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Integration of Human Factors into Safety and Environmental Management Systems

A. Ciavarelli, Human Factors Associates, Inc.

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Abstract

This paper addresses human performance risk mitigation strategies for incorporation into a Safety and Environmental Management System (SEMS). A framework is provided that identifies human factors considerations and evaluation criteria needed for successful integration of Human Factors into a company's SEMS. A methodology is presented for assessing safety culture and the effectiveness of SEMS implementation. Results from employee surveys, taken across various high-risk industries, will be presented. The survey findings illustrate the common difficulties encountered in establishing and maintaining a strong safety culture and the challenges in achieving an effective SEMS.

Successful integration of Human Factors in SEMS for the Oil and Gas Industry can reduce the risks of accidents and manmade disasters, such as the Macondo Well blowout.

Integrating Human Factors into an SEMS might also improve operational efficiency and effectiveness, because Human Factors considers all levels of performance improvement, the individual worker, the work crew (team), and management. Optimum performance by all employees is necessary in order to attain a high level of organizational reliability.

These are some components of Human Factors that contribute to improved safety performance and might help to prevent human error accidents and organizational failures:

- Clear specification of personnel qualification standards and required knowledge and skill competencies for both workers and supervisors.
- Utilization of advanced simulation training for individuals and teams.
- Improved collection, analysis, and display of safety critical well test, and other operational data, with better human – interface technology, improved operational procedures, and continuous technical training.
- Identifying critical Human Factors hazards and risk mitigation procedures for inclusion in the overall Safety Environment Management Systems.
- Safety training for line supervisors to include human performance and, communication and risk decision- making limitations and High Reliability Organization – HRO – Culture management principles.

- Routine assessment of Safety Climate and Culture based on HRO principles – to include valid metrics, benchmarking and desired norms.

These factors are critical components for an effective SEMS - that if missing, or poorly implemented, can serve as the roots of accidents and manmade disasters like Macondo. They are also key areas of assessment that the author has used across industries to evaluate the strength of safety culture and to judge the effectiveness of a successful integration of Human Factors into a company's SEMS. This methodology and lessons learned from the application of these methods can and should be considered for use in the oil and gas industry for achieving a successful implementation of SEMS.

Introduction

Purpose.

The paper presents a broad overview of methods used by Human Factors professionals in the design, development, implementation, test and evaluation, and operation of complex sociotechnical systems. The intent of the paper is to recommend selected human factors methods that should be integrated into the BSEE SEMS for the offshore oil and gas (O&G) industry.

Background.

A brief review of some of the more notable offshore disasters, and accident statistics is presented as a backdrop for identifying methodologies intended to help reduce human error accidents. The author believes that successful integration of key human factors engineering methods and periodic safety culture assessments would help to reduce the chances of system failure and injury accidents, and the suggested organizational interventions would reduce the risk of catastrophic accidents like the Deepwater Horizon.

Discussion

Human Factors in Offshore Accidents and Disasters.

Offshore Occupational Accident Occurrences.

The Center for Disease Control and Prevention (CDC, 2013) reported that during the 2003 to 2010 period, the US O&G industry had an overall fatality rate that was *seven times higher than all U.S. workers* in other industries. (27.1% versus 3.8% deaths for 100,000 workers). There were 128 fatalities that occurred during offshore O&G operations, with transportation events as the leading cause of death (65 fatalities, or 51%). The majority of the transportation accidents were aircraft crashes (49 fatalities, or 75%).

Christou and Konstantinidou (2012) conducted a comprehensive analysis of the world Offshore Accident Databank (WOAD) database and extracted the percent of accidents due to various human errors and equipment failures.

Most human errors in this particular database were attributed to the use of unsafe procedures (37%) or unsafe acts (44%). Other human errors were improper design (8%) and miscellaneous errors (12%). The authors commented, however, that the accident investigation process *did not include possible contributing human factors* due to management and organizational issues.

BSEE (2016) reports a downward trend in fatal injuries and accidents over the five-year period (2011 - 2015) following the Deepwater Horizon - Macondo well blowout, as shown in **Table 1** below:

Table 1–Fatal Accidents in Gulf of Mexico

2008	2009	2010	2011	2012	2013	2014	2015
11	4	12	3	4	3	1	0

It is not known if the downward trend is due to new process safety measures emphasized in the aftermath of the Deepwater Horizon disaster or to cutbacks in the number of operating oil rigs over the past few years due to the oil price decline.

Offshore Oil and Gas Operations Disasters.

Piper Alpha – was an accident on a North Sea oil production platform, operated by Occidental Petroleum (Caledonia) Ltd., which resulted in the deaths of 167 workers in 1988. Pate' Cornell (1992), in her comprehensive analysis of the accident, concluded that the most significant causes were "rooted in the organization, its structure, procedures and culture." A few of the issues mentioned in her analysis were (p. 226):

- Poor judgment regarding decisions between safety and production
- Flaws in design and use of design guidelines
- Lack of attention to equipment maintenance and inspection
- Poor work and supervisory information transfer

Macondo – The Deepwater Horizon drilling rig accident that occurred on the Macondo exploratory well in 2010 is a highly publicized major disaster due to an oil well blowout and fire that killed 11 workers and resulted in devastating damage to coastal waters from an uncontained oil spill.

There was common agreement among several accident investigation and study reports as to the influence of human factors. Some of the main issues identified by accident studies are factors that can be traced to a series of mistakes and risky decision errors made by BP and its contractors, such as:

- Pressure to quickly complete well abandonment operations at the risk of safety.
- Management "complacency" on the Deepwater Horizon rig as the rig owner (Transocean) was in process of celebrating an accident free seven-year period.
- Conducting simultaneous operations accompanied by poor work team communications regarding correct operating procedures, and well conditions.
- Inappropriate cement mixture and cementing procedures.
- Misinterpretation of well pressure test data.
- Failure to follow best practices for well drilling and abandonment procedures.
- Failure to recognize and act upon early signs of well disintegration and control (earlier well "kicks" - upsurges in well fluids and rubber debris – likely from a damaged blowout preventer (BOP).
- Failure to correctly operate and maintain safety critical equipment.

(Adapted from reports of National Academy of Sciences, 2011; National Committee, 2011; DHSG, 2011; Wassel, 2012)

It is abundantly clear from the accident reports of the Piper Alpha and Deepwater Horizon offshore platform disasters that the main causes of these disasters were not necessarily found only in the physical failure of technology or equipment. But rather these accidents were mistakes made in the organizational decision processes and the failure to follow prescribed best practices or standard procedures – ***the causes were in fact, human failures.*** The facts surrounding these cases, and other offshore O&G accidents, support the idea of paying *closer attention to organizational and human performance factors* as essential to the effective development and implementation of the regulatory rules and O&G industry safety management processes.

Organizational Accidents.

Figure 1 shows a graphic description of a so-called organizational accident model used as a point of illustration by Deepwater Horizon Study Group's analysis of the Macondo disaster (DHSG, 2011). The figure is based on the organizational accident model developed by Reason (2010, 1997) and depicts the breakdown in safety barriers running from poor design through mistakes and errors made during the planning and execution of an organization's operations. This figure shows that an accident develops when the hazards confronting a system are able to successfully penetrate the barriers through aligned *holes* (defects, deficiencies) in the barriers formed by the Risk Control System (RCS).

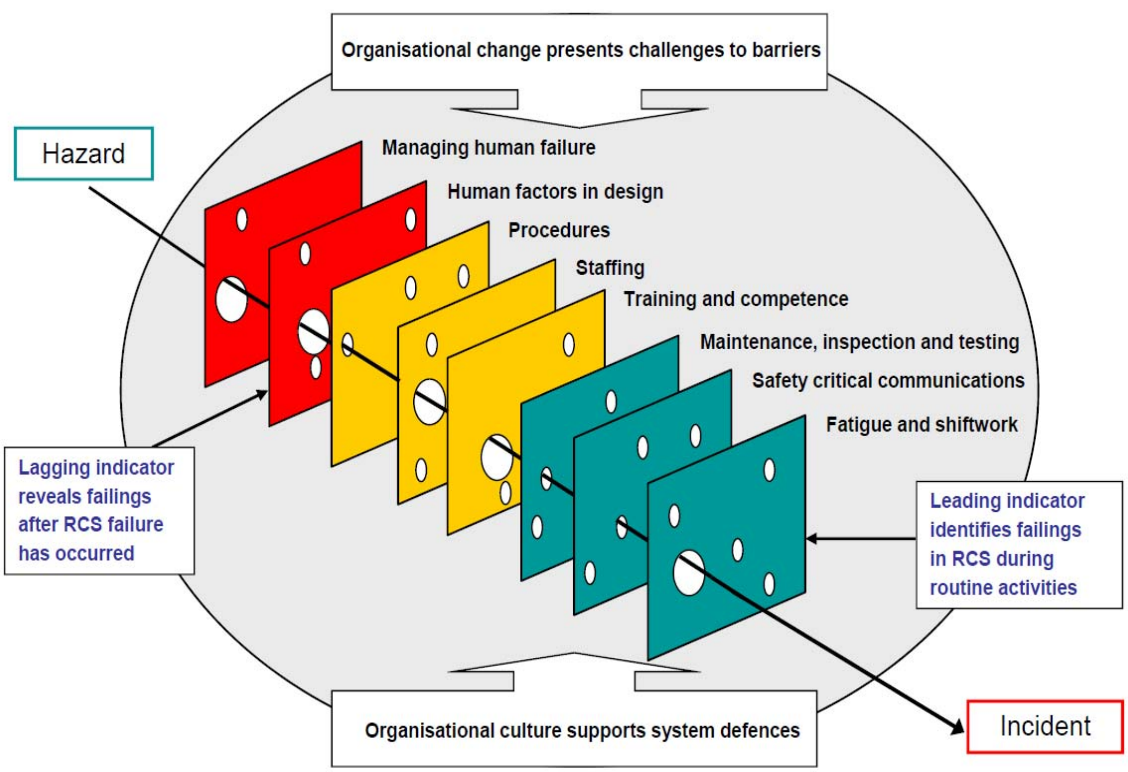

Figure 1–Organizational Factors in Accidents and Disasters
Center for Risk Management, UC Berkeley (DHSG 2011, p.75)

The DHSG study of the Deepwater Horizon disaster focused on the concept of a High Reliability Organization (HRO). HRO's are organizations that are able to operate in high hazard environments, with a low accident rate because the leadership of an HRO is dedicated to conducting safe operations.

Safety is achieved because leadership places safety as a high order priority. HRO management provides adequate resources for safety, and effectively manages risk and establishes the policies and procedures necessary to operate safely (Lekka, 2011; Roberts and Bea, 2001; Roberts, 1990-1993).

The concept of the High Reliability Organizations (HRO) was created by social scientists and engineers like Roberts and Bea (2001) and Weick (1999). HRO was brought to broader exposure in a book published by Karl Weick and Kathleen Sutcliffe in 2007 entitled "Managing the Unexpected."

The basic concept of HRO is that there are some organizations that function very effectively and safely because their leadership and organizational management are able to control risks in spite of having to operate in a very hazardous environment. HRO specialists often mention the U.S. Navy – particularly Naval Aviation operating on Aircraft Carriers – as exemplary HRO organizations (Roberts, Rousseau, and La Porte, 1994). HRO advocates also mention the nuclear industry, commercial aviation and air traffic control organizations as operating in a highly reliable way (Roberts, 1993).

There are different views regarding which attributes organizations must have in order to function as an HRO. Some of the more common attributes considered by Bea and Roberts (2000) and Weick and Sutcliffe (2007) include: (1) clear leadership commitment to safety, (2) intense attention to potential failures, (3) a non-punitive safety reporting culture, (4) allowing the critical risk decisions to be made by the most qualified individual, and (5) not relying solely on authority to make risk decisions.

Safety Culture.

James Reason, a well-known organizational safety scientist, succinctly defines the components of organizational culture, as follows:

> **Shared Values** *(What is important)* and **Beliefs** *(How things work)* that interact with an organizations structures and control systems to produce **Behavioral Norms** *(The way things work around here).* (Reason 1997, p.192)

The safety culture focuses on issues regarding what is and what is not believed to be safe, and the accepted values and norms of safe behavior. The safety culture underlies what attitudes and behaviors are rewarded and what attitudes and behaviors are punished or corrected. In a just culture frontline workers are comfortable disclosing their own errors – but they are accountable for any willful violation of rules or procedures.

A "just culture" recognizes that individual practitioners should not be held accountable for system failings over which they have no control *(*AHRQ, 2008). Some of the key aspects of a "strong", and "just" safety culture are:

- Shared values about what is safe and unsafe
- Common beliefs about how to conduct safe operations
- Open Reporting – "just culture" advocacy
- Behavioral norms that govern risk-taking, everyday procedures and precautions
- Transmission of values, beliefs and accepted practices to others

It was apparent, as mentioned earlier in this report, that both the Piper Alpha and Macondo offshore platform disasters also were instances of organizational failure.

It also should not go without comment that the underlying root cause of such failures are rooted in a culture that pursues a path that does not adequately address operational risks – to the point of ignoring some obvious deterioration in conditions that lead to the final disasters. It is especially salient in the Macondo well blowout, during which operators deviated from best practices for well abandonment, and then ignored or rationalized anomalous signs indicating the loss of well integrity.

The importance of safety culture was a topic discussed in several Macondo accident studies (NAS, 2011; NAS, 2012; DHSG, 2011). Apparently, the primary Macondo operating company (BP) had established a reputation for *not promoting a strong safety culture*, as was cited in the documented cases of Macondo and also the Texas City Oil Refinery explosion as reported by the Chemical Safety Board (CSB, 2007). Lustgarten (2012) discusses the history of BP and an eroding safety culture leading up to the Macondo oil well blowout disaster. It is clear from notable O&G offshore disasters like Piper Alpha and Macondo that the risk management process needs to pay closer attention to understanding the relationship between a weak safety culture and "human error." There needs to be a better awareness of the consequences of failure by giving ample consideration to the potential catastrophic impact on the environment in any planned technology application where an equipment failure – or more likely a decision mistake or human error – can lead to serious threats to human health and safety, and severe environmental impact. Safety culture then might be considered a term that can be used to depict accidents of the sort in which leadership has failed to recognize inherent operational risks, and has not taken appropriate measures to ensure the safety of key operations.

Some of the human factor issues and conditions reflecting a weak safety culture include:

- Poor risk perception and accident threat recognition
- Lack of leadership commitment to safeguards
- Inadequate management oversight and control
- Inadequate or unclear risk-decision criteria
- Too difficult to report safety concerns and at-risk decisions/behaviors
- Policy and incentives reward excess risk taking
- Culture does not support desired attitudes/behavior
- Unhealthy attitudes about safety, risk tolerance, and performance expectations
- Inadequate performance standards or poor training
- Schedule and production dominance over safety

Emergence of Safety and Environment Management Systems (SEMS).

SEMS is envisioned as a performance based safety management process, rather than a prescriptive one that relies on external regulatory operational inspection process.

> *SEMS is a safety management system (SEMS) aimed at shifting from a completely prescriptive regulatory approach to one that is proactive, risk based, and goal oriented in an attempt to improve safety and reduce the likelihood that events similar to the Macondo incident will reoccur. (National Academy of Sciences, 2012, p.1)*

SEMS Development for Offshore O&G Operations.

The Bureau of Ocean Energy Management Regulation and Enforcement (BOEMRE) issued the "final rule", October 2010, for the Safety and Environmental Management Systems (SEMS). This rule represented a paradigm shift in the approach to managing safety. The SEMS approach moved away from total reliance on a safety inspection process, and worked toward shifting the process of safety assurance and management to the service operators.

O&G industry operators now would be more responsible to indicate how they would manage safety and how they would implement procedures that would help to prevent personnel injuries, and help to prevent spills and environmental damage.

This new rule was based upon the use of the American Petroleum Institute (API) developed API Recommended Practice (RP) 75, *Recommended Practice for Development of a Safety and Environmental Management Program for Offshore Operations and Facilities* (API, 1994; API, 2004). Offshore operators were required to comply with SEMS implementation by November 15, 2011. The federal regulatory agency proposed new rule making that would require each offshore operator to "implement, maintain, and operate" a SEMS program in accordance with four key elements of the Recommended Practice. Those four elements are: (1) Hazards Analysis, (2) Management of Change, (3) Standard Operating Procedures, and (4) Mechanical Integrity.

The change over to SEMS was accelerated and strongly promoted following the 2010 Macondo well blowout. The final SEMS Rule I was promulgated in the Federal Register (30 CFR 250, Subpart S) on October 15, 2010, and became effective on November 15, 2011. SEMS I includes, hazard and risk analysis, operating procedures, training and safe practices, improved training, emergency response plans, and more inclusive record keeping.

The Bureau of Safety and Environmental Enforcement (BSEE) was formed by the U.S. Department of the Interior in October 2011. BSEE then took responsibility for continuing the SEMS implementation and enforcement. In the 2011 regulation, BSEE mandated a requirement for all operators to use SEMS to manage safety by considering environmental hazards and impacts of operations during design, construction, operation, inspection, and maintenance of all new and existing offshore facilities. Operators were required to conduct a safety audit and to submit results by November 15, 2013.

SEMS II was subsequently formulated and put into effect on June 4, 2013, and all audits were required to be compliant by June 4, 2015. SEMS II added several important rules to SEMS, including developing and implementing a "stop work authority" that enables any worker to request stopping work if he/she observes an unsafe condition. SEMS II also includes rules required to promote greater engagement of employees to participate in identifying and mitigating work hazards, and encourages more active safety reporting.

More detailed Information regarding the objectives, policy and SEMS regulatory policy can be obtained from the BSEE website below:

http://www.bsee.gov/Regulations-and-Guidance/Safety-and-Environmental-Management-Systems---SEMS/Safety-and-Environmental-Management-Systems---SEMS/

Operators responded to SEMS performance requirements in a variety of ways, some of which were not considered adequate and fully compliant (Morris, 2014). Operators varied considerably in their internal audit process and audit submissions. Some only completed very top-level checklists, with little clarity on the actual state of safety and SEMS implementation. *Furthermore, operators might not have understood the most appropriate human factors methodologies, which are needed to reduce the likelihood of human errors and organizational accidents.*

Human Factors Concerns for Offshore O&G Operations.

Most accidents and disasters result from unsafe operational conditions, poor risk decisions, or safety system deficiencies, rather than a single unsafe act by a front line worker. Here are a few key issues regarding the types of failures that lead to injury accidents and organizational disasters:

Human Factors Contributing to Current Accidents.

Following is a partial list of human-related factors that may contribute to accidents:

- Failure to recognize the influence of crew behaviors and safety culture on procedural compliance and risk decisions.
- Inadequate leadership training and work crew training.
- Lack of a non-punitive hazard and incident reporting system and availability of an industry wide data sharing process.
- Focus on equipment/material failure rather than human performance factors and error prone system designs.

Challenges for Future Offshore Oil and Gas Operations.

Challenges that may be encountered in future O&G operations include:

- Lack of inclusion of human factors in the design and operation of remote sensing and command control systems.
- Emerging cyber and malware threats, given growth in information technology (IT).
- Tendency to overuse automation as a means to reduce workload and to eliminate the problem of human error.
- Economic impact of oil demand and supply of available manpower, and of capital requirements for equipment and supplies, and new technologies.

Human Factors Considerations for SEMS.

For purposes of this paper, a key question is whether or not prescriptions in BSEE SEMS adequately address preventing the common human factors failures associated with the O&G accidents and disasters – as well as the anticipated changes in the offshore exploration and production operations and new technologies.

Integration of human factors in SEMS for the O&G industry can reduce the risks of accidents and disasters, such as the Macondo well blowout. Human factors' methods include: human factors hazard analysis, user-centered design of command and control systems, use of advanced simulation for training operators and decision makers, crew resource management training, implementation of a non-punitive safety reporting system, and use of reliable and valid methods to assess safety culture and evaluate the effectiveness of SEMS implementation. Human factors place great emphasis on managing safety in keeping with process safety doctrine, by applying good design principles, engineering, and operating and maintenance practices (OGP, 2013).

Integrating human factors into an SEMS might also improve operational efficiency and effectiveness, because human factors engineering considers all levels of performance improvement - the individual worker, the work crew (team), and management. Optimum performance by all employees and contractors is necessary in order to attain a high level of organizational reliability.

Some key components of human factors that contribute to improved safety performance and might help to prevent human error accidents and organizational failures are:

- Clear specification of personnel qualification standards and required knowledge and skill competencies for both workers and supervisors.
- Scenario – based simulation training for individuals and teams for normal and emergency operations.

- Improved collection, analysis, and display of safety critical well test data, and other operational data, with better human - interface technology, improved operational procedures, and continuous technical training.
- Identifying critical human factors hazards and risk mitigation procedures for inclusion in the overall SEMS.
- Safety training for line supervisors to include human performance and, communication and risk decision-making limitations, and HRO – Culture Management principles.
- Creating a clear channel for open reporting of safety concerns and feedback from front line workers to management (without fear of reprisal).
- Conducting periodic assessments of a Safety Climate and Culture that is based on HRO principles - to include valid metrics, benchmarking, and desired norms.

These factors are critical components for an effective SEMS – if missing, or poorly implemented, they can serve as the roots of accidents and manmade disasters like Macondo.

Human Factors Methods: Levels of Application.

One should think of "Human Factors" as those factors or variables that affect the performance of individuals, work crews and organizations in a work environment.

Each area involving human performance factors is briefly summarized below:

Individual Worker – considerations include, but are not limited to: personnel qualifications, training, and experience requirements; equipment design and system complexity; worker task complexity, workspace design and working conditions; workload and fatigue; local supervision (Salvendy, 1997; Wickens, Lee, Liu, and Becker, 2004).

Crew/Team – considerations include, but are not limited to: crew composition (mixed skill set, and national origin – language and culture); work leader's use of authority, supervisory style and oversight permissions; on the job communications and prescribed communication protocols; task coordination required; and crew training in teamwork or crew resource training (Helmreich and Merritt, 2000; Bjellos, 2012).

Organization – includes leadership style and commitment to safe operations versus production goals; adequacy of resources (time and materials); working conditions; and organizational and workplace cultures (Bea and Roberts, 2000; Roberts, 1993; Weick and Sutcliffe, 2007).

Human Factors Methods for Technology Development.

Brief definitions for some of the human factors methods used at various stages of system development are presented below:

HFE-Ergonomics – *HFE* at its basic level focuses on designing human interfaces (be they physical- workstation and work environment or interactive computer systems) with an emphasis on understanding the human task requirements, human performance limitations, and the operating environment. HFE addresses workstation design, and design standards for controls and displays, and physical work environment, including stairs, walkways, and crawlspaces (Salvendy, 1997; Helander, 1997; Hendrick, 2000; Wickens et al., 2004; API, 2001, 2008; ISO 2000, 2003, 2008).

Human–Computer Interaction – *HCI* – is a specialized field of HFE that deals specifically with computer-based interactive systems. This subfield introduced and elaborated on usability testing that provides a methodology to test and evaluate user satisfaction and potential errors of operation while interacting with a new system under controlled laboratory conditions. HCI focuses on design process, guidelines, and standards for interacting with computer based systems (Jacko, J.A., 2013; Stone, Jarrett, Woodroffe, and Minocha, 2005).

Human System Integration – *HSI* – expands the methodology and scope of human factors engineering to include consideration of the total system, human, machine, teamwork, working conditions, and physical environment, as well as supervisory and management oversight and practices (APA, 2015; ASTM, 2015; Booher, 2003; DOD, 2011; OGP 2013).

Crew Resource Management – *CRM* – is based upon a need for crews to develop improved communication and coordination skills and to offset "group" behavior failures due to poor team leadership, tendency for conformity to a group norm ("group think'), and risk misperceptions due to flawed group (team) failure to communicate perceived hazards (Helmreich and Merritt, 2000).

Organizational Climate–Culture Assessment – Workers are embedded in an organizational climate and underlying "safety culture" that establishes what is perceived to be or believed to be safe and free of exceptional risk. A flawed safety culture is all too often at the root of a major or catastrophic accident like Macondo. Safety audits frequently to not conduct a full evaluation of the safety culture (Ciavarelli, 2007, 2008; Flin, Mearns, O'Connor, and Bryden, 2000).

Table 2, *Human Factors Over Technology / System Life Cycle*, below, shows the application of various human factors methods against different stages of engineering development – Discovery, Design, Development, Testing, and Deployment.

During early phases of development, the primary consideration is given to designing error tolerant human – interactive systems, such as well monitoring systems, command – control systems and other control – display systems such as those used for operating remote sensing vehicles and platforms. In addition, attention is paid to ergonomic design of workstations and the physical work environment in order to reduce work injuries. After Deployment, we are most concerned with operating and maintaining performance as safely and effectively as possible. At this stage the selection and training of individuals and teams is critical, and it is most important that corporate leadership and local supervision are committed to, and engaged in, establishing sound safety policies and procedures, and providing adequate resources to ensure the that operations can be safely executed.

Table 2 Human Factors over Technology / System Life Cycle

Discovery – Technology /system needs assessment and requirements definition
Development – Human centered – HFE-HSI design process – Job Task Analysis, Hazards and Risk Assessment – Use of design criteria/standards – Adherence to regulatory rules – Prototyping; testing and production – Specifications for operator/maintainer training qualifications and – Definition of Training requirements
Test and Evaluation – Functional specification and human – system interaction usability tests
Deployment – Field acceptance testing – Standard procedures and regulatory compliance – Operator/maintainer training – Crew/team training (CRM) – Local on work site supervision – Workload and Fatigue management – Safety Reporting of hazards, incidents and equipment/system deficiencies – Safety Climate – Culture Assessments (including corporate leadership commitment to safety; published policy; supportive structure; open reporting; safety culture; and adequacy of personnel and safety system resources)

There are many human factors design standards and guidelines that can be used during system design and development, including: *Human-centered design processes for interactive systems, ISO 13407*, Ergonomics principles in the *design of work systems, ISO 6385*, *Ergonomic Design of Control Centers, ISO 11064.* ISO design standards available at: http://www.iso.org/iso/home/store/catalogue_ics.htm. Other guidelines and design standards that directly focus on O&G industry facility development include:

API RP 14J, *Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities*. 2001. Washington, DC: API.

ASTM F1337-10. ASTM, *Standard Practice for Human Systems Integration Program Requirements for Ships and Marine Systems, Equipment, and Facilities*. 2015. ASTM International.

Finally, two excellent organizations that provide updated information and resources for Human Factors Engineering, User Centered Design, and Human System Integration are:

National Academy of Sciences: http://sites.nationalacademies.org/DBASSE/BOHSI/index.htm

National Aeronautics and Space Administration: http://humansystems.arc.nasa.gov/

Human Factors System Design Principles for Reducing Error.

When system developers and engineers review various technology strategies and process alternatives, it is recommended that attention be given to determining whether or not the methods and process alternative options for selecting the best available and safest technologies include consideration to the critical human factors, including the use of a human-centered design during system development and technology selection. Human factors considerations should begin early in the design process, and continue throughout technology development and deployment in order to adequately cover critical human performance and safety issues over the entire life cycle of the technology.

It is especially important that critical data monitoring systems be carefully designed with attention to human factors, including human – machine interfaces used for oilrig command control operations centers (Operational Centers) and oil well data monitoring systems (Driller's Data Display Stations). HFE design criteria, operator qualifications, and training requirements should be included in any defined technology selection or development process for all systems in which humans interact with and depend upon for critical operational and safety information.

Some of the important human factors' fundamentals that should be addressed during any human–machine/system development, acceptance and application are as follows:

1. How are system, and user, interface system information requirements determined?
2. Is the target user of the technology involved in the design and evaluation of the system under development?
3. Are Human Factors Engineering design standards or usability design criteria applied?
4. Are lessons learned from human error accidents part of the design database?
5. Do designers apply a human factors knowledge base on equipment automation issues?
6. Have the designers carefully evaluated the most appropriate use of automation?
7. Do designers apply a human factors knowledge base on the pros and cons of selecting analog verses digital displays?
8. Are there qualification standards specified for equipment operators and maintainers?
9. Are training standards and training programs for operators and maintainers available?
10. Are training records kept regarding trainee/operator/maintainer qualifications?
11. Is there an appropriate cost – effective means to use training simulation devices to teach the correct operation and maintenance procedures for safety critical equipment?
12. Is the environment, including hazards and risks, defined in the job task analysis?
13. Are organizational factors, such as management commitment to safety, and adequate procedures, manpower and training, considered prior to technology deployment?

Use of Automated Systems.

It is believed that O&G, like other industries, will experience a substantial growth in the application of remote sensing and controls systems. Such systems are used for obtaining and observing oil well drilling and production measures, as well as the operation of remotely controlled submersible vehicles used for exploration and well integrity tests.

These systems are quite sophisticated in their operation and maintenance – and all pose a possibility of human error due to the complexity of control and display interfaces.

These systems have a high potential for erroneous user inputs and possible misinterpretation of data displays. Operators, now and in the future, will base critical risk decisions on data obtained from remote sensing and display systems. As we have seen in the case of Macondo, decisions based on well measures (pressure and chemical composition of well fluids) – if wrong – can have serious consequences to health, safety, and environment.

Further, there is increased use of technological innovations for reducing operator workload and to improve task efficiency through application of automation – using advanced computer driven algorithms that sometimes include artificial intelligence (intelligent agents). For example, Norway's Drilling Systems is designing robots to take over the repeatable tasks now done by roughnecks and pipe handlers.

> *In the longer term, the O&G industry will replace humans with robots. Norway's Drilling Systems is designing robots to take over the repeatable tasks now done by roughnecks and pipe handlers. The Company predicts that fully automated rigs will someday travel to drill sites guided by satellite* (Weaver, 2014, p2).

We have learned from the aviation industry that the introduction of high levels of automation to replace human operator functions is not without risk and difficulties. The risks imposed with advanced automation technology include operator complacency (that automation is working as intended – when it in fact is not) and operator confusion regarding control and display modes of operation and automated functions performed. The level of complexity and operation by the users has often resulted in a failure to correctly interpret the actual operating state of a system (such as aircraft flight control accuracy and system status data). Errors have been made in determining exactly what functions the automated system is actually performing, and how to recover from erroneous inputs that cause serious system malfunction (Lee, 2008; Sheridan, 2001).

Human Factors and the Systems Approach.

HFE embraces the "systems approach" in the design and development of new technologically based systems. This approach calls for consideration of how the system operator and maintainer, or any worker for that matter, would actually perform their job.

The systems approach often calls for specific abilities or specialized educational requirements in jobs requiring complex skilled performance like operation of aircraft or the use of other complex control systems, with attention to hazard exposure and human survivability.

In the larger context of human factors application in large-scale system development, application of the "systems approach" is commonly referred to as Human System Integration, or HSI. HSI originated as an institutionalized system-engineering model used principally by the Department of Defense (DoD) and its major military departments, US Navy, Air Force, and Army (APA 2015; Booher, 2003; DOD 2011; USN/AEP 2012,).

However, the HSI idea has taken hold and is considered an important methodology for the design and development of all complex sociotechnical systems - those systems that include multiple personnel, and technology driven production and service operations. HSI can be applied on a smaller scale, sometimes only selecting various components of his, such as HFE, Habitability, or Training for specific consideration analysis or application.

Here are some of top-level components of HSI (Adapted from Pharmer (2012)).

Manpower – Training

Health/Safety – **HUMAN SYSTEMS INTEGRATION** – Environment

Survivability – Habitability

Human Factors Methods for Operations.

Crew Resource Management (CRM).

CRM is a form of "work team training" that has become a regular means to train airline personnel (pilots, cabin crew, aircraft mechanics, ramp workers, and others) who often work together to complete daily operational tasks. The training originated as a result of several major air crashes that showed clear breakdowns in crew communication and coordination as critical links in the causal chain of the air crashes. The training has become a standard training requirement in the aviation and aerospace industry, the nuclear industry, and in Hospital surgery and emergency rooms. The basis for CRM training is to offset human errors due to miscommunication among work team members, and to reduce the tendency for work crews to challenge their supervisors during operations, when a lower ranking work crew member observes an anomalous condition, safety hazard, or impending failure of an operating system.

In some instances, CRM training also provides cross-cultural approaches serving to improve communication among work teams and supervisors that might be from different national cultures. As workers from different countries or nationalities often operate offshore platforms, a cross, often a cultural, approach might be a wise training strategy (Helmreich and Merritt, 2000; Bjellos, 2012).

Non-Punitive Safety Reporting System.

Non-punitive safety reporting has become an accepted practice for promoting a strong safety culture. The idea is based on the fact that there are many more incidents that occur compared to accidents, and the type and frequency of incidents provides a valuable database for judging risks associated the safety of operations, and a means to reduce the chances of an accident by early detection and removal of hazards identified, or mitigation of accident risk.

The reporting system should operate as an independent, external body, the guaranteed protection of reporter confidentiality; and the non-punitive nature of the reporting allow the people on the frontline to report within a protected mechanism. In the aviation community, the so-called Aviation Safety Reporting System (ASRS) has successfully attained limited legal immunity protection resulting from reporting a safety violation under FAA-AC00-46D (Connell, 2013). Confidential reports are submitted by front line personnel from the aviation community (e.g., pilots, flight crew, or air traffic controllers) are used to publish safety alerts, as well as to provide a body of data for analyzing hazardous trends and resolving safety-related problems.

Safety Climate-Culture and Safety of Operations.

A High Reliability Organization (HRO) is believed to have a strongly ingrained safety culture, and an organizational climate that actively promotes safety. So it would seem that some method to assess the organizational climate (commitment to safety by leadership), and the strength of the safety culture, would be an integral part of an assessment the effectiveness of an SEMS.

The assessment of SEMS effectiveness, including inspections, internal and external audits, and non-punitive safety reporting, etc., can, and should, be accompanied by assessment of the organization's safety climate and culture – especially as the O&G industry is fixed on moving from a "compliance mentality" to a "culture of safety."

The National Academy of Sciences (2012) reviewed options for estimating the effectiveness of SEMS and recommended a "holistic" approach that included inspections, internal (operator) and external (BSEE) audits, use of key performance indicators, and inclusion of a "whistle blower" program for anonymous reporting of safety concerns. Surprisingly, the authors discuss the importance of safety culture, and the importance of the industry moving away from a "compliance mentality", but they did not specifically suggest metrics that directly assess organizational climate and culture.

Safety climate and culture are key areas of assessment that the author has used across industries to evaluate the strength of safety culture and to judge the effectiveness of a successful integration of human factors into a company's SEMS. This methodology and lessons learned from the application of these methods can and should be considered for use in the Oil and Gas Industry for achieving a successful implementation of SEMS.

Assessing Safety Climate and Culture.

Flin, Mearns, O'Connor, and Brydon, (2000) discuss the differences between safety culture and safety climate. Safety culture typically refers to the values, beliefs, and norms of behavior that are prevalent in an organization. Safety culture is considered by most safety scientists to be difficult, if not impossible, to measure directly. So safety experts often turn to the use of metrics related to Safety Climate. Safety Climate is considered a measureable "surface feature" of safety culture. Safety Climate metrics, derived from employee surveys, are used to determine employee attitudes and opinions regarding the perceived leadership commitment to safe operations, and to examine employee agreement ratings that management has provided the policies, procedures, and resources to safely operate in hazardous environments. Measures of safety climate are considered one of the key indicators of the underlying safety culture.

Following a rash of major aircraft accidents in Naval Aviation from 1997 – 2000, the U.S. Naval Aviation implemented a number of enhancements to Aviation safety management system, including improvements to CRM training, new guidelines for operational risk management, and greater focus on understanding human error. Another key change in U.S. Naval Aviation was the implementation of "safety climate and culture" assessment.

A web-based Command Climate Safety Assessment (CSA) was developed to provide U.S. Naval Commanders with anonymous and confidential feedback from Naval personnel regarding a commands safety climate and the effectiveness of the Commands safety management system (Ciavarelli, 1997; Ciavarelli, Figlock, Sengupta, and Roberts, 2001). The CSA process was based upon a body of literature related to high reliability organizations and safety climate and culture research and application. Ciavarelli (2007, 2008) discussed the application of similar methods in commercial aviation and other high hazard industries.

Safety Climate – Culture Assessment in Civilian Organizations.

As a result of the success of applying survey methodology to assess U.S. Naval Aviation organizations in terms of their overall safety climate and organizational effectiveness, the survey methodology migrated out to civilian aviation, aerospace, and healthcare services. Ciavarelli (2007) has developed and applied similar safety climate and assessment methods across numerous high-hazard civilian business sectors, including the commercial aviation and aerospace industry, O&G helicopter air transport, air ambulance services, critical care (ICU) facilities, electric utility, and government agencies, Lawrence Livermore National Laboratory, FAA Air Traffic Control, and both NASA Space Centers and NASA Flight Research Centers. The survey can be adapted to any organization that by necessity operates in high hazard, high-risk environment because survey items represent attributes related to organizational reliability and effectiveness.

The survey instrument has evolved over the past 15 years and is referred to as the *Organizational Safety Effectiveness Survey (OSES).* OSES is composed of survey items that address typical areas of safety climate, culture, and organizational effectiveness.

It should be emphasized that OSES measures the dimension of "safety climate", and that the survey is used in conjunction with in depth interviews, focus group discussion, and a review of an organization's policies, procedures, and safety process documentation in order to gain a better perspective on safety culture.

OSES Measurement Framework.

NASA sponsored an OSES statistical validation and questionnaire improvement study in which extensive Factor Analysis and measurement reliability testing was performed (Ciavarelli, 2012). The study produced a revised Measurement Framework that identified critical areas of a high-reliability organization's safety culture and the degree of organizational effectiveness. The resulting Measurement Framework is shown below in **Table 3.** It is believed that survey questionnaire items, like those shown in the Table 2 below, are useful in capturing the perceptions of survey respondents regarding whether or not their work group or organization is truly operating as a high reliability organization with a healthy safety culture. The OSES instrument is administered over the Web and provides online diagnostic analysis and feedback to safety and management personnel regarding safety climate and culture, and organizational effectiveness.

Table 3–Organizational Safety Effectiveness Assessment Framework

ASSESSMENT AREAS (FACTORS)	SAMPLE SURVYE ITEMS
Safety Climate – Culture - SCC	• All employees feel free to report errors without fear of retribution.
Safety Supervision - SSM	• My supervisor sets the example for compliance with standard procedures.
Organizational Effectiveness - ORG	• I believe that morale is high at in my work group or base.
Safety Information Management - SIM	• I get all the information that I need to perform my job safely.
Workload/Fatigue Management - WFM	• I seldom feel overburdened by my daily work assignments • I can usually complete my assigned tasks during my shift.

Part of the survey analysis uses a metric referred to as *Favorability Agreement.* This metric is reported in terms of favorability agreement percentages based on the 1 to 5-point Likert type rating scale. Values assigned to the rating scale are based upon the level of agreement on the scale item, ranging from a lowest agreement level of 1.0 to a highest agreement level of 5.

The rating scale spectrum is: 1 = Strongly Disagree; 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. All rating items are positive statements such that a high agreement rating of 4 or 5 is favorable and ratings of 1 or 2 on the scale are considered unfavorable and "problematic."

Figures 2 and **3** show examples of survey results feedback charts provided to safety personnel and line managers. Figure 2 is used as a diagnostic framework for assessing key components of safety climate and culture, as well as several areas of assessment related to safety management and organizational effectiveness.

Figure 3 shows the relative percentage of responses over the 5-point scale. Data presented in these two charts can be applied as "normalized" statistical summaries for benchmark comparisons over time for separate survey administrations, or for comparing results across operational domains.

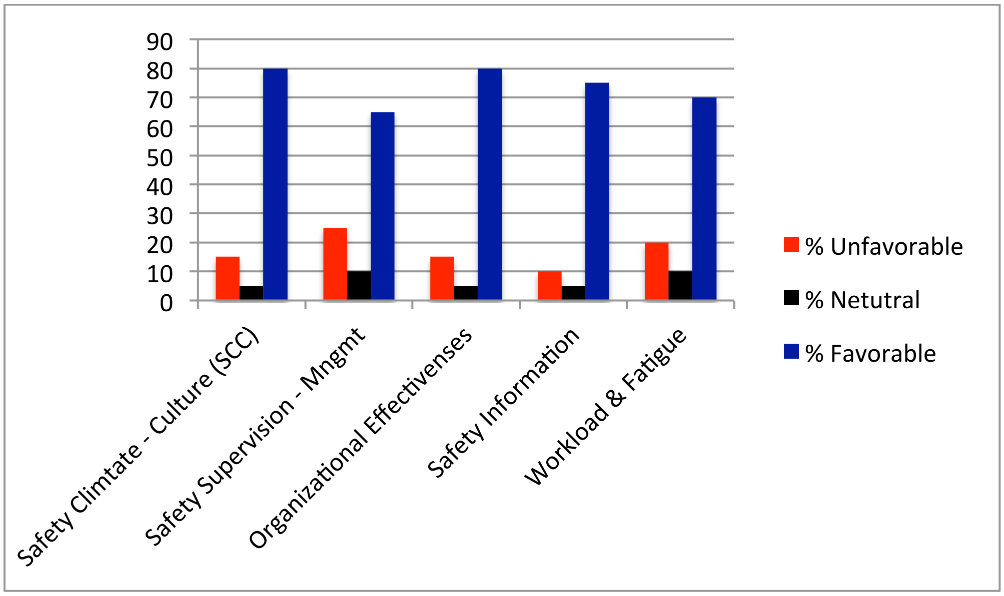

Figure 2—Percent Favorable Rating Responses Compared Across OSES Assessment Areas (fictitious data)

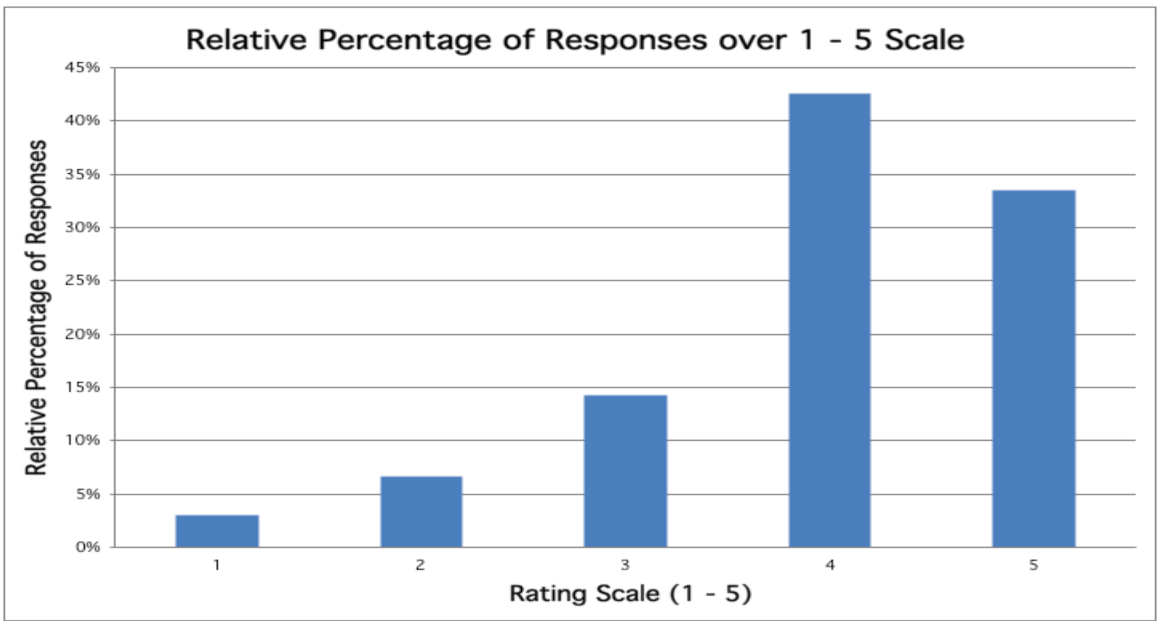

Figure 3–Percent Distribution of Survey Responses (fictitious data)

Some of the OSES Assessment areas found to be most problematic across industries are:

- Schedule Pressure – rush to complete
- Staff Shortages – not enough qualified personnel
- Lack of trust between workers and supervisors
- Reluctance to Report (safety concerns)
- Poor communications up and down the organization
- Cost cutting impacts safety

Table 4 below shows the percentage of problematic ratings (survey items receiving 1 and 2 on a 5-point scale) compared across different domains (Ciavarelli, 2007, 2008).

Table 4–Comparison of Results Taken Across Industries *

(Problematic percentages are 1 - 2 ratings on a 5-point scale)

Comparison	% Problematic
U.S. Naval Aviation	4.1%
U.S. Hospitals	12.1%
General Aviation (ground)	14.4%
Air Medical Transport	15.0%
Energy – Power Utility	10.6%
Offshore Helicopter Transport	19.2%

*** Data taken from 2006 - 2010**

Our findings, which were taken across 15 years of survey testing, show statistically significant differences in overall safety climate ratings between supervisors and workers. Front line workers, safety climate ratings are much lower, showing workers to be far more pessimistic with regard to the safety climate and the effectiveness of safety processes compared to supervisory staff and executives (Ciavarelli, 2005). This lack of "alignment" between supervisors and staff in perceived safety climate status is consistent across domains surveyed, military and civilian aviation, aerospace, and U.S. hospitals.

Conclusions and Recommendations

Offshore oil and gas industry accidents and major disasters can mostly be attributed to human errors sometimes made by front line workers, but are often rooted in poor risk decisions made by their supervisors. The regulatory agencies have promoted SEMS as a means to improve operational safety. Although the regulatory rules are acceptable, if they are to be effectively implemented, greater attention has to be made to integrate a broad based application of human factors engineering and assessments of organizational culture and risk. This paper has outlined some of the most appropriate methodologies for consideration, covering human factors methods commonly used to design error tolerant, more usable interactive systems, and injury free work environments.

Human Factors Engineering (HFE), Human Computer Interaction (HCI), and Human System Integration (HSI) are the primary methods used by Human Factors engineers to create safe and effective systems.

It is suggested that human errors made by front line workers can be reduced by following prescriptive design methods incorporated in human factors engineering, user-centered design principles, and human systems integration.

Following system deployment and the conduct of operations, closer attention must be paid to organizational factors related to management and operational practices. The safety and effectiveness of operations can be enhanced through use of non-punitive safety reporting, providing crew resource management training, as well as the application of safety climate-culture assessment methods that provide reliable and valid information feedback to safety personnel and management regarding actual safety status and operational conditions as perceived by front line workers.

It is believed that the methodology for assessing Safety Climate and Culture presented here can be adapted for offshore O&G exploration, drilling and production operations. The core OSES questionnaire items are designed to assess how well an organization manages risks due to problems with a poor safety climate resulting from a lack of leadership commitment to safety, inadequate resources for safe operations, failure to follow procedures or best practices, badly designed human interactive systems, poor risk decisions, and/or a weak safety culture.

References and Other Relevant Sources

AHRQ. 2008. Becoming a high reliability organization: Operational Advice for Hospital leaders. Prepared by the Lewin Group, Falls Church, VA.

API RP 75, Recommended Practice for Development of a Safety and Environmental Management – Program for Outer Continental Shelf (OCS) Operations and Facilities. API Recommended Practice. 2008. Washington, DC: API.

API RP 75, *Recommended Practice for Development of a Safety and Environmental Management Program for Offshore Operations and Facilities,* 3rd ed. 2004. Washington DC: API

API RP 14J, *Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities. 2001.* Washington, DC: API

ASTM F1337-10. ASTM, *Standard Practice for Human Systems Integration Program Requirements for Ships and Marine Systems, Equipment, and Facilities*. 2015. ASTM International.

Bohme-Davis, L. Durso, F.T., and Lee, J.D., 2015. APA Handbook of Human Systems Integration. American Psychological Association Press.

Booher, H.R., 2003. Handbook of Human System Integration (HSI). Wiley.

Bjellos, D.M., 2012. Multicultural Crew Resource Management (CRM). Aero Safety World: The Journal of the Flight Safety Foundation. Washington, DC.

Bureau of Labor Statistics, 2014 Report. http://data.bls.gov/cgi-bin/print.pl/iif/oshwc/cfoi/osar0018.htm (accessed 18 January 2016).

CDC 2013. Fatalities in the Oil and Gas Extraction Industry. (62 (16), 301-4). http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6216a2.htm (accessed 26 April 2015).

Christou, M., and Konstantinidou, M., 2012. Safety of offshore oil and gas operations: Lessons from past accident analysis. JRC Scientific and Policy Reports.

http://publications.jrc.ec.europa.eu/repository/handle/111111111/27463 (accessed 15 January 2016).

Ciavarelli, A.P. (2008, February). Culture Counts. *Aero Safety World,* Washington, DC. Flight Safety Foundation.

Ciavarelli, A.P (2007, October). Assessing safety climate and organizational risk. Baltimore, MD, *HFES Annual Meeting*.

Ciavarelli, A.P., 2005. Assessing Safety Climate and Culture: From Aviation to Medicine. *In, St. Louis University Conference Proceedings on Safety in High-Consequence Industries*. St. Louis, MO.

Ciavarelli, A.P, Figlock, R., Sengupta, K., and Roberts, K. (2001) Assessing organizational accident risk through survey questionnaire methods. *In, Proceedings of the Annual International Aviation Psychology Conference*. Columbus, OH.

Ciavarelli, A.P. and Figlock, R., 1997. Organizational factors in Naval Aviation accidents. *Proceedings of the International Aviation Psychologists* Columbus, OH.

CDC (2013, April) *Fatal injuries in Offshore Oil and Gas Operations (2003 – 2010). MMR Report*, Center for Disease Control and Prevention. Retrieved from *http://www.cdc.gov/mmwr/preview/mmrhtml/mm6216a2.htm (accessed 15 January 2016).*

Connell, L. 2013, May. Aviation Safety Reporting System (ASRS): Program Brief. Prepared for the BAST Committee.

U.S. Department of the Interior. November 2011. Technology. *Technology assessment and research.* Washington, DC.

CSB. 2007. Investigation Report: Texas Refinery Explosion and Fire. http://www.csb.gov/assets/1/19/csbfinalreportbp.pdf (accessed January 2016)

U.S. Department of the Interior. Bureau of Safety and Environmental Enforcement 30 CFR Part 250 [Docket ID: BSEE–2012–0011] RIN 1014–AA04 - Federal Register/ Vol. 78, No. 66 / Friday, April 5, 2013 / Rules and Regulations. www.gpo.gov/fdsys/pkg/FR-2013-04-05/pdf/2013-07738.pdf (accessed 15 January 2016).

DHSG. 2011. *Final Report on the investigation of the Macondo Well Blowout.* Center for Catastrophic Risk Management, UC Berkeley. http://ccrm.berkeley.edu/deepwaterhorizonstudygroup/dhsg_reportsandtestimony.shtml (accessed 24 June 2013).

DOD. 2011. *Department of Defense: Human Systems Integration Management Plan*. Human Performance Training & Biosystems, Washington DC- Department of Defense for FY 2011. www.acq.osd.mil/se/docs/FY11-**DoD**-HSI-**Management-Plan**-101213.pdf (accessed 24 June 2013).

Federal Register Vol. 78, No.66. 2013. Rules and Regulations: Bureau of Safety and Environmental Enforcement – 30 CFR Part 250 (Docket I: BSEE-2012-0011) RIN 1014-AA04.

Flin, R., Mearns, K., O'Connor, P., and Bryden, R., 2000. Measuring safety climate: Identifying the common features. *Safety Science*, 34, 177-92.

Fitts, D.J., Sandor, A.A., and Tillman, B., Human Factors in Human System Integration *(Poster). NASA*. *http://www.nasa.gov/centers/johnson/pdf/486068main_HRP-SHFE-Human-Factors-in-Human-Systems-Integration%28Feb2008%29.pdf.* (accessed 15 January 2016).

Green, R.J., Self, H.C., and Ellifritt, T.S. (1995). 50 years of human engineering. Wright - Patterson AFB: Crew Systems Division.

Helander, M. G., 1997. The human factors profession, in G. Salvendy (ed.), *Handbook of Human Factors and Ergonomics*, 2nd ed. (New York: Wiley), 3 -16.

Helmreich, R.L., Merritt, A.C., and Wilhelm, J.A., 1999. The evolution of Crew Resource Management training in commercial aviation. *International Journal of Aviation Psychology*, 9 (1), 19-32.

Helmreich, R., and Merritt, L., 2000. *Safety and Error Management: The role of Crew Resource Management (CRM)*. The University of Texas at Austin. Retrieved from: http://homepage.psy.utexas.edu/homepage/group/helmreichlab/publications/publications.html (accessed 15 January 2016).

Hendrick, H.W., 2000. The technology of ergonomics. Theoretical issues in Ergonomic *Science,* Vol. 1 (1), 22-23.

IAEA. 1992. The Chernobyl accident: Updating of INSAG-1: A report by INSAG.

Safety Series No. 75- INSAG-7-24. http://www.pub.inea.org/MTCD/publicationos/PDF/Pub913e_web.pdf (accessed 15 January, 2016).

INSAG (1989). Report on the Chernobyl Nuclear Accident (INSAG-3). Vienna, Austria.

IPD NO.: 2013-01. BSEE Interim Policy Document. http://www.bsee.gov/WorkArea/DownloadAsset.aspx?id=36507222399 (accessed January, 2016)

ISO 924-171. Human Centered design processes for interactive systems. 2008. Montreal: ISO.

ISO TR 18529. Ergonomics of human system interaction. International Organization for Standardization. 2000. Montreal: ISO.

ISO PAS 18152. A specification for the process assessment of human-system issues. International Organization for Standardization. 2003. Montreal: ISO.

ISO 17776 - ET. Petroleum and natural gas industries – Offshore production installations – Guidelines on tools and techniques for hazard identification and risk assessment*.* 2000. Montreal: ISO.

ISO 6385. Ergonomics in the design of work systems. 2004 Montreal: ISO.

Jacko, J.A., 2013. The Computer Interaction Handbook (3rd ed.). CRC Press.

Jones, P.M., 1999. Human error and its amelioration. A.P Sage and W.B. Rouse (Eds). *Handbook of Systems Engineering and Management.* pp. 690-702. NY: John Wiley & Sons.

Libuser, C.B., 1994. Organizational structure and risk mitigation (Ph.D. Dissertation. UCLA). Los Angeles, CA.

Lee, J.D., 2008. Review of a pivotal Human Factors Article: Humans and automation: Use, misuse, disuse and abuse. *Human Factors*. (3), 405-10.

Lekka, C., 2011. High Reliability Organizations: A Review of Literature (RR 899 Research Report). Health and Safety Institute (HSE), UK.

Levine, W., 2013. Options for implementing the Requirement of Best Available and Safest Technologies (BAST) for Offshore Oil and Gas Operation. National Academy of Sciences: BSEE Power Point Presentation. Ocean Energy Safety Institute Risk Form. Houston, TX.

Lustgarten, A., 2012. Run to failure: BP and the making of the Deepwater Horizon Disaster. NY: W.W. Norton & Company.

Marais, K., Dulac, N., and Leveson, N., 2004. Beyond Normal Accidents and High Reliability Organizations: The need for an alternative approach to safety in complex systems. Cambridge, MA: MIT.

Morris, D. Dwarnick, S., and Kaczmarek, S., 2015. BSEE Priorities Regarding Offshore Technology Conference 2015. BSEE

Safety and Environmental Management Systems Forum. Houston, TX.

Morris, D. 2014. BSEE Issue Memorandum: SEMS Program Summary – First Audit Cycle (2011-2013). Washington DC: Department of Interior.

NASA. 2003. Columbia Accident Investigation Board: STS-107. (pp.177-181).

National Academy of Sciences. 1979. Implementing Best and Safest Technologies for Offshore Oil and Gas. NAS- NRC: Washington DC.

National Academies. 2013. Best Available and Safest Technologies for Offshore Oil and Gas Operations**.** Washington DC: National Academy Press.

National Academy of Sciences. 2011. Macondo Well Deepwater Horizon blowout: Lessons for improving offshore drilling safety. Washington DC: National Academy.

National Academies Press. 2012**.** *Transportation Research Board special report – 309: Evaluating the effectiveness of offshore safety and environmental management systems*. Washington D.C: National Research Board. http://www.nap.edu/catalog/13434/trb-special-report-309-evaluating-the-effectiveness-of-offshore-safety-and-environmental-management-systems (accessed 19 January 2016).

National Committee. 2011. Report to the President on the BP Deepwater Horizon Oil Spill and Offshore Drilling. www.oilspillcomission.gov/sites/default/files/documents/DEEPWATER_Reportothepresident_FINAL.pdf (accessed 15 June, 2013).

OCSLA. 1978. The Outer Continental Shelf Lands Act (OCSLA) 9/18/1978 public law 95-372. International Association of Oil and Gas Producers

OGP. 2014. The Human Factor: Process safety and culture. International Association of Oil and Gas Producers.

OGP. 2013a. Shaping safety culture through safety leadership: OGP Report No. 452. International Association of Oil and Gas Producers.

OGP 2013b. Process safety events 2011-2012 Data: OGP Data Series – Report No 2012. International Association of Oil and Gas Producers

OGP. 2011. Human factors engineering in projects (Report No 454). International Association of Oil and Gas Producers.

OGP Report 368, Human Factors – A means of improving HSE performance, London. http://www.ogp.org.uk/pubs/368.pdf. International Association of Oil and Gas Producers. (accessed 15 January 2016).

OGP. 2013. Process safety events – 2011 – 2012 (Report No 2012p). International Association of Oil and Gas Producers.

Kaczmarek, S. (2015). BSEE View of SEMS. *OESI SEMS Forum*. Houston.

Parasuraman R., and Riley, V., 1997. Humans and automation: Use, misuse, disuse and abuse. *The Journal of the Homan Factors and Ergonomics Society*, 39, (2), 230-253.

Pate'- Cornell, M., 1993. Learning from the Piper Alpha accident: A Postmortem analysis of technical and organizational factors. *Risk Analysis*, Vol. 13, (2), 215- 232.

Pew, R.W., and Mavor, A.S., (Eds.). 2001. Human Systems Integration in the system development process**.** Washington DC National Research Council - National Academy of Sciences.

Pharmer, J., 2012. Application of HSI to Navy Acquisition Process*.* *Call Signs***.** USN AEP Society, Vol.3, Issue 2, p.6, Winter 2012.

Problete, B.R., Parker, C.W., Ranasinghe, S., and Gandhi, M.S. (2014, May). Human Factors in Hazard Analysis (OTC-25280-MS*)*. Houston TX: Offshore Technology Conference.

Reason.J. 2010. Human performance indicators for the Energy and Related Process Industries. London: Energy Institute.

Reason, J. 1997. Managing risks of organizational accidents*.* Brookfield: Ashgate.

Roberts, K.H. and Bea, R. 2001. Must accidents happen? Lessons from high-reliability organizations. *Academy of Management Executives*. Vol. 15, No.3, 70-79.

Roberts, K.H. 1990. Managing high-reliability organizations. California *Management Review*. 32, (4), 101- 113.

Roberts, K. H.1993. Culture characteristics of reliability enhancing organizations. *Journal of Managerial Issues*, 5, 165-181.

Roberts, K., Rousseau, D., and La Porte, T. 1994. The culture of high reliability: quantitative and qualitative assessment aboard nuclear powered aircraft carriers*. Journal of High Technology Management Research*, 5, 141 -161.

Sage, A.P. and Rouse, W.B. 1999. Handbook of System Engineering and Management. NY: John Wiley & Sons.

Salvendy, G. 1997. Handbook of Human Factors and Ergonomics. NY: Wiley.

Sheridan, T.B. 2002. Humans and automation: System design and research issues. Santa Monica: John Wiley and Sons.

Schein, E.H. 1996. Culture: The missing concept in organizational studies. *Administrative Science Quarterly*, 41, 229-240.

Schein, E.H. 1990. Organizational culture. *American Psychologist*. , 45, (2), 109-119

SPE. 2014. The Human Factor: Process Safety and Culture – SPE 170575-TR. Society of Professional Engineers.

Stone, D., Jarrett, C., Woodroffe, M, and Minocha, S., 2005. User interface design and evaluatio*n.* Amsterdam: Elsevier.

U.S. Navy AEP Society. 2012*. Special Issue: US Navy Human – System Integration*, Vol. 3, No. 2. Washington DC: US Naval Aerospace Experimental Psychology Society.

Waller, M. J., and Roberts, K. H., 2003. High reliability and organisational behaviour: Finally the twain must meet. *Journal of Organizational Behavior*, 24, 813-814.

Wassel, R. 2012. Lessons from the Macondo Well blowout in the Gulf of Mexico. Washington DC. National Academy Press.

Weaver, J.L., 2014. Offshore safety in the wake of the Macondo Disaster: Business as usual or Sea Change? *Houston Journal of International Law*.

Weick, K.E. 1999. Organizing for high reliability: Processes of collective mindfulness. *Research in Organizational Behavio*r, 21, 81-123.

Weick, K.E. and Sutcliffe, K.M., 2007. Managing the unexpected*.* John Wiley & Sons.

Wickens, C.D., Lee, J., Liu, Y. and Becker, S., 2004. An introduction to Human Factors Engineering*.* New Jersey: Prentice Hall.

Weiner, E.L., Kanki, B.G., and Helmreich, R.L., 2010. Crew Resource Management. Academic Press.

Woods, D., Dekker, S., Cook, R., and Johannesen, L., 2010. Behind Human Error. 2nd Edition, Ashgate.