sponsored by US Minerals Management Service, UK Health and Safety Executive, Canada's National Energy Board, California State Lands Commission, American Bureau of Shipping, Chevron and Texaco and run by Paragon Engineering Services and the University of California-Berkley.

Evaluations that use an interview process often require time on location and may require interviews with staff at all levels of the organization to be able to assess the

[5] "A Guide to Selecting Appropriate Tools to Improve HSE Culture," International Association of Oil and Gas Producers (OGP), Report No. 435, March 2010, available as a download from OGP website.
[6] Safety Assessment of Management Systems Joint Industry Project, http://www.slc.ca.gov/division_pages/mfd/MFD_Programs/SAMS/samsleg3.pdf

level of safety culture.[7] The process is somewhat subjective and does not lend itself to a pass/fail analysis. What is important is identifying weaknesses and trends and reporting them to management so corrective action can be taken.

Various organizations are attempting to develop objective metrics that indicate the level of safety culture. These include the UK Health and Safety Executive (UK HSE), and the Norwegian Petroleum Safety Authority (PSA) in its RNNP program. As yet, however, there is no agreement on a set of metrics or proof that one can be directly correlated to levels of safety culture.

What people do *after* measurement is as critical as measurement itself. Actions involve discovering what needs to be done, implementing changes, and generalizing to generic training. These actions are some, but not all, the ways to demonstrate double-loop learning that goes further than discovering individual problems and fixing them in a single feedback loop to identifying systemic issues and acting on addressing them organization-wide.

3.3 Experience in Other High-Hazard Industries

Other industries, particularly commercial aviation, the nuclear industry and mining, have developed strong process safety cultures. The nuclear industry, through the United Nations International Atomic Energy Agency (IAEA), set up specific activities to understand and ensure development of safety cultures shortly after Three Mile Island and the Chernobyl disaster. The mining industry had a summit meeting on safety in 2005 after a large number of accidents.

Aviation has relied on a highly regulated international environment. The International Civil Aviation Authority (ICAO), also a United Nations, and ICAO Standards and Recommended Practices have the status of international treaties. The success of civil aviation has been attained even though its Safety Management System (SMS) was made mandatory for airlines only in 2009. Commercial aviation is characterized by a culture that expects and invests in high levels of discipline, professionalism, training and regulation. For example, failure to pass annual medical and technical tests results in grounding, regardless of the seniority of staff. To achieve the current level of safety performance, a special culture had to be developed that supports challenge to authority and a deeply embedded personal interest in safety.

3.4 Assurance of Safety Culture Improvement in Organizations

Safety culture is a complex concept that is a process of continuous improvement that is evolutionary rather than once-and-for-all. Culture surveys form one tool for the assessment of the culture, but they cannot be relied on by themselves because the measurement depends on honest and truthful responses. Surveys are of most value when they are repeated and changes to the cultural norms and expectations can be monitored and tracked over time.

One major area for assessment and assurance is leadership behaviors. Success in developing leadership behaviors focused on personal safety can be leveraged into the identification and assessment of equivalent behaviors for process safety. Leaders can be

[7] "Evaluating the Effectiveness of Offshore Safety and Environmental Management Systems," Report 309, Transportation Research Board (TRB) of the National Academies (2012), National Academies Press, Washington, DC., available as a download from the TRB website.

trained in what behaviors during site visits have the most impact on process safety. Before making visits and inspections, leaders can be prepared on what to look for, what to ask for, and how to understand what the answers mean. While such approaches can never be technically fool proof, and executives and other managers can be misled, it is the activity itself that is most critical. Such activities send a clear message about what the leader finds important enough to ask about.

3.5 The Role of Regulation

People and organizations are not always willing to take the necessary steps to improve their safety culture. One way of ensuring that they take steps in the right direction is through strong regulation. A common approach to regulation is to develop a list of specific prescriptive requirements, backed up by a regulatory audit or inspection with sanctions for noncompliance. This requires the regulator to develop a comprehensive and credible list that covers the latest technologies and insights. This approach, however, provides no incentives for organizations to go beyond minimal compliance. It encourages a type of "compliance mentality" described in the National Academies' report,[8] where management's attitude can become, "If I am in compliance with the regulations, then I must be safe," rather than the continual introspection on safety and dissatisfaction with performance required by a "Generative" safety culture.

An alternative method of regulation by goal-setting relies on organizations to identify and set their requirements. It is thought that organizations that are involved in developing performance goals will be more likely to "buy into" and practice the behaviors and also be the most informed on how to apply them in specific instances. A regulator that sets performance goals and then audits the organization's processes and compliance with its self-set goals is better able to work cooperatively with the organization to identify weaknesses and encourage improvements. This is especially true if the regulator concentrates on continuous improvement and coaching to influence behaviours rather than relying on legal sanctions alone.

Both approaches require the regulator to apply significant sanctions in the case of either noncompliance to requirements or failure to meet goals. Behind failures of either of these may be an organizational culture that finds such failures inevitable and even acceptable. Valid questions then arise such as: "Can the actions of the regulator help create a culture of safety that goes beyond minimum compliance?" and "What is the role of a regulator in this instance?" Answers to these questions require a mature understanding of what a safety culture applied to both personal and process safety looks like from the viewpoints of both the organization and the regulatory bodies. By ensuring an adequate and jointly agreed definition of what a safety culture looks like for both process and personal safety, regulators can support organizations taking active steps to improve their safety culture.

4.0 Perception of Risk and Decision-Making

People make decisions on what to do next all the time, ranging from senior executives making strategic choices to front-line personnel assessing the situation with the associated risks and making split second decisions on how to go about a task. Both

[8] "Evaluating the Effectiveness of Offshore Safety and Environmental Management Systems," Report 309, Transportation Research Board of the National Academies (2012), National Academies Press, Washington, DC.

types of decisions can be safety-critical. Most of the time people get it right, but sometimes decisions have regrettable consequences. This has to do with *cognitive limits* and biases in human decision-making, *physiological factors* that affect an individual's ability to make decisions (e.g. drugs, alcohol, illness, injury, fatigue, etc.), and the *organizational conditions* under which decisions are made. Decisions are often required under the stress of time pressure, with competing goals and with inadequate, insufficient or uncertain information and unknown consequences.

Considerable scientific literature is available on why experienced, trained and skilled people may make decisions that, in hindsight, appear to have been poor or even bad. Some of this knowledge has been applied in the oil and gas industry to train people to make better decisions under challenging circumstances. However, implementation is inconsistent, and most people in the industry lack awareness of the realities and limitations of human cognition and the "tricks" the brain uses to be able to function in the complex modern world. Few people in the industry have had a chance to practice decision-making in a fail-safe environment.

4.1 Decision-Making Process

Decision-making involves the entire *process* from awareness of a situation (perceiving a potential hazard or failing to do so), making projections of what might happen, planning possible courses of action, and choosing what to do. This process is sometimes conscious and deliberate (for example, when buying a house or planning a well). Rational decision-making models apply to these situations. Such models assume people systematically compare options and make rational, optimized decisions when there is sufficient time and information. Most of the time, however, decisions are made subconsciously, almost automatically; such as when driving a car or interpreting a display or chart. People then use a strategy of choosing something good enough for the moment and adapting the course of action if necessary. While this strategy is sufficient in most ordinary situations, it can be problematic in highly safety-critical situations.

4.2 Cognitive Bias in Decision-Making

Research has also shown that rational/deliberate decision-making is often affected by many types of subconscious cognitive bias.[9] An example of a cognitive bias is the *confirmation bias*: We perceive new information in light of what we already know about the situation and what we expect. From an evolutionary perspective, this makes processing information quicker, but in safety-critical situations it can lead to overlooking or reinterpreting information that does not fit what the individual believes is the situation into information that the individual believes makes better sense.

4.3 Perception of Risk

How people *perceive* risk is intimately connected with how we make decisions. People systematically misunderstand probabilities, influenced by the (often illusory) level of control they feel they can exercise. This is particularly common in hazardous situations that are very familiar (such as driving), where people feel in control and experience them as less dangerous than they are. The information that individuals, from executives to the front line, seek out shapes their understanding of what is critical and which

[9] "Cognitive Issues Associated with Process Safety and Environmental Incidents", International Association of Oil and Gas producers, Report 460, July, 2012, available as a download on the OGP website.

controls are important. KPIs that focus on high-frequency personal outcomes, such as LTIs and reactive controls, can create a very different understanding when compared with proactive controls on process hazards. Even the way identical information is presented influences perception of risk: "Risk framing" describes a cognitive bias where, for example, people see a 90% chance of success as less risky than when the same operation is described as having a 10% chance of failure.

There are many examples of cognitive bias interfering with accurate and rationale assessment of risk. Alarmingly, research has shown that most of these biases favor "hawks" (a tendency to accept higher risk) over "doves" (a tendency towards risk-aversion). This is recognized as "risky shift" and was first described by Kogan and Wallach (1967).[10]

4.4 Group Decision-Making Factors

Groups can also affect decision-making processes. Most significant operational decisions involve groups working to an agreed position. Involving other people can be a great asset, as it brings more experience and diverse perspectives to the table. But group decision-making also presents challenges. It is typically slower than one individual, requires energy and resources, and it may not be clear who is ultimately responsible, resulting in nobody taking action or taking responsibility for the decision.

Evidence also suggests that individuals will go along with group decisions because they want to be accepted. Social pressure can lead to riskier decisions than each individual would have made alone. Those who are more vocal or have more status can have a disproportionate influence on the decision, causing those with more technical expertise to feel less confident about their judgments or prevent them from being heard.

These influences can be counteracted by using groups as an instrument to critically review a decision. In that way, groups can compensate for the limitations of individual decision-making if trained to question each other in a supportive environment.

4.5 Situations and Decision-Making

The *situations* people find themselves in can also influence the quality of their decision-making. Time pressure, poor information presentation, ambiguity of information and conflicting goals can lead to poor decisions. In dynamic, safety-critical situations, rapid decisions may be required. Tightly coupled, complex processes may leave little or no time to explore alternatives. Also many real-world processes are nonlinear, information is uncertain and feedback about the correctness of a decision may come too late to correct. These considerations can apply equally to organizations, leading to a loss of "organizational situation awareness," especially with small, slow organizational changes and mission creep. Safety-critical decisions may be especially subject to premature closure under time pressure or the perceived need to make a decision. All individuals, but especially leaders, need to be aware of factors that subtly increase the chances of making and accepting decisions that are increasingly risky.

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[10] Kagan, M. and Wallach, M.A. 1967 Risky-shift phenomenon in small decision-making groups: A test of the information-exchange hypothesis. J. of Experimental Social Philosophy **3** (1): 75-84 http://www.sciencedirect.com/science/article/pii/0022103167900388

4.6 Challenges for the Industry

The following are the challenges for the E&P industry:

- Recognize the nature and limitations of human decision-making as it affects oil and gas operations, and the impact that cognitive bias can have on assessment of risk and decision-making in both real-time and in back-office activities.
- Gain more familiarity with existing knowledge on decision-making and risk awareness.
- Identify and implement training protocols, methods, and review procedures that reduce the adverse effect of our cognitive biases.
- Review the effectiveness of initiatives in reducing errors in safety-critical decisions.
- Reflect the importance of decision-making skills in the industry's recruitment and performance development processes.

4.7 Possible Solutions

Developing analytical and nonanalytical reasoning skills has been shown to improve the quality of decision-making, as has the use of experiential training methods. In other high-risk industries and in a few areas of the oil and gas industry, *scenario-based training* has been successful, conducted either in simulators or as table-top exercises. An experienced facilitator pushes a team of people to their limits in a challenging scenario and guides their subsequent reflection and analysis to capture learning. Repeated practice is particularly important to build the team's repertoire of behavior that can then be used under high-stress conditions.

To combat the biases mentioned above, organizations can develop decision reviewing procedures to support critical analysis and to actively challenge decisions. While cognitive biases will not disappear, team processes can help to compensate for what individuals may overlook. For example, team members can take turns in playing the role of "devil's advocate," and the leader can make a habit of asking for deviating opinions or constructive challenge. At the planning stage, more time can be invested in anticipating and assessing possible consequences and alternative courses of action. Also for these organizational processes, simulator training could be developed. In time-critical situations, simple tools are needed to support decision-making. Supervisors could encourage before-and-after action reviews as part of their daily routine.

4.8 Assurance

Assurance methods need to address decision-making at three levels:

1. The individual level of those working in safety-critical situations.
2. The procedures for reviewing decision-making and decision support initiatives at the planning stage.
3. The strategic decisions about the design, operation and effectiveness of the entire safety management system.

Possible assurance methods include documentation, procedures, MOC, and internal audits. It is important that lessons learned relate to the decision-making *process* rather than only the outcome of the decision. The "health status" can be assessed through regular meetings, facilitated focus groups, perception surveys and management reviews with corrective actions. Safety management systems and their assurance measures need to be tailored to the maturity of the organization.

5.0 Individual and Team Capacity

Most major accidents are avoidable. Proper system design and/or timely and appropriate human action can usually be shown to have been able to prevent almost all unsafe outcomes. From that perspective, it is attractive to take the attitude that "if we just had people with the right competency then everything would be okay."

The reality is that training and competency alone will not assure operational integrity. Training, certification and licensing are necessary but not sufficient. Adherence to the principles of safe design and appropriate safety management systems are critical to the prevention of major accidents. Training, and more importantly, competency development in the larger sense, certainly plays an important part. Operational integrity is always affected by the knowledge, skill and behaviors of those who are relied on to operate, maintain and support critical systems.

What role should training, certification and licensing play in ensuring operational safety, and how can it support an integrated approach to delivering operational integrity? To answer this question, the industry needs to agree on (1) what it knows about the role training, certification, and licensing play in operational integrity, and (2) the questions the industry will need to answer to properly address the issue.

5.1 The Role of Training, Certification and Licensing

The SME's at the summit agreed upon the following list of what is known by the industry about the role of training, certification and licensing:

1) Developing proper technical[11] and nontechnical[12] competencies are a critical part of assuring operational safety. Both are necessary, but neither alone is sufficient.
2) Generally, there is a common understanding of the technical competencies required for key job roles in our industry. Detailed definitions of technical competencies exist in some job roles in some organizations. However, specific, documented, industry-wide definitions of technical competencies do not exist.
3) The definition and development of technical competencies will need to be continually reviewed and updated due to increasing complexity of operations, technological advancements, and the demographic situation facing the industry.
4) Significant opportunities to improve operational integrity through improvements in nontechnical skills and behaviors currently exist.[13]
5) Several groups[14] have useful prototypes for some roles, but there is no common industry agreement on the nontechnical skills needed for specific jobs. Currently available nontechnical training needs to improve, particularly for handling uncertainty and abnormal events. Current training does not often address

[11] By "technical competencies" we mean the industrial process, equipment, design, and operational technological knowledge and skills necessary to accomplish a task.

[12] By "nontechnical competencies" we mean the social, management, and interpersonal knowledge, skills, and behaviours required to address personal effort, motivation, and the wide range of human interactions within small and large work teams and diverse, cross cultural or multidisciplinary working groups. In the operational safety context, key nontechnical competencies typically include situational awareness, leadership, teamwork, communication, decision-making, risk awareness, etc.

[13] Studies supporting this statement include: work by Hopkins, the Chemical Safety Board, Borthwick, and others.

[14] The OGP, for one, is researching a 'syllabus' for training of nontechnical skills for some well crews roles. The syllabus is expected to be published by OGP in 2013.

understanding the limits of expert judgment and intuition, and the behaviors most appropriate for preventing and responding to emergency situations.

6) Different selection processes, wide variation of personnel and roles, the dynamic nature of many petroleum processes, and complex contractual relationships within a team mean that the many beneficial nontechnical programs that exist in other industries[15] will require significant customization to be useful in the oil and gas industry. However, a core syllabus could define the requirements for basic nontechnical skills needed to work in most jobs in the E&P industry.
7) While some issues related to competency development can be addressed within the context of a single company, because of the extensive use of contractor services and partnerships, there is a critical industry-wide component to properly addressing this challenge.
8) The lack of a common terminology in the area of operational integrity/process safety hampers the industry's ability to cooperate across companies or countries.

5.2 Open Questions Relating to Training and Competency

The following are questions around key themes that will require answers.

1. **Common Standards:**
   a. Should the industry agree to define measurable guidelines for common technical competencies? If so how?
   b. Should the industry agree to define measurable guidelines for common non-technical[16] competencies? If so how?
   c. Should a common basic training syllabus be defined so that new hires with little to no experience will have a base education that is accepted and understood by the employers in the E&P industry. If so how?
   d. Should the industry agree to adhere to agreed common measurable guidelines? If so how?
2. **Certification and/or Licensing:**
   a. What is the role of industry vs. company-specific certification and/or licensing to verify/ensure necessary competencies?
   b. What is the best way to achieve cross-industry cooperation?
3. **Sharing Best Practices**
   a. How can best practices for training, development, and certification/licensing be most productively shared across the industry (between companies and across regions)?
   b. How can learnings from nontechnical training programs of leading safety performance E&P companies and other industries (aviation, nuclear, military, and marine) be most productively transferred to the petroleum industry?
   c. How can the industry most productively institute processes/practices to learn from incidents and continuously improve competency definitions and development?

[15] Aviation, Nuclear Power, Military and others industries have benefited from definition of and directed training for nontechnical competencies. As one example benchmark, aviation has mandatory and apparently valuable CRM, Line Oriented Flight Training (LOFT – simulator based training) and Line Operational Safety Audit (LOSA – in cockpit assessments) programs in place.

[16] Notechs, Flin and Crichton at Aberdeen University, and the University of Texas LOSA Cooperative have approaches to measure behavioral competency in aviation and medicine.

5.3 Operational Control of Work

Upstream E&P operations often have worksites that are remote from the planning organization. Communication and control links are consequently much weaker. Production operations and maintenance activities have inherent risks in the possible failure of containment barriers. Barriers containing hydrocarbons and other hazards can weaken by tolerating small internal or external changes over time or by worsening design assumptions about corrosion, unexpected fatigue loading or stress. Risks are also inherent for non-routine procedures or well operations if there are uncertainties about the condition of the plant or the characteristics of the formations.

For many E&P process-safety-critical activities, essential engineering support may not be immediately available, which can create unique problems. Either there will be delays to production while a support team is assembled to address the issue, or safety may be compromised if the on-site team attempts to resolve the matter.

This stands in stark contrast to many critical downstream activities, notably plant turn-around, that are exhaustively planned to the finest detail in the recognition that delays are costly and unexpected events must be dealt with rapidly and effectively. In these cases, an engineering team is on site and dedicated to supporting the operation.

The E&P industry has little formalism around the workflows, communication protocols, decision-making rights, competencies and training programs to provide a framework to guide people involved in remote activities. In most cases, practices have evolved over time. They are seldom documented or part of formal training, but are passed down across successive generations of workers. Within a company, practices may vary significantly between worksites, even within the same region.

Operational Control of Work addresses these issues. At the organizational and human factors level, Operational Control of Work sets out the workflows, communication protocols, decision-making rights, competencies and training programs necessary for the safe and efficient execution of operations. At the technical level, it encompasses the way designs are translated into on-site executable instructions and how the status of the operation is monitored for deviations. It provides a standard framework across an organization within which staff can be educated, trained and assessed. Operational Control of Work focuses on raising the awareness of human factors, developing the nontechnical skills needed for effective teamwork, detecting the weak signals of insidious change and managing change effectively in response to unexpected events.

5.4 NASA and Integrated Operations

As an example of Operational Control of Work, the NASA experience is instructive. A highly disciplined organization that managed complex operations and dealt with unexpected events in a highly competent manner was the cornerstone of the US space program for 40 years. The Mission Control organization was underpinned by very clear, documented "Mission Rules" that clearly defined responsibilities and set out clear boundaries within which individuals could take action up to, for example, the ultimate authority: "The Flight Director, after analysis of the flight condition, may choose to take any necessary real-time action required to ensure the safety of the shuttle and crew."

What is distinctive about the NASA experience is the amount of time spent training not only the flight crews, but also the Mission Control personnel. The NASA example should challenge the industry as to whether our Operational Control of Work practices are adequate for the complexity and intensity of the operations that are now being undertaken by an increasingly inexperienced workforce, often with increasing degrees of remote control.

5.5 Management of Change

At first sight, Operational Control of Work may be viewed as merely disciplined Management of Change. Operational Control of Work as a concept, however, goes beyond Management of Change as currently understood in projects and engineering. It includes planning for operations in explicitly dynamic environments and preparing to be organized and capable of recognizing and dealing with unexpected events, especially when changes are small and the rate of change slow.

A major risk that can be addressed through Operational Control of Work is the problem of multiple, incompatible goals. Once a plan has been agreed upon, it has to be implemented in an environment where priorities may change. Recognizing that a change is sufficiently large to be treated formally as a significant change is a challenge. The challenge is compounded when several small changes collectively make up a large change, but one that is only recognized as such after the event.

In a dynamic environment, people are expected to adapt to circumstances. The problem is when each adaptation moves imperceptibly closer to an unacceptable situation. Mission "creep" occurs when short-term gains, quite possibly individually subjected to a Management of Change process, progressively move the process away from the original design goals. Each single solution to a goal conflict may alone be safe and sensible, but unless managed, the mission may stray into unplanned territory, a process that may be too subtle for those involved to notice. Analyses of a number of major incidents in different high-hazard industries have been shown to result from such a "drift into danger."

The major challenge in managing change is to be aware of and react to the weak signals of insidious change. The monitoring aspect of Operational Control of Work is crucial to detecting subtle changes and weak signals. This must be combined with a formal escalation procedure to ensure that warnings of anomalies are rapidly communicated through the organization and dealt with effectively. The necessary skills, characterized by the notion of "chronic unease," are acquired through training and experience and must be instilled at two levels:

- A team proficient in understanding and recognizing changes
- A resilient organization to enable teams to deal with change

More advanced safety cultures are sensitive to small but important changes, possibly flagged by weak signals, and attentive to the opinions of subject matter experts who may not be high in the hierarchy. Such organizations are skilled at developing and implementing plans with processes that demonstrate consideration of a wider range of potential conditions and complications than other organizations consider need to be taken into account.

One important aspect of Operational Control of Work centers on the role of risk assessment. Experience has shown that those closest to the action become biased in favor of achieving the goal and downplay risks. The closer to the workface, the more decision-making should be rule-based rather than risk-based.

As such, skilled Management of Change is an essential component of Operational Control of Work, but not sufficient in itself. While discrete changes can be captured by formal Management of Change processes, the concept of Operational Control of Work embraces wider issues such as "mission creep" at the strategic level, as well as rapid changes due to unexpected and potentially critical problems at the tactical level, possibly when there is insufficient time or resources available to take a considered Management of Change approach.

5.6 Assurance of Operational Control of Work Capability

An assurance framework is an essential component to make the workings visible and to demonstrate that the system is effective and working as intended.

In addition to formal audits and health checks to ensure that the system is in place and being used as required, performance measurement is an essential aspect to ensure that Operational Control of Work delivers the desired outcomes. Appropriate Operational Control of Work KPIs must be selected carefully to ensure that the right behaviors are promoted. The KPIs should be appropriate to the E&P industry and be tailored to reflect the diversity of activity from seismic field work, drilling and well operations through to production operations and facilities maintenance. Duplication and re-invention should be avoided. There is already an extensive literature in this area from bodies as diverse as the UK HSE,[17] the Organization for Economic Cooperation and Development, API,[18] and the Center for Chemical Plant Safety.[19]

Effective deployment of nontechnical skills (leadership, communication, decision-making, teamwork, situation awareness and stress management) are essential to proper functioning of high-reliability organizations. These aspects must play an integral part in selection, training and assessment of those involved in Operational Control of Work.

5.7 The Way Ahead for Operational Control of Work

The industry must move to the point where, for any operation, people understand:

1) That a safety-critical activity is one where a breach or failure of a barrier almost immediately exposes the underlying hazard situation.
2) Whether a mission has safety-critical activities within it that could lead to catastrophe
3) The execution plan and decision rules for each such activity and available time dimension of the decision window.

6.0 Integrating Human Factors Into IT Development

The oil and gas industry is faced with a number of key human factors issues related to risk-critical IT systems.

1. Information overload in the operational environment is a serious and growing issue:
    - The increasing availability of information in ever-larger volumes from surface and downhole sensing devices

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[17] *High level framework for process safety management,* Energy Institute (2010) ISBN 978-0852935842.
[18] API RP 754, Process Safety Performance Indicators for the Refining and Petrochemical Industries, first edition. 2010, Washington, DC: API.
[19] *Guidelines for risk-based process safety*, Center for Chemical Process Safety (2007) ISBN 978-0470165690

- Over-emphasis on presentation of data (i.e., as gathered by sensors) rather than information (i.e., as used in thinking)
- Lack of integration between the many data sources, as well as between the IT systems of the various involved stakeholders, unnecessarily increasing the risk of human error when making key operational decisions
- Incompatibility between the way information is presented and the way the human brain thinks and processes it, including inconsistencies in the format and presentation of similar data or information

2. Human factors-centric MOC for new IT systems is a rarity:
   - In the aviation industry, human-factors-focused MOC is the standard for any information system, but in the E&P industry it is not mandatory and sometimes not considered. Some organizations take human factors issues in IT seriously, but many still do not, and the heterogeneous nature of the industry means users may still be confronted with poorly managed designs.
   - Research into major human-factors-impacting changes (e.g., remote offshore operations) rarely looks at the potentially adverse effects on human behavior. The loss of bodily sensations in a dry IT environment far removed from the action, compared to the feedback experienced in a physical drilling operational environment, is something that deserves serious research into effects on human performance.
   - IT systems development is too focused on the upside of new technology, with too little regard for the potential downsides of adverse effects on human cognition and performance. The bias of "The computer says it is ok, so we do not have to give this situation another thought" is a potentially very dangerous heuristic.
3. In emergency situations in which critical decision-making needs to take place under severe time pressures, today's IT environment may confuse or increase the difficulty level for the users it is supposed to support:
   - The information overload already present in a normal situation may paralyze people's ability to cope effectively with an emergency situation where the information and signal flood turns into a tsunami (e.g., with so-called alarm avalanching).
   - Different systems may not be aligned to prioritize amongst themselves, causing less important information and signals (such as alarms) to distract the user.

6.1 Critical Need for Improvement

Integrating human factors into IT development is critical because of the volume of technology and systems in the operational environment that place demands on people's cognitive abilities. Summit participants thought that, when a process control event with major adverse outcomes, like Macondo, occurs, the cause is usually a chain of human errors, rather than a massive engineering failure. Any contribution that human-factors-optimized IT systems can make to eliminate or contain such chains of human errors can thus provide a step change in E&P process safety.

The summit revealed a notable lack of significant investment in research into the complex human/machine interfaces in the E&P industry. Many questions posed were answered with "It would be great if someone would look into that." The risk exposure in the drilling environment in particular, is extreme. The end goal is clear: IT systems must be augmented with the ability to recognize and support the peculiar strengths and weaknesses of humans for the two to perform effectively together, no matter if it is through enforcement or re-enforcement of human actions. In an emergency situation, such an advance in IT systems may well contribute critically to the preservation of life.

6.2 Aligning Technology with Human Nature

Summit participants identified the following areas for improvement in IT design and development:

1. **Make a step-change improvement in how IT systems are developed:**
   - Implement an integrated, multidisciplinary development process involving human factors as an integral part of the initial design to make IT systems more human-error-resilient.
   - Take quality assurance and MOC processes in IT systems development to the next level.
2. **Use a mental models approach to IT systems design:**
   - Design IT systems to reflect the optimal mental model that is taught rather than training being bent around the way the systems work.
   - Align IT systems to support CRM (a successful approach from aviation) or other such risk-based mental models to strengthen and solidify training, skills and competency development in a CRM approach.
3. **Design intelligent IT systems that expand the cognitive capacities of the operational environment under critical conditions:**
   - Address the complexity of current E&P operational environments that require people to cope with a highly complex technology environment even under critical, time-pressured conditions. (Research in other fields, such as aviation and the chemical process industry, has demonstrated that such expectations set people up for failure, with potentially disastrous consequences.)
   - Provide intelligent supporting systems that can reason with lots of data. To address drilling operations, existing technologies need to be adapted:
     - Uncertainty in drilling is often high. User interface design needs to indicate when data are significantly unreliable.
     - Operational people should be able to press an "I disagree" button on an IT system, and IT system then provide the rationale for its conclusions, ideally expressed in natural language.[20] Thus, intelligent IT systems also become training tools that are improved through human feedback. Something like an "I disagree" button signals to people that the intelligent IT system is there to support "thinking it through" not "just telling you what to do."
     - Pull in a lot more risk-critical data from design tools into the operational (intelligent) environment.
     - Most people do not read the manufacturer's design (risk) study documentation/QRAs/FMEAs before they get into their new car. However, intelligent systems that reason with a multitude of data can easily convert it to information and track low-probability, high-consequence failure modes. This is an area in which IT systems excel, even if such failure modes consist of complex interactions unfolding over longer time periods. For such problems, the failure rate of the human working memory, in particular in an operational environment with lots of distractions and to-do's, is very high.

[20] The Operational Advisories model from UReason (www.ureason.com) is one well-established approach to natural language reasoning based on the intelligent, real-time analysis of large quantities of risk-critical data.

Another approach, adopted in the nuclear industry, is extensive safety automation systems. Unsafe levels trigger safety systems that automatically contain situations without human intervention. Such systems have clear benefits but can have very high costs when an automatic shutdown is unnecessarily triggered, particularly in drilling. Drilling IT systems require more sophisticated intelligence because drilling operations can be highly dynamic. The qualitative differences between different phases of drilling operations can be extreme compared to, for instance, those in a refinery.

7.0 Conclusions

- Leadership is critical to a process safety culture. The decisions, actions, and statements made by leaders, the reward and incentive structures that leaders implement, the way leaders behave and interact with people throughout the organization, and the decisions and actions they take to balance safety against commercial imperatives, directly determine the attitude to safety within an organization.
- More attention needs to be given to the experiences of other industries (like aviation, nuclear, and chemical processing) and how the solutions they developed to limit human factors risk can be adapted for the E&P industry.
- The common regulatory approach of rules and audits for compliance provides no incentives for organizations to go beyond minimal compliance. Regulatory approaches should encourage organizations to continually assess safety performance and to be chronically dissatisfied.
- The extensive use of contractor services and partnerships adds a critical industry-wide component to addressing process safety in the E&P industry. This creates a need for a common definition of competency requirements, particularly in nontechnical skills, and a common terminology in operational integrity/process safety.
- Operational Control of Work offers a framework for formalizing workflows, communication protocols, decision-making rights, competencies and training programs that can address challenges inherent in remote, distributed teams.
- The extensive research into the psychology of how irrationality and cognitive bias lead to poor risk assessment and decision-making and the practical solutions to counter these biases should be used more extensively to improve training of people involved in safety-critical operations in the E&P industry.
- Integrating human factors into IT development is critical. Significant potential exists for human-factors-optimized IT systems to make a larger contribution to eliminating or containing the chains of human errors that are usually behind major process control events.

8.0 Recommendations to SPE

Summit participants identified the following actions SPE could take to move the topics, conclusions, and recommendations from the summit forward in the E&P industry.

1. Form a Technical Section on human factors to bring together specialists and interested parties to create programs, workshops and conferences on issues identified during the summit that need more discussion or industry education. Provide staff resources to help the group accomplish these tasks. (Note: SPE formed

the Human Factors Technical Section in August 2012. Any SPE member can join at http://www.spe.org/network/technicalsections.php.)

2. Establish a discussion list server to extend debate on questions raised, to develop answers and to share best practices. (Note: The SPE Human Factors Technical Section site includes a discussion board the alerts members by email when new postings are made.)
3. Provide information on Operational Control of Work in HSE publications, workshops, and conferences to drive evolution and acceptance of the concept. Use these forums to build consensus on the definition of Operational Control of Work, the protocols and workflows, the choice of performance metrics to drive the required behaviors, the taxonomy of nontechnical skills, and training required to underpin the discipline.
4. Provide information and benchmarking tools to address decision-making issues identified by the summit:
   - Develop SPE scenario-based training to address cognitive bias for the oil and gas industry and provide it globally.
   - Develop methods to share best practices and examples of the incorporation of critical peer review of decisions into procedures.
   - Conduct benchmarking studies on assurance methods for decision-making processes and provide results to the industry.
     - Develop a benchmarking questionnaire/self-assessment tool (a few questions on implementation of decision-making assurance (e.g., scoring 0= not done, 1= started, plan in place, 2= established, still improving, 3= best practice, externally verified).
   - Create a website on decision-making as a source for information.
     - Have the Human Factors Technical Section write introductory text on decision-making and risk-taking behavior in the E&P industry. Provide explanatory text on the relevance of decision-making and the value for business (based on the Center for Chemical Process Safety (CCPS) business case for process safety)
     - Provide models, case studies, and visual information (possibly as downloadable presentations). Establish a repository of case studies that demonstrate the need for operational excellence as a result of better decision-making processes (things that worked).

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