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Application of Human Factors in Reducing Human Error in Existing Offshore Facilities

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APPLICATION OF HUMAN FACTORS ENGINEERING IN REDUCING HUMAN ERROR IN EXISTING OFFSHORE SYSTEMS

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPLICATION OF HUMAN FACTORS ENGINEERING IN REDUCING HUMAN ERROR IN EXISTING OFFSHORE SYSTEMS

1.0 INTRODUCTION

Human factors engineering (HFE) is the scientific and engineering discipline concerned with improving human performance and reducing human error in complex systems. HFE represents a merging of behavioral science and systems engineering and is directed at integrating people into the workplace. The discipline had its start in the aviation and aerospace industries.

The objective of HFE is to minimize the potential for human error and accidents by ensuring that the human can perform assigned activities as efficiently and effectively as possible. At a very basic level, a definition of human error can be “any deviation from expected human performance” (Senders and Moray 1991).“ Other definitions exist that have a qualifier of human error include, such as “failure to respond to a situation within time constraints, responding with insufficient precision of control, or deciding upon inappropriate courses of action.” Example of human error is:

- Starting the wrong pump
- Skipping a step in a procedure
- Entering the wrong set point

According to the association of Oil and Gas Producers (OGP), human factors can be defined as “the term used to describe the interaction of individuals with each other, with facilities and equipment, and with management systems.” OGP further states that “this interaction is influenced by both the working environment and the culture of the people involved . . . Human factors analysis focuses on how these interactions contribute towards the creation of a safe workplace. Figure 1 presents the OGP model of human factors (www.ogp.org.uk/pubs/hf.pdf).

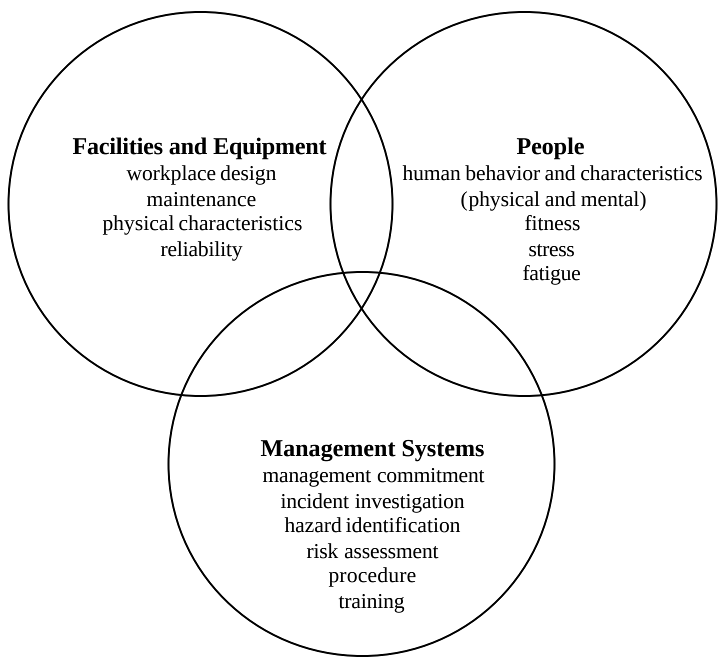

Figure 1. Human Factors and their Interactions

HFE begins with the assumption that the human is an integral component of the system rather than an element to be accommodated after completion of system design. The body of knowledge of HFE encompasses knowledge of: (1) human capabilities (for example, humans have good sensory and perceptual capabilities, are adaptive controllers, and can make decisions and plans of action based on incomplete or evolving information) and (2) human limitations (e.g., we have poor qualities of endurance and ability to exert forces, we must operate in highly constrained physical environments, and we are highly variable in our mental and physical ability and reliability), and (3) methods, principles and data addressing the application of this knowledge.

The objective of this paper is to illustrate, for designers, operators, managers, and maintainers of offshore facilities, the methods, tools and techniques that can influence human performance and error in complex systems. To do this requires an introduction to the objectives and issues of HFE, as well as an introduction to the body of HFE literature and data that support human performance and safety design.

Today the methods and data of HFE are being applied to a wide variety of activities and operations. HFE methods for reducing human errors include (1) the use of established design standards, (2) reliance on test and evaluation procedures, such as interviewing subject matter experts, examination of a work sample, experimentation, measurement of human performance in on-going task sequences, and use of human-in-the-loop simulation (including the training, knowledge and skills a person need to properly run a system) and (3) investigation of incidents to understand the causes of human error.

Human error is a major source of risk in existing offshore systems. The International Maritime Organization and the U.S. Coast Guard have independently estimated that human error is the direct cause of 80% of ship accidents and incidents. Chadwell et al (1999) investigated the role of human error in petroleum system incidents and found that in 47% in these incidents, human error was judged to be a causal or contributory factor. Human error is a leading cause of incidents which result in loss of life or injury to workers, leading to lost time, and lost capacity to the company. Human error also leads to financial losses due to lost drilling time, production downtime, damage to the environment, and unavailability of or damage to systems or equipment. In many cases of loss due to human error, errors are often related to several key factors, including external factors such human-machine interface design, design of procedures and job performance aids, as well as internal factors such as fatigue.

Modifying existing systems to reduce the potential and impact of human error can be difficult due to costs and potential interruption of production or drilling operators. These include the costs of making the modifications, the constraints on the extent to which a system, already designed and in operation, can actually be modified, and the increased potential for human error in making procedural changes to a system for which operating personnel have been trained to follow established procedures.

This paper discusses:

- Human performance implications for various classes of human machine interfaces
- Human performance problems for existing offshore systems
- A process for applying human factors engineering to reduce the potential for human error in existing systems
- Methods and measures for improving human performance in existing systems

2.0 HUMAN PERFORMANCE ISSUES BY CLASSES OF HUMAN-MACHINE INTERFACES

In its concern for system design, HFE is involved in the design, development, testing and evaluation of human-machine interfaces. Consistent with the OGP model, divisions of interfaces can be defined as equipment related, people related, and management systems related working environment and culture.

2.1 Equipment Interfaces

Equipment interfaces can include: computers, workstations, control panels, buttons, switches and other types of controls.

Physical interfaces include the physical, structural, and workstation elements with which the human interacts in performing assigned tasks. Interfaces include:

- Workstations
- Control panels and consoles
- Displays and display elements (screens, windows, icons, graphics)
- Controls and data input and manipulation devices (keyboards, action buttons, switches, hand controllers)
- Labels and markings
- Structural components (doors, ladders, stairs, hand holds, etc.)

Computing devices should be designed to be usable to the human user. In this context usability of a system interface refers to extent to which:

- Human-computer interfaces have been designed in accordance with user cognitive, perceptual, and memory capabilities
- Software command modes are transparent to the user
- Displays are standardized and are easily read and interpreted
- The user is always aware of where he or she is in a program or problem diagnosis (situational awareness)
- On-line help is available and responsive
- The user is only provided with that information needed when it is needed
- The user understands how to navigate through a program and retrieve needed information

For these interfaces the major problems are associated with design approaches that contribute to human errors and potential incidents (Controls that are not logically organized, ladders at a severe angle, etc.).

2.2 Management Systems Interfaces

The major organizational issues for this class of interface are the determination of the roles of the human vs. automation, and the factors that impact the ability of the human to perform assigned functions and tasks. In modern offshore systems a key component is "information." Interfaces include "organizational" factors and operational factors that manage the flow of information throughout the system, and maximize the accuracy, timeliness, and usability of information as set out in a company's Management Systems. The management of information has become a major issue for system effectiveness, and the major challenge for system technology. Problems with information include: excessive information, complex information handling, non-availability of needed information not available, non-currency of information, and inaccuracy of information.

Problems for this class of interface include excessive administrative and supervisory workloads, ineffective organizational lines of authority, and policies that inhibit effective human performance.

<u>Operational interfaces</u> include: operating, maintenance, and emergency procedures; workloads; skill requirements; personnel manning levels; and system response time constraints. Problems related to operational interfaces include excessive administrative and supervisory workloads, ineffective organizational lines of authority, and policies that inhibit effective human performance.

2.3 People Related Interfaces

Interfaces are primarily concerned with issues such as communication, collaboration, and team performance. Problems for this class of interfaces include inadequate communications, and ineffective collaboration and team performance. Communications problems can occur on offshore platforms and can significantly contribute to human errors. Examples are too noisy to hear commands/instructions, inadequate communications devices. Offshore systems for which manning where been reduced will be less capable of employing the strategy of having supervisors checking operators work, and could result in less operator collaboration to collectively solve a problem.

People issues also address the cognitive function, operating either collectively as a team or independently. Components of the cognitive class of human interfaces include:

- Decision rules, strategies for formulating and implementing decisions
- Mental integration of information from several sources and at different times
- Diagnostic problem solving
- Short term memory aids
- Cognitive maps, mental representations of spatial relationships
- Situational awareness, or understanding what is happening, and the implications for continued safe operations

2.4 Work Environment Interfaces

Work environment includes such factors as noise, lighting and climate.

Environmental Interfaces are concerned with the physical environment (illumination, noise, temperature, vibration, etc.), workspace arrangement, facility layout and arrangement, and environmental controls, specifically in terms of how environmental factors contribute to human performance and safety and health.

The concerns for environmental interfaces are that they induce fatigue and/or distract attention from the primary task, resulting in increased potential for human error (e.g. glare, noisy environment where alarms cannot be heard, too tight workspace to adequate remove or work on equipment).

3.0 UNDERSTANDING HUMAN ERROR IN EXISTING SYSTEMS

3.1 Human Error as a Contributing Factor to Accidents

It is widely held that human error contributes to 80% of marine casualties and accidents (O'Neill, 1994, McCafferty and Baker, 2002, Baker, et. al., 2002). The Marine Accident Investigation Branch (MAIB) of the United Kingdom Department of the Environment publishes an annual report of maritime accidents. For the year 1999, the MAIB noted the relative causal factors of maritime fatalities. Figure 2, below, summarizes their findings (http://www.maib.detr.gov.uk/ar1999/04.htm). In this figure, 37% of accidents leading to death are attributable to human factors. Looking deeper, 25% are attributable to "Working Methods" and an additional 17% to "Movement about Ship." In the United States, the Human Factors and Ergonomics community considers working methods and movement around marine structures to be within the scope of human factors/ergonomic concerns (e.g., task and vessel design and procedural practices). As a result, if figures for all of these causal factors are combined, fully 79% of fatalities, as reviewed by MAIB, were related to human factors/ergonomics design (McCafferty, et. al, 2001).

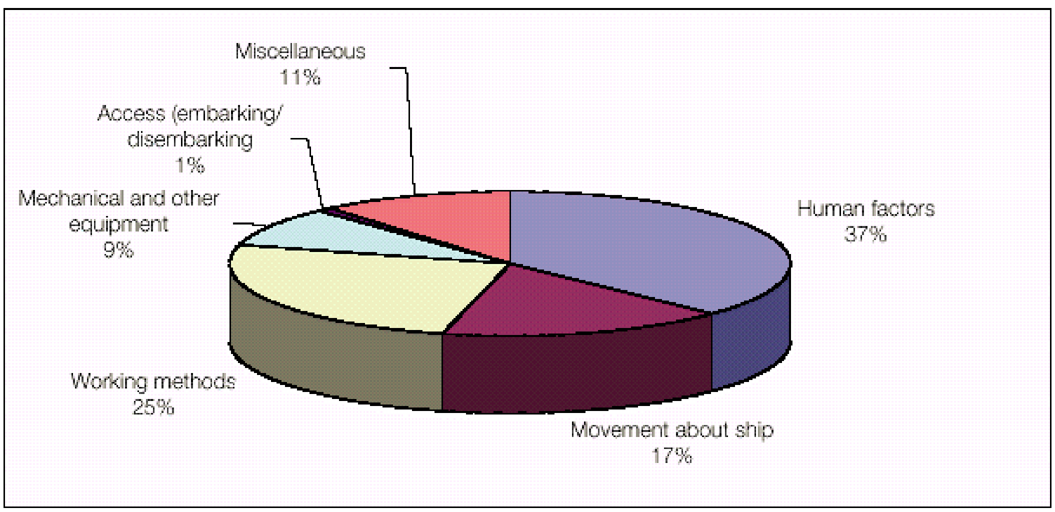

Figure 2. MAIB Allocation of Root Causes to Maritime Fatalities

While the figures discussed above may seem unduly large, they are not unsubstantiated, nor are they inconsistent with observations of other studies and other industries:

- Bea (1994), citing evidence of major claims associated with commercial shipping during 1993, concludes that human errors that occurred during operations were responsible for approximately 62 percent of the major claims
- The Government Accounting Office (GAO) reported in 1981 that at least 50% of military system failures are the direct result of human error
- 66% of offshore crane accidents are caused by human error
- 90% of ship collisions (Nations Transportation Safety Board)
- 85% of ship accidents (Navy Safety Center)
- 75% of merchant ship accidents (Germany)
- 66% of marine oil spills (UK)
- 90% of nuclear emergencies (American Nuclear Society, 50% according to the US Nuclear Regulatory Commission)
- 62% of hazardous materials spills (Office of Technology Assessment)
- 65% of all airliner accidents (Boeing)
- 90% of automobile accidents (US Department of Transportation)

Chadwell et al (1999) investigated the role of human error in operating petroleum systems by analyzing 130 reported incidents. For 47% of these incidents, human error was judged to be a causal or contributory factor. This 47% was comprised of errors in application of procedures (20%); errors due to management factors (training, communications, and scheduling) (15%); random human error (9%); and errors due to facility design factors (controls, environment, and equipment design) (3%).

The remainder of this section will discuss the nature of human error in terms of error types, causes, and potential means to wrest control of risk attributable to human error.

3.2 Types of Human Error

Numerous authors (Meister,1971, Woodson, 1981, and Baker, et. all, 2002) distinguish among different types of human error in terms of the causes of those errors. These classifications generally include:

- System-induced errors
- Design-induced error
- Human-induced error

System-induced errors reflect deficiencies in the way a system was implemented. They include mistakes in designating the numbers and types of personnel, in system operating policies, in training (competency assurance), in data resources, in logistics, in organizational responsibilities, and in maintenance requirements and support.

Human induced error, according to Meister (1971), are characteristics of people that influence the potential for errors. These are Meister's "human-induced errors" and include such factors as fitness for duty (e.g., fatigue, disorientation, distraction, impaired attention, lack of motivation, forgetting, complacency, confusion, incorrect expectancy, excessive stress, boredom, inadequate skills and knowledge, and inadequate or impaired perceptual or cognitive ability). Such factors can certainly contribute to the occurrence of errors, and in some cases even cause errors. Recognizing that potential errors are associated with inadequate skills or knowledge, many employers address this issue in their safety programs with restrictions and specific criteria for use of "short service employees." Although definitions for short service employees vary, typically a short service employee may be one new (less than 1 year) to the industry, the company or to the task being performed.

It must be noted that some HFE professionals view the occurrence of human-induced error as an *effect of design*, and not a cause. These practitioners suggest that since no human intends to fail (or very rarely), then it must be that management system and interface design characteristics are to blame for human error – after all, the human is only responding to the system and the design of its interfaces, management procedures, and policy. Whatever viewpoint is taken, it is important to emphasize that a "blaming culture" is not conducive to avoiding accidents and incidents.

Design-induced errors result from human incompatibilities with the design of equipment. The resulting equipment design characteristics create special difficulties for the operator which substantially increase the potential for error. Examples include inadequate workspace for maintenance, poor color/contrast of display screens, inadequate labeling of controls and difficult to reach valve location.

Factors external to the individual can influence the potential for human error. These include the system-induced and design-induced errors also described by Meister (1971). Elements of the job or task, design of equipment, operating procedures and training can all affect the potential for error. Factors related to the design-induced errors can be described as "design factors." Factors external to the person for the system-induced class of errors can be designated as "system factors." System factors include those aspects of the operational setting, other than design, which influence human errors. These include: task difficulty, time constraints, interfering activities, poor communications, excessive workloads, and other factors such as climate conditions, noise, and vibration.

Design factors include aspects of the system hardware, software, procedures, environment and training which affect the likelihood of human error. Design factors encompass such aspects of the system as: human-machine interface design; information characteristics (availability, accessibility, readability, currency, accuracy and meaningfulness); workspace arrangement; procedures; environments; and training, etc).

3.3 Characteristics and Causes of Human Error

Examinations of critical incidents leading, to or involving, human error have led HFE specialists to identify several common characteristics. These include:

- Situations that can lead to error (infrequent task) generally involve combinations of conditions (e.g., performing high workload under adverse weather conditions while a major systems test is being performed) which may seem independent of each other, and, at other times, directly related
- There is sometimes an erroneous expectancy on the part of personnel as to what is happening in the system (inaccurate perception of a situation)
- Personnel may be under some form of stress
- There usually exists some degree of complacency on the part of the individuals involved. (habit – done task many times in past with no consequences)
- Frequently error situations are the result, at least in part, of the man-machine interface (MMI) design
- Many incidents involve a training related issue

The HFE approach to describing human cognitive processes states that humans build up a cognitive model of the system and the system environment. The extent to which the mental model is in agreement with the real world is represented by the concept of "conceptual fidelity." In a situation of high conceptual fidelity, the human observer is correct in his expectations of what is happening in the system, what action is required, and how these actions will affect the system.

In low conceptual fidelity the mental model which the operator has conceived is in basic disagreement to what is actually happening, and it leads to responses and actions which are erroneous. Sources of diminished conceptual fidelity include poor human factors design, poor training, stress, and the past experience of the person involved.

Expectancy also plays a role in the establishment of design conventions, such as that a toggle switch is moved up to activate, a rotary moves clockwise to increase, and red means danger. Such conventions form the basis for many HFE standards. Human errors frequently are attributed to violations of these design conventions.

Personnel committing errors leading to incidents are often under some form of stress. The errors may be attributed to time stress, psychological stress resulting from the unavailability of needed information, external stress (e.g., personal issues) and the situation which is actually the opposite to stress, boredom and resultant relaxation of vigilance.

Investigators of incidents are increasingly aware of the fact that operators of high technology, complex and sophisticated systems tend to become overly complacent, and show an extreme level of confidence on reliable system operation. Complacency has been identified by the National Transportation Safety Board (NTSB) to be the determining factor in a number of airline incidents.

The HFE approach to reducing incidents is concerned with prevention of human errors, and control of human errors once they have occurred. According to Malone et al (1996), it must also be acknowledged that human errors do, at times, result from slips, lapses, and simple mistakes, on the part of the human operator; i.e. errors can be traced to personnel as opposed to design characteristics. Such error situations typically can not be effectively prevented through improved organizations and designs, since the number of possible error modes is virtually infinite, and not all error situations can be foreseen.

The importance of HFE for human-induced errors is: 1) to enhance the likelihood that, having occurred, an error will be detected and corrected in time to avoid serious consequences; 2) to ensure fitness for duty, defined as assurance that, a person is fully rested, capable, motivated, and attentive, 3) to reduce the impact of an error on the system and personnel safety and performance capability by making the system more “error tolerant.” The objective of HFE with respect to human errors is therefore to prevent error situations by reducing the incidence of errors; and to control errors by reducing their impact.

3.4 Human Error Offshore

Numerous HFE reviews have been conducted on offshore operations. Based on these reviews, examples of human performance problems are presented below. When reviewing this sample of offshore HFE observations, consider them in the context of the characteristics and causes of human error as discussed in Section 3.3,

- Mud from mud pits must be sampled every 30 minutes. There is no provision for obtaining these samples such as sample valves built into the mud pits. It is necessary to open a hatch at the top of the mud pit and obtain a sample using a bucket on a line. With frequent sampling, it can be a task that could result in a person being exposed to hazardous vapors/materials.
- The weight on a bit gauge presents weight on bit in two different scale resolutions. The displays are error prone given movement of the block and the service loops. Some of the weight of the service loops is borne by the drill pipe, resulting in gauge error for the high resolution weight on bit gauge. The high resolution Information display seems to be subjected to the greatest amount of display error. It is not clear why the two scales are offset (zero position), and why is zero not at the 12 O'Clock position? Nor is it clear what are scale units, and what are the nominal limits (warning limits)? The weight on bit gauge presents too much information to the operator, in a confusing manner, while not presenting needed information, such as the meaning of each scale.
- The cementer on a rig has problems with dust - when the dust collector fills up, cement dust is blown all over their room and makes the air unbreathable and interferes with vision. The dust Collector is a 55 gallon drum that must be manhandled to a point where it can be emptied. There are no sensors aboard to tell how full the drum is. The dust requires significant cleanup time as the dust settles on the controls in the cementers workstation.
- High noise levels interfere with speech communications. Levels reached 98 dB(a) resulting in a severe interruption in ability to communicate and a potential for hearing loss. GaiTronics communications are not used due to noise levels. The operator uses a Radius P1225 UHF radio headset, which is uncomfortable for long periods of time, and is incompatible with hardhats.
- High temperatures are reported in the cementing area. Ventilation is inadequate and can only be increased by leaving a water barrier door open. This door is supposed to be closed.
- Glare problems have been observed on computer displays (e.g., driller screens). Drillers request that the ship be turned to change the position of sun relative to Drilling displays.

- Operating procedures were not provided for the dual turning gear system. The drillers, assistant drillers, and tool pushers have been working as a team to develop operating procedures that are generated as they are required. There is no formal mechanism to verify and validate procedures, nor is there a method to identify what procedures may be needed in the future. It is possible that a situation could occur in the future that requires immediate response, and for which no emergency or off-normal procedures will be immediately available.
- Informal shift handover. No specific process for shift handovers. No specific formulation of data supporting handover. Objective of formalized shift handover is to enhance the situational awareness of oncoming shift. It is most important for a handover for personnel just coming aboard the ship (and less so for those just coming off a 12 hour rest cycle).
- Drill room: some communications that seem best handled by verbal communication are done by hand signals to roughnecks who are outside. Drillers use hand signals, tap on window to get attention, or go out to drill floor to communicate. The most significant problem reported by drillers concerns the area of communications between the drill shack and the roughnecks on the drill floor.
- On one offshore structure the in-place communications system did not work, and had not worked since the structure was constructed. In one case, the operator was observed to leave his workstation in the control room to communicate with the outside operators on the platform. Hand signals are often used, but are not usually effective. Hand signals typically only work when there are a few discrete messages to be communicated, and the signals are unambiguous.
- Two operators' workstations are mirror imaged. This will lead to confusion whenever an operator must move from one station to the other.
- Alarm levels for the mud storage tanks (running pits) are set at the operators discretion. Alarm set points can be set for the continuous range of mud level within the tanks. A decision to set a level too high can result in mud overflows. It is understood that different alarm levels need to be set depending on the operations at hand; however, a limit should be set on the highest set point that can be allowed. This will preclude operators from setting set points at too high a level. It was reported that in the past several months tank overflows have occurred in the mud pit area, requiring extensive cleanup of the mud pit floor.
- A problem with valve access constituted a safety hazard in that users have to stand on the railing to access the valve.

- On one platform there was noted an unsafe access to the crane cab. Crane access required standing on a fixed handrail to access a ladder which goes up to the cab level. The ladder moves with the crane when it is rotated. The crane operator stated that this is a problem in that he is not pre-warned that anyone (i.e. maintenance technician) is accessing the ladder, and may move the crane while that person is trying to gain access. The handrail on which one must stand was also slippery with hydraulic fluid, making the activity even more hazardous.
- Another example of the impact of physical interfaces on error causation is the reported incident which occurred when, after completing a sampling bore hole to the desired depth, the drilling crew was in the process of preparing to recover the drill string when the driller inadvertently operated the wrong control lever. This action resulted in 892 feet of drill string being dropped to the seabed. Dropping the drill string resulted from the driller actuating the deck clamp when he thought he was opening the chuck assembly. This error resulted from poor design and lack of HFE design principles in the location and layout of the control panel and control levers. The design of the control panel did not take into consideration the potential for inadvertent activation and substitution error in selection of these control levers. Although the controls were physically labeled, the design and layout of the control panel is not adequate when they are controls requiring blind operation, such as was required during these task activities.

4.0 HFE PROCESS FOR HUMAN ERROR REDUCTION IN EXISTING SYSTEMS

A process for applying HFE methods and data to the reduction of human errors in existing offshore systems is presented in Figure 3.

A description of the activities associated with each step of Figure 3 is presented in the following sections.

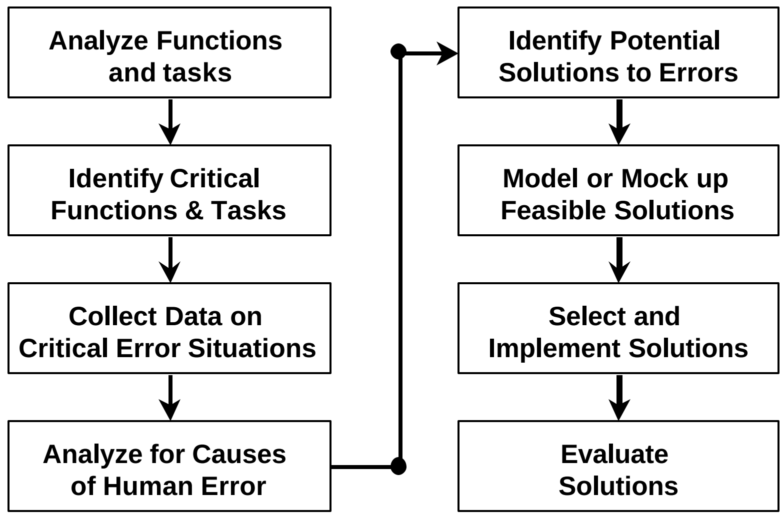

Figure 3. Process for Applying HFE Methods and Data for the Reduction of Human Errors

4.1 Step 1 - Analyze System Functions and Tasks

This step begins with selection of a set of operational scenarios which challenge human performance and safety in system operation. For each scenario system functions will be identified and analyzed down to the “task” level. Requirements for task performance within the system will be identified.

Scenarios include representative, typical scenarios as well as worst case scenarios. Representative scenarios include those which make up the routine activities in the offshore system. Worst case scenarios include extreme situations where human performance is challenged by such factors as: tight time constraints, high workloads, high required throughput, situational factors requiring special procedures, requirements for high rates of communications, high levels of uncertainty, low levels of participant experience, and large quantities of information required.

An analysis of each scenario leads to determinations of: actors (persons participating, including operators, maintenance personnel, and supervisors), characteristics of actors, objective of the activities which make up the scenario, events occurring within the scenario, timing of the events (time expected to conduct activities associated with an event); initial conditions for the scenario, terminal conditions, interactions among actors, and decisions made during the scenario.

For each scenario a task analysis is conducted to identify task performance requirements associated with tasks performed by individual actors, and by teams of actors. This analysis produces a comprehensive array of requirements in the context of the specific scenario. Requirements may include (as appropriate to each scenario), for each identified task within each scenario, indications of:

- Criteria for successful task performance.
- Expected task duration under the conditions appropriate for the scenario.
- Limitations on task duration, task initiation time and conditions.
- Frequency with which the task is performed within the scenario.
- Information needed for task performance and characteristics of needed information (source, update rate, quantity, quality).
- Feedback available on adequacy of task performance.
- Special knowledge and skill needed to complete the task.
- Equipment, forms, records, job aids used to perform the task.
- Decisions required to complete the task, decision rules and decision options.
- Short term (working) and long term memory required for task performance.
- Performance tolerances associated with the task.
- Personnel interactions associated with the task.
- Communications associated with the task.
- Error modes - errors which could occur during performance of the task.
- Consequences of each error mode.
- Requirements for detecting and correcting errors, for each error mode.
- Factors that enhance the probability that the error can be avoided.
- Information that must be recorded to obtain a record of an error occurring for an error mode associated with each task.
- Barriers to obtaining the needed feedback on error occurrence.

The result of the task analysis is a description of task performance requirements. It is strongly recommended that a multidiscipline team conduct the task analysis. Team make-up can included operators, maintenance personnel, engineers, supervisors, safety coordinators and HSE.

4.2 Step 2 - Identify Critical Functions, Tasks, and Conditions

For each scenario critical functions, tasks, and scenario conditions are identified. Critical tasks and functions are defined as activities or conditions which:

- Make error detection difficult
- Make error recovery difficult

Use of predictive tools and techniques are appropriate to identify critical functions, tasks, and operating conditions. Tools such as Failure Modes Effects and Criticality Analysis (FMECA), Hazard & Operability Studies (HAZOP), Fault Tree Analysis, event tree analysis and others, are available to support risk analysis during design and operation of a system. The paper authored by Dr. Johan Hendrikse, et alia (Working Group #2), “Effectively Including Human Factors in the Design of New Facilities” discusses many of these techniques, as does the paper authored by Anita Rothblum, et alia (Working Group #1) Improving Incident Investigation through Inclusion of Human Factors.

Another technique that can be brought to bear on risk issues is the Influence Network (BOMEL Limited, 2001). An Influence Network is the definition, structure and quantification of a network of influences affecting the risks associated with human and hardware performance in hazardous situations. The Influence Network is structured from consideration of a generic set of influencing factors, which are hierarchically modelled to represent the influence of various factors such as organizational, management systems and the direct working environment. A Generic Influence Network (GIN), as shown in Figure 4, is used to draw out the specific influencing factors that have an effect on any given accident type. This results in a customised Influence Network which is fully defined in the context of the incident under consideration and the hierarchy of influencing factors upon the incident.

The incident type being considered could be at any level from a specific event, to a failure of an individual component or system in an installation or vessel, to the complete industry wide risk profile. The direct causes of the “top event” can occur as a result of three areas:

- Human failure
- Hardware failure and abnormal
- External events (natural or other party actions)

Influence Networks can, as is stated above, be used to support predictive / proactive risk analysis, as well as support the conduct of accident investigation.

Hierarchical Task Analysis (HTA) (Rezende, 2001) is a method for describing tasks in a clear, unambiguous way, such that there is a understanding of the ways to performing a task. HTA is a powerful tool in that it can used to assess human risk and error likelihood. HTA can be considered an extension to "standard" task analysis techniques by increasing the depth of the error analyses performed. HTA provides the ability to postulate human errors, documents estimations of consequences of error occurrence, identifies potential actions to mitigate error effects, and suggests means to reduce error likelihood. A sample HTA is presented as Table 1.

Use of the tools introduced above, and as discussed by Hendrikse, et.al. and Rothblum, et.al. can be initiated in this step of the process, note however, that these tools have application throughout this design process.

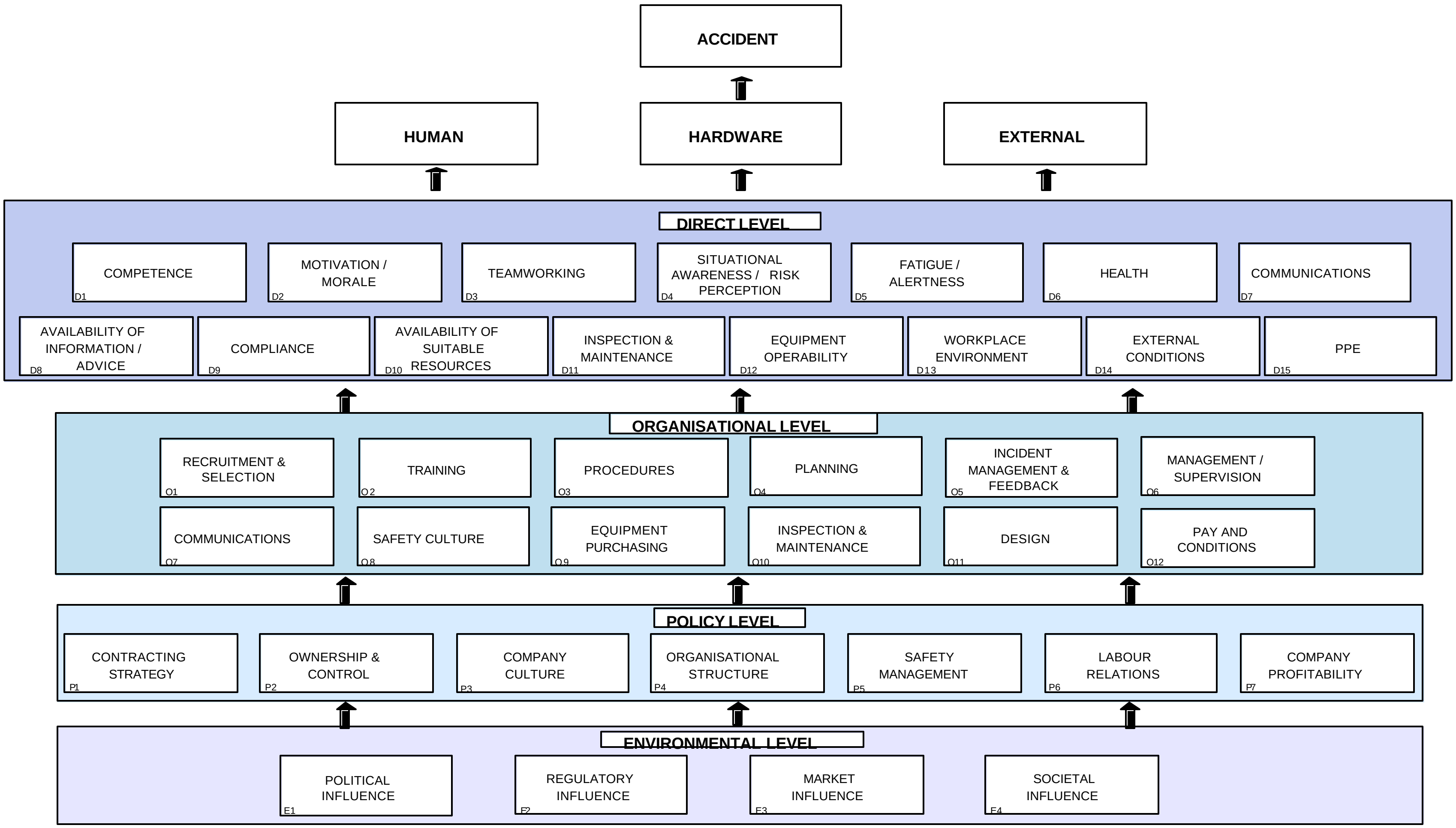

Figure 4. Generic Influence Network

Table 1. Example of a Hierarchical Task Analysis

Task analyses for: Operation in the Liquid Storage Tank System			**Performed by**: Ivan		**Sheet No**: 01/13
Task Step	**Error Type**	**Description**	**Consequences**	**Recovery**	**Error Reduction**
1.1 Operator verifies if LI indicates tank 1 is empty	C1_Check omitted C3_Right check on wrong object C4_Wrong check on right object	Real level is unknown Real level in tank-1 is unknown Real level in tank-1 is unknown	Possible more gas generation when purging with N2 for 15 minutes.	Operator will look at the level when filling tank (Task step 4.1.1).	Training the operator to get his commitment. Place LI near Valve A, then operator can look LI when operating valve A. The name Tank-1 must be painted near the LI. Provide a check list to write hour and level.
1.2 Operator verifies if LI indicates tank 2 is empty	C1_Check omitted C3_Right check on wrong object C4_Wrong check on right object	Real level is unknown Real level in tank-2 is unknown Real level in tank-2 is unknown	Possible more gas generation when purging with N2 for 15 minutes.	Operator will look at the level when filling tank (Task step 4.2.2).	Training the operator to get his commitment Place LI near Valve B, then the operator can look LI when operating valve B. The name Tank-1 must be painted near the LI. Provide a check list to write hour and level.

4.3 Step 3 - Collect Data on Critical Error Situations

The HFE analysis conducted for each system consists of five major data acquisition activities: (1) interview of job incumbents and supervisors; (2) review of records (e.g. incidents/near misses/unsafe acts and behavior); (3) review of the processes in place for recording errors, near misses and unsafe acts/behaviors; (4) conduct walkthroughs and observations of system tasks; and (5) determination of the extent to which errors can be expected based on human-system interfaces implemented in the system.

Personnel Interviews are conducted with job incumbents, supervisors, subject matter consultants for jobs associated with critical functions, tasks and conditions for scenarios analyzed in Steps 1 and 2. The interviews will focus on identifying critical incidents where errors or near misses were observed or could be expected for specific tasks in the scenario based on such factors as fitness for duty of participating personnel, conditions under which tasks were performed, and likely causes and contributory factors. The interviews will also address disincentives of reporting errors, either one's own errors or those of others, and what incentives or precautions could be employed to enhance the reporting of errors, such as anonymous reporting, focus on near misses rather than actual incidents, and reward of employees for error reporting.

Records Review is focused on a review of records describing actual error or near miss occurrences and available information describing the event.

Review of Recording Procedures and Materials: an assessment of the techniques in place to identify and record incidents and near misses for each system. The review will focus on identified disincentives which would be expected to prevent the identification and recording of human error situations in offshore systems, such as, for instance, fear of legal action, fear of license or privileging restrictions, fear of reprisals from supervisors or peers, fear of loss of career advancement, organizational factors such as the culture and policy which may mitigate against error reporting.

Conduct walkthroughs: observing performance of tasks associated with selected scenarios in the actual environment wherein job incumbents proceed step by step through a procedure while being observed by HFE analysts. This analysis provides input to the task analysis identification of potential errors associated with individual tasks within scenarios.

Conduct observations/verifications: HFE analysts observe on-going system activities as described in Step 1, and will identify and record any deviations from standard procedure. In addition a verification checklist will be completed which will prompt the analyst to verify that a task has been performed correctly, and that a decision or action associated with a task has been performed accurately and timely.

Assessing human/system/organizational interfaces: involves identifying the human/system/organizational interfaces associated with each task in each scenario, and defining requirements for the interfaces that will promote error-free performance. The assessment of interfaces associated with each scenario is based on a determination of the extent to which the interfaces comply with good human factors principles.

Assessing human-machine/equipment interfaces: assessing the extent to which these interfaces meet appropriate human factors engineering standards and design guidelines. (for example, making sure that appropriate color coding and prioritization of alarms, proper layout of a control panel are provided).

4.4 Step 4 - Analyze Causes of Human Error, and Constraints on Error Reduction

Analysis of data in step 3 leads to identified causes of human error and expected error modes, consequences of errors, requirements for making the system error tolerant, and requirements for recording the occurrence of the error.

Potential errors will be prioritized in terms of two considerations: (1) severity of consequences for personnel health and safety, public health and safety, and cost to the owner; and (2) frequency of the error situation in the system. This approach leads to use of a risk matrix.

As needed, insights into error situations should be developed from reconstruction of identified error situations judged to be of high priority (serious consequences and/or high frequency). Reconstruction entail assembling personnel representative of those involved in the error, and walking through the tasks involved in the error situation, with commentary from participants concerning what may have contributed to the cause of the error.

The thrust to identify error situations for an offshore system will focus on the following two activities:

- Identifying error situations that have occurred through review of incident / near miss reports, and interviews with system personnel.
- Identifying error situations that are expected in the future (indications of high error likelihood) based on the HFE assessment of the adequacy of human / machine / system interfaces used in specific system operation and maintenance tasks.

One of the most useful sources of information on human error situations is data on actual incidents / near miss, recorded in the actual work environment. Such reports should contain information on precisely what error occurred, what task was the error associated with, what were the working conditions at the time of the error, what human interfaces were involved, when was the error discovered, an indication of whether or not it was discovered in time to recover, what were the causal factors, what were root causes, what were the consequences, and how was an incident avoided in the case of a near miss.

Barach and Small, in the March 2000 edition of the British Medical Journal, reported that schemes for reporting near misses (also termed close calls or sentinel or warning events) have been institutionalized in aviation, nuclear power systems, petrochemical processing, steel production, military operations, and transportation. Better near miss data can help to identify human error situations and lead to actions to reduce their occurrence.

The U.S. Coast Guard has attempted to implement an error reporting protocol in its shipboard operations, and has included in the reporting process the recording of near misses. A near miss is defined as a situation where an error was prevented or circumvented by some action on the part of the operator or other personnel. The Coast Guard noted that near misses are some 60 times more frequent than actual errors, and they can provide the same insight into error etiology as actual errors, without the stigma of having to report on one's own or an associate's mistakes.

The root causes of each identified error situation should be identified or at least postulated by a review of the error situations. In a similar fashion, factors that may have contributed to the error or near miss will also be identified. Root Cause analysis tools include TapRooT, SCAT, TRIPOD BETA, etc. These tools will assist in identifying Performance Influencing Factors. The paper by Dr. Anita Rothblum of Working Group #1 "Improving Incident Investigation through inclusion of Human Factors" provides a comprehensive coverage of the tools and techniques in the area of accident, incident, and near miss analysis and reporting. Another technique that can be used to help identify root causes is the Influence Network (BOMEL Limited, 2001) which is discussed in Section 4.2.

In the analysis of incidents sometimes participants have expectations about what is happening and why, and these expectations are not always accurate. People can build up an erroneous mental model of what is happening in the situation, based on faulty or incomplete evidence, and this leads them to act inappropriately. Stress is also usually cited as a cause of human errors.

Error situations of the type expected in offshore systems can result from people forming an incorrect mental model from incomplete or ambiguous information which can, result in erroneous expectancy, manifested in decisions and actions that are wrong. The solution to this problem is to provide complete, accurate, reliable, timely and valid information concerning the operational situation, which will enable development of a mental model which conforms with reality.

In terms of the impact of psychological stress, in critical incidents, the level of stress generally varies as a direct function of the extent to which the human understands the situation, and what to do about it. The HFE approach is to intensively analyze the functions, tasks, conditions, and decisions required, identify information requirements and information processing and display needs, and ensure that humans are provided with the proper information and knowledge to correctly complete a task.

Innovations in technology have led to the use of advanced automated systems on modern maritime vessels. However, bridge automation has also changed the role of the watch officer on the ship. The watch officer, who previously was active in obtaining information about the environment and used this information for controlling the ship, is now “out of the control loop” and is in more of a monitoring mode.

The primary constraints on error reduction include:

- Costs of redesign and modification of existing structures and system components
- The need to modify procedures and training systems to reflect the changes to equipment
- The possibility of negative transfer of training when operators must be retrained to operate modified control systems

Constraints on solutions for identified error situations will be defined prior to the selection of specific solutions.

4.5 Step 5 - Identify Potential Solutions to Errors

The objective in this step is to minimize 1) chance that the error will occur and 2) reduce the consequences if the error does occur. Making systems more error tolerant reduces the impact of human error. This process involves determining what human errors will have serious implications for crew/operator safety, and designing techniques to either promptly alert the operator that an error has occurred and how to correct it; or to enable the system to continue to operate safely until the error is recognized and corrected.

Potential solutions will include:

- Reengineering of the allocation of functions to humans and machines. (example manual handling of sacks of chemicals to an automated conveyor system).
- Redesign human-machine interfaces (push button instead of switch, light indicating alarm instead of a gauge, additional information shown on hazards in control screen).
- Modifications to procedures and systems documentation (e.g., clarify procedure steps, one action per step, include warnings/precautions in procedure).
- Modifications to training content or to training systems.
- Provision of instructions, advisories, warnings (signs and labels).

The HTA tool discussed in section 4.2 can be used to support the task of identifying solutions to human error potential.

According to Miller (1999), an order of preference to mitigate human error and its possible effects is as follows:

- Redesign interfaces (where possible)
- Provide guards
- Provide training
- Revise procedures
- Provide warnings, markings, and labels

4.6 Step 6 - Model the Feasible Error Solutions

Selected error solutions can be modeled to assess human performance with the solution. An example would be for control system redesign where the new design could be modeled on a simulator and reviewed with operators to determine the effectiveness of the new design.

Task network modeling involves modeling the operation of a human-machine system as a network of tasks. Tasks are assigned in a fixed or variable manner to selected operators which often represent humans but can also represent machines or other resources. The time taken to perform each task is modeled as a random variable having a specified probability distribution. Task sequence relationships can be probabilistic so that various contingencies can be represented as occurring with specified probabilities. Task network simulation tools use Monte Carlo methods to sample probabilistic task sequencing and distributions of task time. Time and accuracy data can be obtained for a baseline configuration of the system, and after installation of the error reduction solution.

The human-machine system models that result can have considerable flexibility and can represent real-world scenarios. When the model is run, the program records statistical data such as the numbers of completions of tasks, the time spent per task per operator and total busy/idle time per operator.

Human-in-the-loop simulation techniques and usability testing can focus on cognitive, information processing and decision making aspects of human performance. If a simulation test subject receives specified information via a monitor, reaches a decision and then makes a response via a data entry device, the response time and accuracy of the response can be determined. Human performance with human-machine interface representations from the baseline system and with the addition of error reduction solutions can be directly compared. Over a number of trials, statistical data can be obtained on errors, magnitude of errors and response time.

4.7 Step 7 - Select and Implement Solutions

This step addresses how error reduction solutions can be selected and implemented into an existing system. The following should be considered in selected solution(s):

- Overall human performance capability
- Human workload (especially cognitive workload)
- Additional human performance or safety problems caused by the solution
- System error tolerance
- Operating and support costs
- Training burden
- System manning
- Compliance with government regulations
- Compliance with HFE standards including astm-1166, and ABS HFE standards
- Personnel safety

A plan and time schedule should be develop for implementation. There should be a follow-up process to monitor the progress (against plans) and effectiveness (reduction in incidents/near misses, unsafe acts/behaviors) of the selected solutions. Management of change processes should be followed necessary.

4.8 Step 8 – Evaluate Solutions

The key point for this discussion is that evaluations should be conducted for human factors initiatives. These evaluation assessments should include analysis of:

- Personnel functions, processes and performance
- Human interfaces, including equipment, procedures, job aids, and communications, teamwork, etc.
- Training, including new hire, refresher, special, and contractor
- Personnel fitness for duty, including physical health, freedom from stress and fatigue

Appropriate groups (inducing engineering, safety, purchasing, maintenance, operations, policy, and human factors) should have input and be award of changes. This is essential since changes under the purview of one group likely will have implications for HF. For example, equipment replacements (by engineering personnel) may spawn new or different requirements for training and design of operational and maintenance procedures. Changes in operating policy will likewise influence training. Further, human factors personnel can participate in engineering tradeoffs by supporting selection of new equipment, or by helping to devise solutions other than engineering. Those that are personnel related should also be reviewed for implications to training, job aids, and workload/job design. Changes in personnel onboard a platform, including contractors, personnel rotations, shift work, or tour rotations necessitate ensuring that safety is maintained during these changeovers. Finally, changeovers in management such as company or platform acquisition, restructuring of a company or the acquisition or loss of personnel directly responsible for safety personnel should be considered as it affects safety.

Most organizations and theorists would agree that changes to the design and operation of a system must included segments which require both investigations of incidents and some means of soliciting the opinions and comments of the workers affected by those changes. Also within the area of HF, evaluation is directed at elements such as: personnel training, environmental control, design of human-equipment interfaces, protective gear, maintenance and assessment of personnel readiness/fitness for duty, communications (organizational, operational, and maintenance), maintenance and usability of procedures/job aids, and operating practices, procedures, and policies.

Specific HFE considerations in evaluations should include:

- Is there a need to change or modify the approach of the solutions chosen?
- Have all HF disciplines been considered (e.g. HF Engineering, Process Safety and Behavioral Science)?

5.0 EXAMPLE ACTION PLANS FOR IMPROVING HUMAN PERFORMANCE ON EXISTING SYSTEMS

Section 4 presented a general approach for integrating HFE data into systems design. This section provides specific guidance addressing the improvement of the following HFE issues:

- Communications (Table 2)
- Labels and signs (Table 3)
- Procedures and job aids (Table 4)
- Information Transfer and Display (Table 5)
- Human machine (Table 6)
- Training (Table 7)
- HFE Issues (Table 8)

Process guidance is presented in Tables 2 through 8.

Table 2. Sample Process for Improvement of Communications

Objectives. The objectives of this activity are to analyze communications in terms of communication links and how communications are made, and to recommend modifications to the communication systems.
Worksteps
Step 1. Analyze communications in terms of the links, frequency, information importance, and environmental conditions under which communications are made. (e.g., noise level)
Step 2. Generate a link analysis of communications requirements among various stations (e.g.,, control rooms outside stations).
Step 3. Identify conditions that can potentially interfere with speech communications and speech intelligibility. (e.g., noisy equipment)
Step 4. Conduct a communications "error analysis" to identify, for selected links, communications requirements, environmental conditions, potential errors, error criticality, and causal and contributory factors.
Step 5. Develop communications criteria, including standard message format and syntax, links and modes of communications among stations, to reduce error likelihood and improve communications accuracy.
Step 6. Survey communications devices meeting requirements that are not in place (for example, use of noise canceling technology).
Step 7. Make specific recommendations concerning improved communications system design based on assessments of the capabilities of state-of-the-art communications devices.
Step 8. Prepare HFE design specifications for communications (e.g., noise levels, types of communications, location of communication devices, etc.)
Step 9. Perform speech intelligibility testing under realistic conditions.
Step 10. Generate an implementation plan and a cost estimate for implementing the Communications Systems specification and recommendations.
Products. The products of this activity will be a series of recommendations and design specifications related to communications hardware and software, human-machine interfaces, message format and syntax, a list of constraints associated with communications (e.g., ambient noise), and a plan and cost estimate to implement the communications system recommendations.

Table 3. Sample Process for Improvement of Labels and Signs

Objectives. The objectives are to develop and implement standards for labeling and marking of operating components. These include Controls, displays, pipes and valves, major equipment and associated operating components.
Worksteps
Step 1. Survey color coding and other conventions used by company.
Step 2. Survey general offshore coding conventions.
Step 3. Review applicable standards and guidelines related to design of labels and signs and other identifying markings in industrial applications, from HFE literature, Industry conventions, and ASTM-1166.
Step 4. Establish a specific Labels and Signs Standard. This Standard should address the following: • Content • Wording and nomenclature • Colors, fonts, and other detailed characteristics • Method of affixing to components labeled • Style guides for warnings and cautions • Consistency with written documentation, procedures, and computer display nomenclature • Method of generation of labels and markings (engraving for example)
Step 5. Develop list of required signs and labels*.*
Step 6. Develop a label consistent with the labeling standard, for all components specified.
Step 7. Assist in having manufactured the labels and markings.
Step 8. Monitor installation of the levels and markings.
Step 9. Verify and validate: All labels and markings installed undergo a verification and validation step.
Products. The products of this activity include: • A platform- specific "Style Guide" and standard for labels and markings. • Procedures for specifying and acquiring levels, markings and warning placards. • Procedures for verifying had and validating the content and accuracy of labels, markings, and placards.

Table 4. Sample Process for Improvement of Procedures/Job Aids

Objective. The objective of this activity will be to specify requirements associated with generation of operating and maintenance procedures and job aids. Specific objectives include: • Identification of required procedures based on failure modes effects and criticality analysis (FMECA) or similar analysis. • Identification of required procedures based on routine and normal operating and maintenance requirements. • Generation of procedures style guides. • Generation of written procedures based on the style guides and requirements.
Worksteps
Step 1. Identify normal operating procedures that are used in the conduct of normal and routine drilling operations.
Step 2. Identify abnormal or emergency operating procedures. These will be identified via failure modes and effects and criticality analyses, or similar, and on a historic events and situations that have been realized in offshore drilling.
Step 3. Survey coding information presentation conventions. Survey general offshore *procedures design conventions.*
Step 4. Review applicable standards and guidelines related to design of procedures.
Step 5. Establish procedures writing guide. This standard will address procedure: • Content, wording and nomenclature • Colors, fonts, and other detailed characteristics • Information mapping and decision making • Style guides for stepwise activities • Style guides for embedded warnings and cautions • Consistency with labels and marking • Standardized vocabulary • Storage, update, and accessibility • Use as part of team and individual training
Step 6. Develop protocol for verifying and validating procedures as they are written.
Step 7. Assist in writing procedures.
Step 8. Verify and validate - all procedures undergo verification and validation step.
Products. The products of this activity include: • Procedures writing guide • List of applicable procedures, normal and abnormal operations • A complete set of written procedures, verified and validated

Table 5. Sample Process for Improvement of Information Transfer and Displays

Objectives. The objectives of this task are as follows: • Define information requirements per job/location • Define a representative sample of information items • Identify information formats • Design screen layouts and user-computer interfaces per formats • Define data base requirements • Prepare information transfer specification
Worksteps
Step 1. Define Information Requirements per Job/Station Information requirements will identify the information items needed at each location for a given job. For example, a mud logging station needs mud pump on/off and valve open/closed information. In this case, any additional information items would need to be identified.
Step 2. Define a Representative Sample of Information Items Information items from step 1 will be reviewed to establish a representative set of items for further analysis. This step cannot be performed in total independence of step 3 because the intent will be to identify classes of information items and a representative sample of specific items per class. Steps 2 and 3 will be performed in parallel and iterated as required.
Step 3. Identify Information classes and formats for workstations, individual information items will be categorized to identify a number of information classes. Each such class will eventually be represented as an information object in an object oriented data base so definition of object attributes in a data base will need to be considered in defining the classes. Information classes/objects could include message, scheduled event, pump, valve, motor, sensor, BHA component and others as necessary.
Step 4. Design Screen Layouts and User-computer Interfaces per Formats Each information class will have unique attributes and will require a standard format for display of the attributes. User-computer interfaces will also be required for searching the data base and selecting object attributes to be continuously displayed. Users should not have to learn complex query languages to access information.
Step 5. Define Data Base Requirements Information from the above steps including object and attribute characteristics and user-computer interface functionality will be collected and documented in a data base requirements and concepts document.
Step 6. Prepare Information Transfer Specification Information from the above steps including object and attribute characteristics and user-computer interface functionality will be collected and documented in an information transfer specification document. The difference between the data base requirements document and the information transfer specification will be that the former is aimed at providing information for software system procurement while the latter will be aimed at developers and users.
Products. The primary products of this task will be the data base requirements and concepts document from step 5 and the information transfer specification from step 6.

Table 6. Sample Process for Improvement of Human/Machine/Interfaces

Objectives. The objectives of the task described in this SOW are as follows: • Define a representative sample of existing HFE issues. • Identify applicable design criteria and guidelines. • Identify candidate HFE design improvements. • Select HFE design improvements. • Design and document improvements. • Develop HMI interface specification.
Worksteps
Step 1. Define a Representative Sample of HFE Issues associated with human machine. The intent will be to identify issues and potential solutions for HFE issues associated with human machine interfaces.
Step 2. Identify Applicable Design Criteria and Guidelines: Design criteria and guidelines will be proposed. Ideally, the selected design criteria and guidelines will be applied to new operator interfaces in the future.
Step 3. Identify Candidate HFE Design Improvements Candidate improvements to operator interfaces will be developed for each HFE issue from step 1 using the applicable design guidance from step 2. Where required, two or three candidates could be developed for each HFE issue. Definition of candidate improvements will require user input.
Step 4. Select HFE Design Improvements: Candidate improvements from step 3 will be compared on the basis of cost, expected effectiveness and breadth of application on future ships. The set of recommended improvements will be selected using these data.
Step 5. Design and Document Improvements The selected HFE design improvements from step 4 will be designed in detail and documented using descriptions, specifications and graphics sufficiently that they can be implemented.
Step 6. Develop HMI Interface Specification The applicable design criteria and guidelines will be incorporated into an interface specification document suitable for future use in ship design. Applicable design criteria from step 2 will be incorporated and the documentation of the specific improvements from step 5 will be included to provide examples.
Products. The primary products of this task will be the selected HFE improvement concepts and designs from step 5 and the HMI interface specification from step 6.

Table 7. Sample Process for Improvement of Training (individual and team)

Sample Process for Improvement of Training (individual and team)
Objectives. The objectives of this task are as follows: • Identify jobs and tasks for improved training methods. • Develop training objectives/conduct task analysis • Identify performance and skill requirements • Identify training media • Develop training materials • Train to criteria and test skill acquisition
Worksteps
Step 1. Identify Jobs and Tasks for Improved Training Methods : Criteria for selection of jobs and tasks will include the frequency with which the tasks must be performed, the likelihood of operator error and the severity of the consequences of operator error. Tasks that must be performed frequently in daily operations provide opportunities for effective OJT and for extensive operator practice. Many error modes that exist currently are readily detectable and correctable by the operator and errors on these tasks have little or no consequences; it is infrequent performance and nondetectable and noncorrectable error modes that will drive the selection of tasks for improved training. Tasks that have the properties of infrequent performance and severe consequences of error are often those associated with emergency response to equipment failures or other abdominal events. The fact that performance is infrequent means that knowledge and skills associated with these tasks are “degradable” over time. Results of Failure Modes and Effects Analyses (FMEA) or other analysis will be required in this task. The target tasks would then be those necessary to recover from or to mitigate the results of credible events postulated in the FMEA.
Step 2. Develop Training Objectives and conduct Training Task Analysis: Training objectives describe observable and verifiable behaviors that operators should exhibit given necessary information. Training objectives usually involve making correct decisions and taking correct actions following receipt of information about the system, the environment, etc. As related to FMEA events, the decisions involved would be to correctly diagnose the state of the equipment and the environment. The action should be the correct one to rectify or mitigate the effects of the failure or abdominal event that has occurred. A training task analysis should be conducted to identify tasks, conditions, events, information required by the operator, decisions and actions required of the operator and other relevant task descriptors, and needed knowledge and skills to enable performance of the task. This is also sometimes called a “critical task analysis” in that the focus is on the highly important tasks rather than on all tasks. Critical tasks, then, do not necessarily result only from major failures but also from abdominal events that call for critical tasks to be performed. Training objectives will be defined for the tasks identified in step 1.

Sample Process for Improvement of Training (individual and team)
Step 3. Identify Performance and Skill Requirements : Performance refers to measurement of trainee progress in demonstrating mastery of the training objectives. This can range from an indication that the trainee has completed a given module to performance in problem solving exercises or simulations. The intention of any training program is to impart knowledge skills, and abilities (KSAs). In some cases these elements can be treated separately in that knowledge acquisition often involves presentation of factual knowledge and testing involves assessment of acquisition. Skills and abilities usually refer to application of knowledge to problem solving. Certain skills and knowledge may be common across a number of jobs so it may be effective to split out bodies of training materials into modules. Training for a given job then consists of common modules required for the job and job specific modules. Skills, knowledge and performance measurement requirements will be identified. Specific criteria for pass/fail thresholds should be specified.
Step 4. Identify Training Media Training media can be books, overhead slides, CD ROMs, embedded training incorporated into applications software, desk-top simulations, etc. Based on the outputs of step 3, a preferred medium or media will be identified for each training objective and the performance measurement necessary to assess mastery of the objective.
Step 5. Develop Training Materials Training materials include the paper, slides, graphics, tapes, computer presentations and other audio and/or visual elements viewed or heard by the student. Training materials will be developed by: • Preparation of an outline for each module • Preparation of written contents using subject matter expert inputs • Development of a story board for each module • Preparation of the materials including text, graphics, animations, simulations etc. • For computer based training, development of courseware (using course authoring software where necessary)
Step 6. Train to Criteria and Test Knowledge Skill Acquisition The initial application of the training content and materials from the above steps will be tested in the training course(s). Performance measures will be used to identify common errors or failures to master material on the part of students, and to determine how to modify the training materials. Following any necessary modifications, the resulting course(s) will then be ready to be used to train the required audience.
Products. The primary products of this task will be the training materials. (courses, manuals, CDs, etc.)

Table 8. Sample Process for Improvement of HFE Issues

Objective. The objectives of this task are as follows: • Identify tasks and areas with potential HFE issues • Define standardized work environmental limits • Identify safety hazards • Identify design factors for improved HFE • Define specific actions • Prepare HFE specifications
Worksteps
Step 1. Identify Jobs and Areas for Design of Improved Work Environment and Safety A sample of tasks and areas will be selected for further analysis based on HFE issues. This sample will represent extremes in terms of ambient noise, temperature, humidity, illumination, safety related equipment design factors and mechanical hazards. Examples on a drilling rig could include the cement and shaker areas and the engine and fan rooms.
Step 2. Define Standardized Work Environmental Limits: Various standards sources provide guidance on acceptable work environmental limits. These will be used to define a set of proposed limits for work environments.
Step 3. Identify Safety Hazards Representative safety hazards will be identified for facilities and equipment that are involved in the tasks and areas from step 1.
Step 4. Identify Design Factors for Improved HFE potential solutions to be considered will include elimination of the hazard, elimination of human access, barriers and guards, redesign, warning labels, barriers and guards, procedures and special training. For each safety hazard from step 3, a preferred approach will be defined and documented.
Step 5. Define Specific Actions: Treatments of factors that exceed the limits established in step 2 will include design approaches such as noise attenuation at the source, noise attenuation at the ear, enhance ventilation and cooling, protective clothing and fixed or portable additional lighting. The effectiveness of alternate solutions on of environmental factors that exceed the limits from step 2 will be assessed.
Step 6. Prepare HFE Specification The rationales and results from the previous steps will be incorporated into a HFE specification document. This may be applicable to design of work environment and safety improvements on a current project as well as future projects.
Products. The primary product of this task will be the HFE specification from step 6.

6.0 VERIFICATION OF HUMAN PERFORMANCE ON EXISTING SYSTEMS

Table 9 presents a listing of some potential verification measures of human performance. Not all measure may be applicable to a particular facility or project.

Table 9. Potential Verification Measures of Human Performance on Existing System

Evaluate the Assigned Role of the Human in Automation

- Verify that each system function is allocated to human or machine or a combination of the two.
- Verify that the role of the machine in manual tasks is defined.
- Verify that the role-of-human in automated tasks is defined.
- Determine that operator workloads are realistic.

Evaluate Training Concepts

- Verify that the training analysis addresses training requirements based on job requirements.
- Verify that the training analysis addresses all requirements for training devices, trainers, and part task and full task simulators.
- Verify that training requirements are identified in time to allow for development of any new training devices (such as simulators).
- Verify that the analysis addresses lessons learned from similar system training evaluations.

Evaluate Training Concepts

- Verify training requirements include specific knowledge and skills to be acquired.
- Verify training requirements include criteria for judging skills are learned.
- Verify that training requirements include performance measures.

Evaluate Human Machine Interface Requirements

Evaluate Human-Machine Interface (HMI) Design

- Verify that standardization and commonality are addressed in the design of human-machine interfaces.
- Verify that unique human interface requirements, documentation needs, and special software certifications are identified.
- Verify that characteristics of automated decision support systems are identified.
- Verify that human workloads and human performance requirements are assessed through human performance and task modeling, task network simulation, and human-in-the-loop simulation.

- Verify that human engineering design standards are applied to reduce human error potential.

Evaluate Design for Operability *:*

- Verify operator performance capability has been demonstrated.
- Verify that details of the design are consistent with standards.
- Verify that error likelihood analyses have been performed to identify types of performance errors associated with the design approach.
- Verify that operational procedures have been developed.
- Verify that control and display arrangements are based on sequence of use, priority and functional grouping.
- Verify that panels and consoles are designed to be maintainable.
- Verify that warnings are provided for hazardous operations/maintenance actions.
- Verify that panels are operable when operators are wearing protective clothing.
- Verify that work environment effects (e.g., noise, lighting, climate) have been considered in the design.

Evaluate Design for Usability

- Have information requirements been identified?
- Have major HFE deficiencies been identified that might compromise understandability or effectiveness of the proposed displays?
- Have user needs been identified?
- Is the design of human-computer interfaces complete?

Evaluate Communications Concepts

- Verify that sufficient communication devices and systems have been provided for all communication requirements.
- Verify that communications system designs are based on link analyses and operational sequence analyses.
- Verify that speech intelligibility evaluations have been conducted
- Verify that message samples, noise conditions, and device fidelity are acceptable in terms of HFE standards.
- Verify that messages are standardized and are based on constrained language, controlled syntax, and restricted vocabulary.
- Verify that user clothing conditions were considered.
- Verify that the range of potential environments (especially noise and vibration) were considered in design of communications.

Evaluate Design for Habitability • Have facility human functions and associated facility requirements been identified? • Has the design effort identified access safety requirements? • Have requirements for inhabiting the facility been identified? • Verify that environmental controls are included in facilities (e.g., noise, lighting climate).
Evaluate Design for Maintainability • Does design for maintainability include requirements for maintenance information requirements? • Does design for maintainability include design for accessibility? • Does design for maintainability include equipment arrangement to facilitate maintenance? • Does design for maintainability include procedures-number and simplicity? • Does design for maintainability include troubleshooting diagnostics and decisions? • Does design for maintainability include built in test and automatic test equipment? • Does design for maintainability include requirements and approaches for tools and test sets? • Does design for maintainability include requirements and approaches for equipment identification and marking?
Evaluate Design for Safety • Have hazards previously identified been eliminated or the associated risks reduced to an acceptable level? • Are approaches for guarding the hazard adequate? • Are approaches for labeling the hazard adequate? • Are approaches for alarming the hazard adequate? • Are approaches for safety training/procedures adequate?
Evaluate Installations • Have equipment location requirements been identified? • Has space layout for equipment installation been identified? • Have equipment configuration requirements been identified? • Have access/egress requirements been identified? • Has an HFE design evaluation been conducted?

Evaluate HFE inputs to Change Proposals (ECPs)

- Have HFE lessons learned been identified for the element?
- Have critical tasks per function been identified?
- Have human machine interfaces been identified?
- Have task requirements been identified and analyzed?
- Has HFE test and evaluation been conducted to identify problems and/or validate lessons learned data?
- Has the role of human vs. automation been evaluated?
- Have workloads been evaluated?
- Have procedures been evaluated?
- Have effects of use environments been evaluated?

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